

Justifying Energy Efficient and Renewable Energy Technology

Ross McCluney, Ph. D.

Plenary Session, Solar Energy Society of Canada

Waterloo, ON, 24 August 2004

Introduction

Energy efficient technology (EET) is anything that produces the same (or a better) result with less fossil energy input. Compact fluorescent lamps, for example, produce the same light output as an illumination-equivalent tungsten filament lamp, but at substantially less energy cost. They generally produce less heat for the same light output, thereby saving on air conditioning costs too. They are great energy savers, and they even last a lot longer! The only problem is that they cost more, sometimes quite a bit more, inhibiting more widespread use.

Lamps to produce 900 lumens light output ³			
Incandescent		Compact Fluorescent	
Power Consumption	Luminous efficacy Lumens/Watt	Power Consumption	Luminous efficacy Lumens/Watt
60	15	15	60

Renewable energy technology (RET) is any energy generation system that is based upon non-depletable energy sources. Examples include direct solar energy converted to electricity by photovoltaic cell arrays (or by “solar thermal” generating stations), solar water heaters that heat water directly from the sun’s warmth, and a variety of indirect solar technologies such as those using the energy in wind, rain (hydroelectric), waves, and ocean currents.

The advantages of renewable energy technologies are many and numerous. The most important is that the primary source is not depletable, at least for the next several hundred thousand years. Secondly, by not burning fossil fuels in the process of producing energy, most renewable technologies are much less polluting than more conventional conversion systems using nonrenewable fossil resources like coal, oil, and natural gas. Renewable energy technologies generally contribute much less to the problem of global warming. (Exceptions include renewable biomass systems based on combustion. Also, using a

renewable resource at a rate faster than it is replenished is not sustainable, so there are ultimate limits to the uses of renewable technologies.)

Nearly everywhere you turn, people are saying good things about energy saving technology. The reasons are obvious: their unrefuted beneficial environmental, human health, national security, and comfort aspects. Protecting the future for a viable human culture while improving human comfort and security, and saving money in the long run, are benefits to which nearly everyone subscribes. It's like motherhood and apple pie. In spite of this, energy-saving technology is not that widely used. Some reasons are described in this article.

The main apparent drawback to an energy conserving system is that nearly all energy-conserving systems require you to pay more upon installation while reaping savings over time. (In some special cases, the energy-conserving system might cost *less* to install than the less-efficient alternative. Example: Better windows can reduce the size and hence installation cost of the air heating and cooling system, thereby offsetting wholly or partially the higher price of the better windows. In such a case, it can cost less to install the better product and the building's energy bills are subsequently less, too.)

Energy efficient building technology is often a pre-requisite to solar technology. The reason is that the solar system sized to meet a large energy demand, due to inefficient use of energy in the building, is too large and expensive to be affordable. A friend of mine put it this way: Solar provides just enough—but not so much that you can be wasteful with it.⁴

A second reason energy-efficient technology is not widely used is *momentum*, the strong tendency toward “business-as-usual.” Due to historically cheap fossil fuel-based energy in the U.S. and the availability of less costly (usually less efficient) technology, consumers and energy-using system designers have become accustomed to paying less attention to lifetime energy costs. It takes extra work to calculate long-term economic performance, so there is a natural tendency to avoid doing the calculations. When making a sale or convincing a client, it seems easier to specify the least-cost technology, so there is a natural bias, at least in relatively uninformed marketplaces, toward ignoring the energy consequences of the final decision.

This is slightly less true today, and more clients, especially in large projects, *are* going the extra mile and insisting on the long-term energy calculations. Plus there are governmental regulations in many areas that require these calculations to be done. In some cases, minimum efficiency requirements are mandated. I argue in this paper that these success stories are but small drops in the big bucket of what's needed. Even in the exceptionally good cases, the standards are inadequate. They are better than nothing, of course, but for a variety of reasons, current standards and regulations are not pushing the technology toward more energy efficiency or toward renewable energy options hard enough or fast enough. In addition, many energy-using technologies have escaped government regulations on efficiency or on the use of renewable technologies, so the needed incentives are not universally available.

Even when energy-saving technologies *do* have demonstrable long-term economic advantages, ordinary consumers often take the lower initial cost option anyway, and then pay for their bad choice with higher subsequent energy bills. This is mainly a result of lack of knowledge and understanding, or the difficulty ordinary people have in calculating long-term energy savings. In the case of expensive purchases of energy-related products, especially those large enough for an engineer's involvement, longer term economic measures are somewhat more routinely calculated. Then various options are presented to the investor in the energy-using system, be it a large multistory building, an airplane, or a freight hauler. This makes it easier to make an intelligent choice—if the calculations are done adequately, are comprehensive enough, and consider a wide array of alternatives. These caveats can be rather challenging, however, for designers beset with time and monetary constraints and tending toward least-initial-cost options, often needed to please clients who may be relatively uninformed about or are otherwise not interested in long-term energy costs.

The methodologies available for computing long term costs and savings are many and varied. They are covered in a variety of college textbooks on engineering economics, at least those dealing with energy calculations. Even in cases where such careful computations can be done, however, energy-conserving technologies are not as widely used as they could be.

