RENEWABLES: A KEY COMPONENT OF OUR GLOBAL ENERGY FUTURE

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INTRODUCTION

Inclusion of renewable energy sources in national and international energy strategies is a key component of a viable global energy future. The global energy balance is going to shift radically in the near future brought about by significant increases in population in China and India, and increases in the energy intensity of developing countries. To better understand the consequences of such global shifts in energy requirements and to develop appropriate energy strategies to respond to these shifts, we need to look at the factors driving choices among supply options by geopolitical consumers and the impact these factors can have on the future energy mix.

There is no argument that both today and in the future, fossil fuels will account for the lion’s share of energy production. The EIA puts world primary energy production numbers at: fossil fuels - 86.6%, renewables - 7.0%, nuclear - 6.4% (EIA 1993). Of the renewables portion, over 95% is hydropower. The EIA predicts that renewables will grow at a faster rate over the next twenty years (2.3% annual rate of growth) than will energy production overall (1.6%) (EIA 1995).

Geopolitical energy consumption patterns also will shift, with significant economic and political consequences. Predictions are that the world’s population will increase by over 30% in the next 25 years (an increase of 2.7 billion); almost two-thirds of that growth will be in Asia and Latin America (The Economist 1994). China alone is predicted to grow between 100 to 200 million in that period, accounting for up to nearly 10% of that growth (Lu 1993). Energy production in China alone has shown phenomenal increases over the last 30 years, increasing 1,850%, making China the third-largest national producer in the world (Lu 1993).

Key to our argument is the proposition that a 60 quad increase in energy consumption in the industrialized countries has significantly different global consequences in a variety of dimensions than does the same-sized increase in the non-industrialized world. The integrated nature of the global geopolitical community as well as the magnitude of the ecological impact development activities may have suggests that energy production activities anywhere in the world will have consequences throughout the global system. The predicted growth in energy consumption in the developing world thus has particular implications for energy strategies in the industrialized nations - implications which, we suggest, warrant serious consideration and inclusion of renewables in any future energy strategy. An analysis of the factors driving choices among supply options for all countries and the global consequences of such national choices will support this statement.
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Figure 1: Global energy production in quads


Figure 2: Global energy consumption

source: International Energy Outlook, 1995, EIA
RELATIONSHIPS AMONG ENERGY SUPPLY OPTIONS AND FACTORS DRIVING CHOICES AMONG THEM

Energy Supply Options

Energy supply options generally fall into the following categories: fossil fuels, civil nuclear power, renewables, conservation, and new ‘unconventional’ sources under development. Fossil fuels can be further divided into oil, used primarily for transportation, coal, and natural gas. While prices for oil are generally seen to be going up (see, e.g. EIA, IEA, and DRI:McGraw Hill predictions in US Department of Energy, Energy Information Administration, 1995), natural gas is getting cheaper and coal is seen as a readily available and relatively inexpensive energy source. Civil nuclear power is under significant challenge in the US (no new plants are under construction and licenses for current plants will begin to expire around 2010 with controversy regarding extension and renewal), but is seen as a viable new source in developing countries such as China and Indonesia, and is well-established in some industrialized nations such as Japan and France. In the renewables set, we typically assume that this means solar. In fact, hydropower is a well-accepted and relatively inexpensive form of solar energy production and has the greatest commercial usage of the renewables. Hydropower is followed in usage by biomass, geothermal, and wind in that order. Solar power technologies (thermal, photovoltaic) are just beginning to penetrate the commercial world. Conservation has a varied history; as demand-side management and energy-efficient technologies it has gained credibility over the last decade in the US, overcoming some major institutional and infrastructure barriers (such as utilities’ pricing schemes) to do so, while in China it has been called “The Fifth Energy Source” (Lu 1993). ‘Unconventional’ sources such as hydrogen and nuclear fusion are still under development; predictions as to the timing of their emergence from the laboratory to the commercial sector vary widely. In this paper we will focus on the first three supply options (fossil, nuclear, and renewable energy) as conservation is a means for obtaining energy services of a qualitatively different sort (focusing on changes in behavior and technology replacement) and the unconventional sources are too far from market to be commercially feasible.
Factors Driving Choices Among Energy Supply Options

We propose to address choices among these energy supply options in terms of five major factors that drive the decision process: economics; energy self-reliance or independence; the existence of various types of international agreements; the existence or absence of an established infrastructure; and the relationship of the choice to sustainability. Each of these factors has several dimensions, and the application of and weight applied to each factor significantly impacts the world energy mix with implications for global quality of life.