When it comes right down to whether an energy-saving system is purchased, installed, and used in a market-based economy, there seems to be but one dominant criterion for the purchase decision: narrowly-defined monetary benefit, however calculated. Non-monetary benefits (other than aesthetics, functionality, and other personally observable qualities of the product) are rarely considered, especially in consumer markets. A reason is the difficulty of placing accurate monetary values on these benefits. Another is society's (or government's) difficulty in making the prices of both energy-producing and energy-saving technology reflect these benefits. Still another follows from what I charge is the faulty societal paradigm of the industrialized countries, detailed in my new book on this subject¹, but let's leave this out of the argument for the time being. I'll mention it again subsequently.

Quantifying Economic Performance

Most energy-saving systems cost more to purchase and install than those they are targeted to replace. It is fairly easy, in principle, to assess monetary economic viability. (For the details, see any textbook on engineering economics.⁵⁻⁷) First you look at the extra installed cost of the energy-saving strategy. Then you determine the long-term incremental energy savings, in dollars, produced by the strategy. If the annual dollar savings is relatively large compared with the extra installation costs, the investment in energy-saving strategies is deemed a good one. Otherwise, the investment is more difficult to justify.

There are many different ways to measure this economic viability. They include straight and escalated (or “discounted”) payback times, return on investment, cash flow analysis, and life-cycle cost. I describe easy-to-calculate simplified versions of these measures in

the Appendix. If the results of these computations indicate poor economic performance, in terms of long payback times, low returns on the investment, or deleterious cash flows, then it is common to say that the proposed energy-saving strategies are not justified and should not be supported.

There is a flaw in the logic of such narrow economic assessments. There are large societal consequences to them. They usually do not consider all the human factors impacts (positive or negative), the dollar values of improved worker productivity that can result with some technologies, or the wider economy of nature, other life forms on Earth, and general ecosystem health and longevity. Market prices for both the implementation of the energy-saving strategy and the energy saved by it seldom include or reflect a number of these and other costs important to making an appropriate decision. Only the relatively narrow human monetary economy is considered. In consequence, a large number of possible environmentally sound investments in the future fail to be made, every day, all over North America, and around the world.

When fossil fuel prices are as low (in an absolute sense) as they are today, payback times are long. Raising these prices will improve the economic indicators. Unfortunately, however, considerable public policy currently *rewards* fossil-fuel based energy suppliers for keeping energy prices down, with subsidies and other incentives, thereby sending misplaced pricing signals to the energy users.

The subsidies and corporate welfare handed out by governments in this manner, giving tax dollars to polluting and fossil fuel wasting industries, makes the price of fossil fuel energy appear cheaper than its real value in a fair market. The result is strong economic disincentive to use more efficient technology, to build more efficient generating stations, and to employ renewable energy technologies, better protecting our futures. Here I offer an exploration of this topic, and suggest some rationales for “thinking outside of the envelope,” looking at the bigger picture—and in the process considering the future of human life on Earth.

External Costs

External costs are the environmental and human health costs of any business operation that are not included in the business’s profit and loss statement. External costs are “off the books” and not considered a normal cost of doing business. Just because a business does not pay such costs does not mean no one pays them. External costs are indeed paid, by people and the environment—in tax dollars to clean up pollution, in health care dollars to pay medical expenses resulting from the business’s generation of harmful wastes, in the larger and longer term costs of global warming and ozone depletion, and finally in the diminished health of people and other animals. The inherently lower external costs of most renewable energy systems are important measures of their value.

External costs are not directly included in the price of a product. This sends misleading price signals to purchasers and perverts normal market forces. Internalizing costs is the process of pulling external costs back into the corporations generating them, forcing them to include them in their prices offered to customers. This is normally done by government

regulation or by a progressive or “green” tax structure, imposing the highest taxes on the most damaging products.

When government fails to force internalization, the misleading price signals produce the harmful effects just mentioned. Worse still is when government *subsidizes* businesses which are polluting or otherwise generating harmful external costs. We end up paying higher effective prices for the products and services of such businesses. The higher price comes from the “hidden” extra payment—that fraction of our taxes going to subsidize the business’s operations. More-benign product alternatives are generally less expensive if all the costs are properly incorporated in their selling prices.

In a few cases where strong pollution restrictions and recycling requirements are in place, we see an exciting new movement for “products of service” such as refrigerators, television sets, and automobiles never to be sold. Instead, they are leased or rented to the user. The factory retains ownership of and responsibility for the product throughout its life. The owner is thereby forced by the environmental regulations into radical resource efficiency and nearly 100% recycling. Product designs are altered to make such high levels of recycling much easier and less expensive when the product is returned by the user. The overall result is much less pollution or waste, essentially no external costs, and a much more intelligent product system.⁸ This is encouraging, and energy-efficient and renewable energy technologies will play important roles in the movement toward more socially beneficial industry.

Monetary and Non-Monetary Cost-Benefit Analysis

There are problems in calculating the benefits of energy-efficient technologies that reduce societal pollution, can increase health, comfort, and labor productivity, can reduce dependence on foreign energy sources, extend the useful lifetimes of finite stocks of energy resources, and protect habitats and ecosystems. It is difficult, and seldom done, to put accurate dollar values on *these* benefits. As a result they are almost never accurately included in analyses of the benefits of switching to an energy-efficient technology or a renewable energy system. The consumer, designer, or buyer typically goes to the store or a catalog and compares prices, appearances, and expected differences in comfort and utility, generally ignoring the more indirect costs and benefits associated with the pending purchase.