Economics. The economics factor has two primary dimensions: the levelized cost of energy, or the cost per kilowatt-hour to the customer (kwh), and the ease of obtaining financing for energy projects. The cost per kwh is relatively self-explanatory. The ease of obtaining financing for energy projects is critical to developing countries, for they often have significant needs for grid development as well as capital construction, and cannot finance these out of internal cash flows. The picture is complicated as, in general, international lending practices preclude rural electrification (the biggest area of need in developing countries, including China and India) because the return on investment requirements placed by lenders demand an early and substantial cash flow from electricity generation to meet loan payments (cf Mellecker 1995), and political considerations favor those projects which serve the greatest number of people in the shortest amount of time, again favoring grid-connected applications. This type of financial structure favors grid-connected consumers, i.e. urban or developed areas, which will generate quick cash flows, and technologies with low up-front (vs. system or life-time) costs, which will keep the cost of the initial loan low and finance the balance through cash flow.

Energy self-reliance or independence. This, of course, became a recognized and institutionalized concern in many countries (such as Japan and the US) due to the 1973 OPEC oil embargo and the recognition of the economic power wielded by that group of producers.

International agreements. There are two types of international agreements that significantly affect or are affected by choices among energy supply options: environmental and security/defense. The most important environmental agreement is the Framework Convention on Climate Change (FCCC) signed at Rio de Janeiro during the Earth Summit in 1992, and which has since been signed by over 160 countries and ratified by over 118 countries, including the US. The overall goal of the FCCC is to stabilize emissions of greenhouse gases at a level that prevents “dangerous” interference with the climate system. As a first step, the industrialized countries agreed to voluntarily attempt to limit emissions by the year 2000 to 1990 levels. Negotiations are continuing now on a protocol for dealing with future emissions. As we will see later, this agreement tends to have a positive impact on nuclear power and renewables as energy supply options, and a strong negative impact on fossil fuels. The most important international security agreement in the context of this discussion is the Nuclear Non-proliferation Treaty (NPT) which is designed to prevent the transfer of nuclear weapons and nuclear weapons production technologies to non-nuclear weapons states. Clearly, this has had a significant negative impact on the development of civil nuclear power as a viable energy supply choice for some nations (China, for example).

Existence or absence of an established infrastructure. The existence or absence of both an electricity grid, and/or a transportation infrastructure for energy feedstocks such as coal or oil (both of which can be called the “physical infrastructure”) can have a significant impact on the choice of energy supply option. Clearly, if such a physical infrastructure does not exist it must be built and therefore financed, or an energy supply
option which does not require a grid (such as some renewables, and diesel generators) will be chosen. The education or knowledge infrastructure also should impact choice: is requisite knowledge to build, maintain, and repair the chosen energy technologies available in-country or can it be easily developed?

**Relationship of the choice to sustainability.** ‘Sustainability’ is shorthand for a new paradigm of development, a way of looking at social processes that includes consideration of their impact on planetary (and therefore, local) ecology. It requires a long-term, inter-generational perspective (with significant re-definitions of and consequences for ‘return on investment’ concepts). It requires implementation of concepts such as ‘industrial ecology’ which treat industrial (and by extension, social) processes as closed systems, considering systemic consequences of all parts of the process from raw material extraction through waste treatment and disposal (Dambach 1994) where the system is a global one. It thus encompasses and attempts to reconcile concepts of both ‘economic development’ and environmental quality.

We have identified five primary energy supply options (fossil, nuclear, renewables, conservation, and ‘unconventional’) and five key factors driving choices among those options (economics, the desire for energy independence, the existence of international agreements, the existence or absence of established infrastructures, and the relationship of the choice to sustainability). We now will take the three primary supply options (fossil, nuclear, and renewables) and demonstrate in general terms how the factors driving choices among these options could play out with significant negative global consequences and that renewables can, with little additional government support, address some of the more serious of these consequences. We will conclude with an observation that renewables be considered a serious and key part of future global energy strategies.

**Fossil Energy and Factors Driving Choices**

As noted earlier, fossil fuels make up almost 90% of today’s energy mix, and most scenarios see them occupying a similar strong position in the future. If we examine the consequences of such a mix in the light of the factors driving choices among energy supply options, we see both the logic as well as some negative consequences of such selections.

**Economics.** The economics for fossil fuels are generally positive. The retail cost per kwh is relatively low, averaging about 8.4 cents/kwhr in the US (EIA 1995). Fossil fuel technologies are relatively mature, which brings the cost of acquisition down (R&D costs have generally been amortized, and economies of scale and production exist). Coal is generally available worldwide, however, there is uncertainty about future prices. Natural gas prices in the US are dropping because of the profound systemic changes induced by deregulation, and are generally falling world-wide because of recently increased reserve estimates. Environmental costs are externalized and generally not included in cost per kwh calculations. In the financing arena, the mature technology reduces uncertainty and so reassures investors and makes financing relatively easy to acquire for fossil fuel-fired power plants. For distributed power applications such as diesel and small gas turbines, installation (up-front) costs are low, so, once again, financing is relatively easy to obtain.