One problem of doing an analysis of the alternatives, including what were previously external costs and quantifying the indirect benefits, is the great difficulty of getting good numbers for the dollar values associated with these extra (“hidden”) costs and benefits, plus the time and effort required to do the comparison. The latter is more justifiable on large purchases, but the extra effort required remains a serious impediment in all cases. A second problem is incorporating the long-term societal costs in the prices of the technologies involved.

For example, in evaluating a technology with potential contributions to global warming, an attempt can be made to quantify the total global dollar costs associated with a given level of warming and to consider what fraction of these costs is attributable to the

technology under consideration. Determining these costs requires considerable analysis, often with limited information. The further one attempts to go into the future in making consequence estimates, the poorer is the accuracy of the projections, until, at some point, there is no accuracy at all. Furthermore, even if these generalized costs and benefits can be quantified, how can they be effectively incorporated into the purchase and operation of a specific energy-efficient and renewable energy technology?

The usual answer is that this miraculous feat is beyond the capability of either the seller or the buyer. It is generally considered to be more properly a government function.

The Role of Government

Through its power to hire studies and publicize study results, and in its power to pass laws and assess taxes, fines, and tariffs, as well as provide a variety of financial and other incentives, government, in principle, can force the prices of products and services to more accurately reflect the long-term real costs of those products and services.

Even if the adjusted price of an energy-conserving product—after all the incentives and disincentives have been incorporated—is still greater than that of the competing option, this does not mean the product has no value. There are moral and other reasons to do what might not be economically indicated.

But morality has a price too. If the price differential is too great, few will purchase the more energy-efficient product, moral or not. Government-imposed narrowing of the price differential, however, can “sweeten” the moral decision and encourage more people to make the “right” choice. The problem is one of finding good mechanisms suitable for a market economy.

In a free market, or in one manipulated in selfish ways, the cheapest product is not always the best product. Narrow definitions of economic viability don’t generally lead to the best outcome. But in a truly “free” market, narrow monetary costs generally rule. Some say that the result is beneficial for the health of society or its life-support system, the biosphere, at least over the long term. The reason is that such a system is supposed to be “self-correcting.” If a product or service harms people, eventually they will cease to purchase the product or service, possibly by intention, but also possibly as a result of disease and death. Others say that even if we accept the self-correcting hypothesis, much harm still is done to society before the correction is applied “naturally.”

Fortunately, there are instruments available to government for forcing the longer-term benefits of currently “costly” energy conservation and renewable energy sources to be included in their market prices. Developing and promulgating these instruments is a proper role of government. The problem is not so much in discovering effective government tools but in getting the societal and political motivation to use them. Better to understand these motivations, it is worth taking some space for a brief review of our energy history.

Energy History

Before fire was widely used, humanity lived mainly on body energy, derived from the solar-powered food we ate. As fire came into controlled human use, we found ourselves able to use more energy per capita than we could eat. We still lived within our daily budget of energy from the sun, since we mostly burned plant and animal materials, their energy content coming originally from the sun, but our per capita energy consumption rates expanded considerably. Plants and animals were the first solar energy “technologies.” They captured solar energy over large areas and concentrated and stored it in their bodies. This is why I call plants the greatest solar energy collection and storage systems ever known.

When we discovered agriculture our energy use expanded further, and we became able to grow these solar collectors more rapidly and consume still more energy per capita. This made civilization possible, since not everyone had to be involved in food production for a living. Over time, we eventually figured out how, with fire, to manipulate metals and to make steam. This was the beginning of modern technology.

With the discovery and exponential exploitation of the fossil fuels, technology, civilization, and world population grew exponentially—for a couple of centuries. Along the way humanity went through two important transitions. First was the switch from burning wood to burning coal. Coal had a higher energy density and therefore could be transported, stored, and used easier. There was little dissension about the switch to coal. Then came petroleum, also energy dense, but now transportable over great distances through pipelines. And it was cleaner to obtain, transport, store, and burn than coal. Again the superior benefits of oil as a fuel were nearly unanimously accepted, and the transition from coal to oil was nearly complete.

Table 1. Fuel Energy Contents	
Fuel	Energy density, KBtu/ft ³
Wood	100 - 300
Coal	600 - 1,000
Natural gas at atmos. pressure	1.03
Liquified petroleum gas	712
Crude oil	1,029
Gasolene	932
Hydrogen at atmos. pressure	0.27

As we near the peak and subsequent decline in world oil production, however, we are faced not with one universally acclaimed new fuel having universally accepted economic advantages. Instead we see a multiplicity of fuel possibilities, all less desirable, either

from being more dangerous (nuclear), less energy dense (renewable technologies based on dilute solar energy), or more difficult and/or costly to transport and store (solar-generated hydrogen, solar thermal energy, and solar electricity). The transportation of solar-generated electricity is no more difficult nor costly than electricity from any other source. Indeed, since distributed power can be generated closer to where it is used, transport losses are less. The problem with solar electricity is the cost and environmental and other problems associated with its storage. Batteries are expensive and eventually have to be replaced. Many contain lead, an environmentally dangerous element. You can convert solar electricity to transportable and storable hydrogen, but hydrogen, the lightest gas, is notoriously leaky and has costs associated with preventing those leaks. There are also costs to compress it to an adequate energy density. It can be stored densely in chemical form without the need for highly pressurized vessels, but there are significant costs associated with converting it to and from chemical compounds.

The point is that it is much easier and less expensive (at today's prices) to keep on using oil, at least until its shortage-induced price increases become untenable. It is sometimes said that we are running out of oil and this is the reason we should cut way back on burning it. The fact is that we are *not* running out of oil. We may never run out of oil. It will just become increasingly in shorter supply, and more remote and dilute and therefore more expensive to obtain. In open markets, this will lead the price to rise—perhaps steeply, when its dwindling availability becomes more widely known.

Chemical Feedstocks

Fossil fuels are used for much more than just energy generation through their combustion. The entire polymer industry is based almost exclusively on this declining resource. Plastics have become so pervasive in our lives that we hardly notice. Among the products made with fossil fuels we can list plastics, pharmaceuticals, fertilizer, pesticides, textiles, electrical and electronic components, a variety of important industrial chemicals, paint, laquer, and lubricants.

Considering the tremendous variety and pervasiveness of these products, especially for their more durable uses such as in furniture, containers, building products, and appliances, it is hard to believe the we even *consider* burning them up smokestacks or out the tailpipes of cars and trucks. As Kenneth Deffeyes wrote in his book, *Hubbert's Peak*, "In the long run, the eventual use for oil will be for manufacturing useful organic chemicals. I expect our grandchildren to ask, 'You burned it? All those lovely organic molecules, you just burned it?'"⁹, p. 164

Though it may appear that we have considerable quantities of coal, oil, and gas in the ground for future use, and though many industrial countries are making strides toward using them more efficiently, for every reduced use due to improved efficiency there are additional consumers added to the world market.

The question before us is one of whether it will be acceptable to let market forces force a shift to cleaner, renewable fuels naturally, or must we anticipate the coming transition and manage it so as to protect petroleum for use as a chemical feedstock, extending its

availability for tens of decades rather than burning the most abundant supplies in just a few. I favor this latter strategy, my reason for promoting more aggressive government action.

Promoting and Requiring Energy Efficiency and Renewable Energy Use

The problem is that accelerating government control over the harmful consequences of an unfettered free market is an intensely political act. In nominal democracies everyone gets to be heard, but some get to be heard more, or more forcefully, than others. The frequent result is that narrow self-interest can prevail over the broad public good. This is not the place to discuss the perils and pitfalls of creating good government. We focus instead on what individuals can do, and on what true leaders must do.

Education and information dissemination are critical components of any program to encourage more energy efficiency. If the people do not see the value, it is difficult for government and companies to support it. Extensive public education is therefore an essential prerequisite for strong government action. All levels of public and private education must be involved, and the mass media (including the corporations owning them) have important responsibilities to participate as well.

Government and other societal institutions, including electric utility companies (and/or their regulatory agencies) can offer incentives for *exceeding* too-weak energy codes and standards. Even better, the codes and standards themselves can be made tighter, directly *forcing* the use of more EETs. Such action is generally opposed by business. But if it is forced on all businesses, no one of them will receive an unfair economic advantage (except, of course, those marketing energy efficient and renewable energy technologies).

Energy standards generally fall into the categories of either prescriptive or performance based. In the first case, specific components of a system must meet a specific energy requirement. For example, air conditioners for the home can be required to all have or exceed a certain energy efficiency rating. This approach would then be repeated for every other energy-consuming building component. The performance based approach, however, demands a certain over-all system energy efficiency, without requiring any particular efficiency level for any one component. Thus your air conditioner can be a relatively inefficient one, as long as the extra energy costs are made up for in other areas of the building. You might use much more insulation, double pane windows, and energy-efficient electric lights, for example. I believe that a combination of *both* strong minimum prescriptive standards and effective performance ones offers the best hope for stimulating the needed conversions quickly to an EET and RET based global economy.

Setting the bar just right

What degree of energy efficiency should be required? What level of market penetration for renewable energy systems do we need? These questions are not easily answered by simple rational argument. The reason is that humanity is running a race with itself. World population is growing and per capita impact is increasing on average. Both are “growing” total environmental impact at an alarming rate. These growths, nearly everyone agrees,

cannot continue indefinitely. We are facing real limits to the Earth's ability to sustain its human population. Most governments *are* working to reduce the adverse impacts of a growing population and its increasing per capita environmental impact. If the hoped for reductions in population growth and human impact do not happen fast enough, however, we'll lose the race. Humanity will be worse off for it.

In the absence of clear, scientific information concerning how fast we need to reverse the terrible trend, we do not know how high to set the bar or how fast to move it higher. It is critical for the populace to become as informed as possible concerning the larger issues of human survivability and then arrive at generally agreed to standards of population control and market penetration for more benign technology, including energy conservation and renewable energy systems. It is through the political process that the people reach such decisions. For the decisions to be well-founded, the populace needs to be well-informed. Education is again seen as a critical element for the survival of humanity against the onslaught of human-induced destructions of our life-support system.

Government Initiatives

Governments around the globe are experimenting with a variety of devices for steering markets toward sustainability. They include a variety of green taxes, pollution credits, government subsidies, government grants, and flat-out market restrictions through stronger energy and environmental codes and new laws. Paul Hawken described a variety of interesting modifications to the global system of commerce in his book *The Ecology of Commerce*. He and Amory and Hunter Lovins amplified and strengthened the arguments in *Natural Capitalism*. Most of the innovative approaches described in these and the many other books on the subject are enhanced by government incentives. Some are possible only through strict government regulations.

The most effective of the suggestions involve dramatic shifts in the way we do business around the world. It is not a matter of just implementing a little recycling here, installing some compact fluorescent lamps there, and tightening energy codes a little bit once in a while. In order to keep ahead of population growth, per capita growth in energy, and accelerating damage to our life support system, more radical measures are required.

A Matter of Some Urgency

The race we are running against ourselves might be compared to a long-distance marathon. We will not run out of all fossil fuels soon. Technology is being developed to support radical resource efficiency at a fairly rapid rate. There is still a lot of oil in the ground and volumes of coal are there too. Steps are being taken to drastically reduce the adverse environmental consequences of the use of coal. Solar energy is very abundant and widely distributed, though relatively dilute, and many companies are expanding their renewable energy technology offerings. As the argument goes, if we just continue these efforts and wait a while, a great new age of sustainability will come to us. So our policy should be to just continue the course, making incremental improvements as best we can, and hope for the best in the future.

Unfortunately, there are two developments which are making such a strategy likely to fail. They lead us to a sense of real urgency. First is the impending peaking of world oil production. Various petroleum geologists predict that the world will see oil production reach an all-time high, never to be repeated, within the current decade. It will be forever downhill after that.^{9,10, p.82,11, p.41,12,13}

Some of the consequences are easy to predict, others are not. As our growing population and quest for ever greater material standard of living drives energy demand upward faster than we can switch to energy efficient technology, we'll be scrambling around looking for alternatives. We'll see growing use of coal again, a dirty, nasty substance, and considerable cost to try and burn it cleanly and find something to do with the waste products of its mining, transport, and combustion. The prices of plastics will rise as normal feedstocks become in shorter supply. Transportation costs will rise and there will be relocations of places of work and residences to be closer to one another. Our industrial agricultural system, so dependent on petroleum for fuel, fertilizer, pesticides, and herbicides, will undergo major shifts, and food prices will soar. Few people realize how pervasive is our dependence on petroleum, but we are soon to find out. (The fossil fuel subsidy to the average U.S. food production system is approximately ten times the solar energy content of the food we eat, leading to my claim that we are no longer eating solar energy. We are eating fossil fuels.)

The second cause for urgency is what can only be viewed as our systematic destruction of the human life-support system on planet Earth¹ highlighted by a human-induced extinction of species the likes of which the Earth has not seen since the last great extinction, the fifth one, some 15 million years ago. We are extirpating species at the amazing rate of about 200 per day, and it has been going on for quite some time. Daniel Quinn and ecologist Alan Thornhill say that we are systematically replacing nonhuman biomass with human mass.¹⁴ At some point there will be nothing left for us to eat (except each other, perhaps). The reason for this is our growing, unstoppable need for food. We are opening new agricultural lands all over the globe in our quest to feed our growing numbers, and to replace agricultural lands being taken over by housing and other urban developments. In the process we are destroying habitats and extirpating species, most of which have never even been identified. As we switch to massive use of renewable energy, requiring massive new land areas, further pressure on biologically diverse regions will be relentless.

Species extinction is a very serious problem, for a number of important reasons. First of all, a world with fewer plant and animal species, is a world greatly diminished for human habitation. We need the missing plants and animals, not only for our own sustenance and ecological survival, but also for the aesthetic and psychological benefits they provide us. If the only tigers we could ever see again were in digital media and on aging color film stock, our lives will be immeasurably less. Further, some of the species we are extirpating are important to larger ecosystem health and vitality. Their loss will lead to substantial alterations of the ecosystems in which they were so important. There can be serious adverse consequences for humans.

Security goals of saving energy

Saving energy (both fossil generated and renewable), on per capita and total bases, is the right thing to do. The justifications are numerous. A very compelling one is much in the news. As Americans feel more scared than ever, it seems clear that eliminating dependence upon distant countries for energy is critical. The problem, as always, lies in finding ways to incorporate this need into the sales and marketing arguments used by energy buyers to justify their purchases. There is currently no direct mechanism for capturing the saved costs resulting from reduced security needs and putting these saved costs toward purchases of energy efficient technologies.

This brings us right back to the previous argument—the need for government (the rightful entity representing the needs of the people), to act forcefully, intervening in the marketplace either through positive monetary incentives for energy-efficient equipment purchases or through negative monetary consequences for wasteful uses of fossil-fuel based energy. Getting government to “do the right thing” will require substantially increased participation in the political system by those concerned for the future of their children (and for their own economic self-interests) as well as the sustainable health of our Earthly life-support system.

Matters of Judgment and Ethics

Humans have two powerful gifts distinguishing them from other species: intelligence and Judgment. We are presumably more intelligent, and are better able to use our experiences to guide future actions, than any other animal on the planet. This is both a strength and a weakness. Our high intelligence, coupled with a flawed collective Judgment, has *led* Earth to its current difficulty. It is also true that only through correct use of our intelligence and the exercise of good Judgment can we extricate ourselves, and our Earth, from the problems besetting us.

We must find new ways to include in our energy analyses additional information about anticipated environmental and social consequences of proposed energy-saving strategies and the practices they are proposed to replace. We must use our intelligence to find and explore the “hidden” costs of continuing present practices compared with switching to alternatives. Then we must apply our Judgment skills to make more informed decisions concerning the implementation of the new strategies.

The problem is that we are not used to making decisions this way and we don’t have a lot of guidelines to go by in doing so. In other areas of our lives, we *do* make informed decisions—all the time—based on a combination of limited information, past experience, belief systems, and personal intuition. These are not just minor little trivial decisions either. They include major ones affecting our lives, such as what we eat, how fast we drive, how we spend our time, who we choose to have as our friends, and decisions about birth, marriage, and death.

If we make informed decisions based on information, experience, and intuition in *these* areas of our lives, why can’t we do so in *other* areas having major environmental import,

such as what air conditioner to buy, which light bulbs to purchase, which window is best, and whether to pay higher utility bills for getting our energy from renewable sources? We must develop better skills and methodologies for thinking of the ramifications of our decisions, and including additional information beyond narrowly defined economic justifications. Those concerned about the future of humanity, and of our life-support system, can read, learn, and assimilate information relevant to making the future a healthy one filled with promise and hope rather than despair over what could have been but wasn't.

Our failure to see the connections has resulted in what might be called the faulty societal paradigm of the industrialized countries, with their nearly religious pursuit of growth, development, and economic advancement at the expense of our life-support system. Many are calling for a new paradigm, a new philosophical and organizational approach, hopefully better able to provide a sustainable future.

As many people study these issues and experiment with alternate ways of thinking and living hoped to be more conducive to a sustainable future, we must turn this small trend into a worldwide movement, participated in by an increasing fraction of the global citizenry. Some of us believe that the transitions called for herein will be impossible without serious reconsideration of our most fundamental beliefs and tenets as a society. Fortunately, much has been written on this subject, and is widely available in bookstores and through the Internet—for anyone curious enough and determined enough to explore the subject. Web searches on such key topics as sustainability, sustainable values, sustainable development, sustainable society, environmental ethics, environmental futures, earth ethics, environmental values, the greening of religion, environmental philosophy, and transformation to sustainability should prove especially fruitful.

Seeing the Big Picture

Markets often fail to see the bigger picture, until rather late in the game, especially if they are biased in the wrong direction by misplaced government policy. We need to take a longer view, going both backward and forward in time. Fortunately, modern science has provided us with a remarkably extensive picture of who we are and where we live in the long span of cosmological knowledge. The currently known universe was formed some fourteen to fifteen billion years ago in a giant explosion of the very fabric of space, time, and energy. Over several billion subsequent years matter condensed and stars, galaxies, and nebulae were formed. Some 10 billion or so years later this led to the formation of our solar system and the birth of Earth. It is a remarkable fact of science that life formed only half a billion years later. All life is composed of the fundamental matter present at the beginning of the universe. We are indeed made of star stuff, a fact that should help us see more clearly our connections to each other, to the Earth, and to its long history—our species genealogy.

A fundamental fact is that all life is based on energy. Life forms have developed elaborate ways to capture, concentrate, and store solar energy in their bodies. Soon after life occurred on Earth, the incredibly long process of accumulation of dead plant and animal material began, storing the embodied energy therein. Millions and millions of

years later geologic and other processes had transformed this material into deposits of coal, gas, and petroleum inside the Earth.

Only about a century and a half ago, about the time my grandmother was born, our extraction of this buried energy accelerated and we began using it at an exponentially growing rate. With our modern technology we have explored the remaining deposits, charted their boundaries, and estimated the energy contained in them. It is believed that we now have fairly accurate knowledge of the total energy content of coal, oil, and natural gas originally deposited in the ground.

There are about 2700 Gigabarrels of liquid fuel, 1850 Gb of which is regular oil. (There is some dispute over these figures, with the USGS saying that the oil figure will ultimately end up somewhere in the range from 2000 to 2200 Gb. It is unlikely to exceed 2500 Gb.) We've already used about 950 GB of the regular oil—about half way along the depletion scale.

The estimated world gas endowment is approximately 350 trillion cubic meters, about 14% of which has been consumed or flared. The flaring of associated gas has long been connected with oil production. With the value of natural gas appreciating, conservation efforts have increased and gas flaring has been reduced. It is very expensive to liquify and transport natural gas, so the practice is not widespread. According to the website www.hubbertpeak.com, Colin Campbell has estimated the total world natural gas endowment at 1680 Gb of oil equivalent, in energy terms, of which 400 was produced as of 1996. It won't be long before we face the peaking of world gas production and its eventual exhaustion.

According to the World Energy Council (www.worldenergy.org), the proven recoverable coal reserves at the end of 1999 were 984,453 Million tonnes while world annual consumption in 1999 was 4,410 Million tonnes, indicating the massive volume of coal remaining in the ground for future use. But coal is a very dirty fuel. Our ability to use it will depend on the success of current efforts to reduce its adverse environmental impacts to near zero, including figuring out what to do with the carbon by-product of its combustion so that we don't accelerate global warming as we accelerate our use of this old fuel. The same is true of the other remaining fossil fuels.

Population Growth and Energy

According to a 24 March 2004 BBC report on the release of a U.S. Census Bureau publication, the rate of world population growth peaked 40 years ago, when it stood at about 2.2% a year. "The bureau partly attributes the drop to women having fewer children. It also projects a population decline in Africa because of the lower life expectancy due to HIV-Aids. In 1990 women around the world gave birth to 3.3 children on average, the report says. By 2002, the average had dropped to 2.6 children - slightly above the level needed to assure replacement of the population." The United Nations Population Division's March 2002 population projection shows world population growing from the current 6.3 billion people to 9 to 11 billion by mid-century, depending

upon fertility and death rate estimates. An important question to ask is whether the Earth can accommodate another doubling of world population.

The current growth rate is 1.2 percent, implying, according to the UN, a net addition of 77 million people per year. Six countries account for half of that annual increment: India for 21 per cent; China for 12 per cent; Pakistan for 5 per cent; Bangladesh, Nigeria and the United States of America for 4 per cent each, two-thirds of the latter being due to immigration.

China and India, long underdeveloped and with widespread poverty, have embarked upon aggressive industrialization programs. The total population of the two nations is around 2.4 billion, a third of the world total. According to a 1998 article by Thomas Drennen and John Erickson in *Science*, China's real gross domestic product grew an average of over 11% per year throughout the 90s. To help fuel this unprecedented growth, the country became a net importer of oil for the first time in history and these imports were expected to reach 7 to 8 million barrels per day by 2015. "Together with projected global declines in oil production in 20 years, these demands on the global oil market pose a serious threat to future global energy security" the authors wrote.¹⁵ China's automobile ownership has grown from less than a million to over seven million recently. China's State Development and Reform Commission statistics show that about 2.68 million automobiles were produced in China in the first half of this year, and 2.55 million were sold. Production grew 2.5 percent in June. In the recent past China's doubling time for new car production was under 2 years. In spite of some laudable experiments in China and India with high mileage and alternatively fueled vehicles, the vast majority of the vehicles produced in both countries will run on gasoline.

Rapid development, coupled with rapid population growth in China and India, and in many other developing countries, will more than offset efficiency gains and conversions to renewable energy use in the next few years. The growing worldwide demand for oil, just at the time when we are nearing the peak in its production, will eventually lead to strong pressure for energy price inflation. As prices rise, payback times and other economic indicators for energy-saving technologies will show dramatic improvement, providing strong economic incentives for increasing purchases of energy conserving and renewable energy technologies. A number of years could pass, however, before these strong economic incentives push the industrial world to accelerate conversion to energy conservation and renewable by normal market forces. As already mentioned, there are many other reasons besides narrow economic ones for the world to make the energy transition sooner, as soon as possible. Anticipating this, leaders in government, business, science, education, and the military have important responsibilities to educate the public about these issues and begin preparing the governmental actions needed to stimulate rapid change.

The Circular Chain of Inaction

In the light of the above arguments, we should be investing now in the most energy-efficient technology and renewable energy systems available. Instead, we continue to purchase what is cost-effective by narrow monetary economic arguments. One

consequence is that vendors of efficient products have trouble stocking and selling them, further increasing their costs. There are other consequences as well. Decisions whether to employ more efficient technology and renewable energy systems, and to provide education about the need to make these decisions, are made daily by people in nearly all sectors of society. All have the responsibility to make these decisions in favor of accelerating the needed energy transition. Few are meeting this responsibility. Failures of understanding, of education, of leadership, of journalism, and of individual responsibility keep us from moving toward the needed radical resource efficiency.

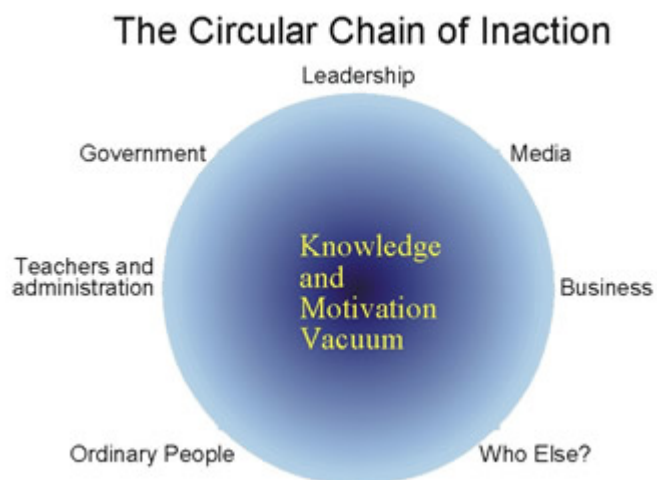
For example, you seldom hear in the media or from politicians that energy should cost *more*, better to reflect its true value in the larger scheme of things. If prices were higher, first cost would be less important, life-cycle costing would be more widely used, transportation energy use would decrease, petroleum would be saved and conserved as the precious commodity it is, extreme energy efficiency would become universal, and renewable energy use would be pushed to its environmental limits.

I see the current situation as one in which we are trapped inside a circular chain of inaction, diagrammed schematically in the illustration below. Educators, for example, could set the stage and get the ball rolling by helping the electorate see the need and put pressure on the leaders to act, but they do not. Builders are in powerful positions to make more efficient buildings incorporating the best renewable energy technologies in every project they complete, but they do not. Legislators can write and pass laws making it easier to do the right thing (or requiring everyone to do so), but they do not. And so it goes around the circle. I call it “a chicken-and-egg problem in a dog-eat-dog world.” Getting the desire and political support to restructure our markets toward the more efficient and renewable products is difficult in a culture dominated by consumerism and narrow cost-accounting.

Conclusions

There are two general approaches to accomplishing the transition away from our heavy dependence on fossil energy sources. One is market-based. It involves education, technical information dissemination, design assistance, financial incentives, and other measures to accelerate *voluntary* adoption of more efficient and renewable energy systems. Second is the regulatory approach, using energy codes, green taxes, and a variety of governmental incentives, plus outright laws mandating better practices. It can be

argued that the regulatory approach is the most cost-effective and permanent mechanism for stimulating the needed changes. A reason is that pushing market transformation in this



way affects all technology, gives clear signals to all designers, manufacturers, and product distributors, can be equally and fairly applied to all market participants, (“leveling the playing field”) and the approach can be persistent over time. It is certainly a more political approach than the market-based one. It can be argued that political action is the only action that can be successful in democratic systems facing a strong need for urgency.

Both approaches can be effective, however. Considering world population growth, the current state of energy affairs, the rapid industrialization of many countries, and the urgency of the matter as we approach peak oil, it seems obvious that both approaches must be pursued vigorously.

This discourse started with a simple question of how to promote energy efficient technology. It led, as most policy arguments do, to a need to look at the bigger picture. Since our current problems are rooted in the long history of life on Earth, this brought us to the history of our species, and indeed of the universe itself. It seems that humanity’s ages old quest for life improvement has painted us into a corner. Rather than tiptoe back across ancient history, we find ourselves having to break down the walls surrounding us, deciding if those walls are relevant any more. The conclusion seems obvious. New directions are needed. We shall, as Einstein once told us, have to develop whole new manners of thinking to survive into the future and to progress.¹⁶ At the heart of the struggle is the need for decisive government action.

Governments of the world have a long way to go toward promoting and requiring energy efficiency and renewable energy use on the massive scale required. It is my belief that for this to be successful it must be coupled with a larger transformation of societal beliefs coupled with restructuring of our systems of government and commerce toward the new beliefs. It is becoming clearer and clearer that these are necessary components of any effective program aimed at saving humanity without massive loss of life, liberty, and the ability to pursue happiness in the process. Let us all invest more time and effort in a two-pronged effort to transform ourselves toward true sustainability: Earth learning and building a new political movement toward true sustainability.

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Appendix. Economic Indicators of Energy Performance

Let C be the total of all extra costs required to purchase and install an energy efficient or renewable energy technology (ET). Let S be the annual dollar savings produced by the ET. S will be either the reduced cost of operation of energy-consuming equipment (such as a space heater or cooler or an electric water heater) or the value of the energy produced by a new system, such as a solar water heater, over the course of a year.

Simple Payback Time. The simple payback time SPT is the ratio of C to S :

Since C is in \$ and S is in \$/yr, the units of SPT are years.

SPT is the time it takes, with no change in the price of energy, for the total dollar savings to equal the extra costs C of the ET. To be more correct, economists or accountants would prefer to calculate what is called the escalated payback time EPT , also sometimes called the discounted payback time. In this case the changing dollar values of the energy saved each year is considered in the analysis along with fluctuations in the value of money. If the price of energy declines over the payback period, for example, the escalated payback time lengthens, due to the fewer dollars being saved each year. If energy prices rise, however, the EPT is shortened, making the technology appear more economically desirable than the SPT would indicate.

Including the fluctuating price of energy over time in such projections of economic viability is somewhat perilous, due to the difficulty in predicting accurately what future nonrenewable energy prices will do. In spite of this, the SPT remains a useful indicator of economic viability because it is so easy to calculate. For short payback times, say under 4 years, the SPT will be not much different from the EPT .

Simple Return on Investment. The return on investment is the percentage of C that is returned each year in the form of savings produced by that investment. The simple return on investment, denoted ROI here, is the first year return on investment. It is equal to the reciprocal of the SPT , expressed as a percent.

A short payback time, for example 4 years, corresponds to a relatively attractive return on investment, 25% in this case. As with payback time, one can calculate an *escalated return on investment*, $EROI$. The $EROI$ takes account of changing future values, but a good straight ROI , as defined above, is still a reasonably good indicator of the return on the investment. An important exception comes when the price of purchased energy increases. As the price of energy goes up, the dollar savings go up as well. The payback time then shortens and the return on investment increases. It is important to consider this when making decisions about which energy-saving technology to purchase.

Cash Flow. Instead of investing your own money, you might borrow the needed money, paying back the loan out of the energy savings (or energy revenue) the investment generates. In cash flow analysis, the monthly savings are compared with the monthly loan repayment premium. If the loan repayment is less than the dollar savings, the cash flow is positive. Otherwise it is negative. Any technology generating a positive cash flow they

day after installation is difficult to resist. The system owner essentially gets someone else to pay for the initial capital outlay—pay the dollars to purchase and install the technology. The investor is paid back with a portion of the energy savings, and the owner gets to keep the rest of the savings as net income. Positive cash flow is easier to realize when interest rates are low than when they are high.

Life-cycle Costs. Life-cycle cost analysis seeks to consider the costs and benefits of an energy-saving technology over the lifetime of the equipment involved. Some initial investment is made. There are annual maintenance and service costs to add in. There are annual energy savings which may be subtracted from the costs. The total costs and savings are projected over the lifetime of the system. The net, end-of-life cost is totaled up and compared with the life-cycle costs of alternative investments.

The least life-cycle cost technology is in many respects the best one to use. It is well-tailored to adding in a variety of societal and other costs associated with the investment, if dollar values can be placed on them.