**Desire for energy independence.** The primary negative for fossil fuels is, of course, in the transportation sector which is almost completely dependent upon oil and so upon the limited number of oil-producing countries in the world. In terms of electricity generation, fossil fuels, particularly coal, look attractive as coal is well distributed geographically (China has significant reserves, although it has infrastructure concerns as most of its coal reserves are located in the northern part of the country while consumption
centers are in the south and southeast, and transportation is poor) and its international movement is not controlled by any cartel-like organization such as OPEC.

**Existence of international agreements.** Fossil fuels are a big negative in the environmental arena. Fossil fuel-fired power plants and the transportation sector (which is almost entirely based on oil) will be responsible for most CO\textsubscript{2} and SO\textsubscript{2} production, affecting compliance with the FCCC. Developing regions will significantly increase their emissions of greenhouse gases in the near future. In the next 20 years, the relative share of CO\textsubscript{2} emissions from the developing world, including China, could increase from 19% to 48%. Furthermore, if developing countries achieve the level of electrification expected by 2040, their relative share would increase to over 70%, even though per capita consumption would remain far below current industrialized world levels (Drennen 1993).

![Figure 4: CO\textsubscript{2} Emissions from Electricity](image)

**Source:** Drennen 1993

A unilateral response by industrialized nations thus would be largely ineffective at reducing global greenhouse gas emissions. The logic of energy choices exercised by the developing countries will have a profound impact in this arena.

The second area of international agreements, that of security treaties related to defense concerns such as proliferation, is positive for fossil fuels. Although there are agreements through the IEA for mutual response in the event of another Arab oil embargo (a commitment that seemed to be demonstrated through the coalition assembled during the Gulf War), the movement of fossil fuels *per se* is not restricted by international agreements of this sort - in fact, it is enhanced and encouraged.

**Existence or absence of established infrastructures.** In terms of physical infrastructures, fossil fuels rack up both negative and positive points, but make strong positive marks in the education/knowledge infrastructure arena. Most developing countries do not have the grid required to distribute electricity to rural areas (and, in some cases, to urban areas) and so would have to finance and construct it. However, the maturity of the technology and construction techniques make the acquisition of such financing relatively easy - and, in those areas where grid development does not seem to be feasible, the relatively low capital costs required for diesel and small gas turbine generators favor the use
of fossil fuel. It is here, too, the absence of coal transportation networks in China becomes relevant. However, again, the technology for constructing such transportation networks is well known and easily available. Finally, the knowledge or education regarding combustion technology is easily available and already relatively widespread.

**Relationship to sustainability.** Fossil comes out with a strong negative here. It is a depletable resource in all its forms (coal, oil, natural gas), and its consumption contributes significantly to environmental degradation through the production of CO₂ and other greenhouse gasses.

Fossil fuel as an energy supply choice provides a mixed bag of positives and negatives when evaluated against the factors driving such choices.

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<th>Economics</th>
<th>Energy Independence</th>
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**Figure 5:** Summary of Fossil Energy as an Energy Fuel Option

In summary, we find on the positive side that historic investments in the knowledge infrastructure have led fossil fuel technologies to their current position as mature technologies. This now contributes to the positive economics of fossil fuel-generated energy, including its relatively low kwh cost and its good borrowing ability. The big negatives for fossil fuel as an energy option are in the environmental arena (particularly with CO₂ emissions and other greenhouse gases, and the way in which they will increase over time) and in sustainability (as we near the limits of recoverable reserves, there will be an adverse affect on price). Note, too, that both negatives are exacerbated by time, i.e. if we take the long-term perspective required by such concepts as industrial ecology and sustainable development, fossil energy looks like an increasingly poor energy supply option.

**Nuclear Energy and Factors Driving Choices**

Nuclear energy also ends up as a mixed bag. While its economics are generally good, they are negatively influenced by uncertainties, and there are significant negatives in the security and environmental/sustainability arenas.

**Economics.** The economics of nuclear power are complicated by the uncertainties introduced by regulatory issues. The cost of production of nuclear power has the potential to be competitive, and the fuel (uranium) is cheap. However, increasingly strict regulations which are generally designed to internalize health and environmental costs, and the regulatory uncertainties present both in the US and in other countries, drive up costs. These same uncertainties make the cost of plant construction variable and so difficult to finance through international lending institutions. However, in some cases, state-sponsored nuclear power developers (such as Electricité de France) can obtain "self-financing," so international lending community does not need to be involved, and nuclear power becomes a more attractive option for developing countries.

**Desire for energy independence.** Many countries such as Japan and France have seen nuclear energy as a path to energy independence and have explicitly designed energy
strategies around it. There is a negative encountered by some developing countries as they attempt to follow this path in the international controls put on the movement of nuclear technologies and special nuclear materials in the name of non-proliferation.

**Existence of international agreements.** The primary concern in the environmental arena is the disposal of waste and the potential for generating radioactive plumes in the event of an accident. (For example, Indonesia’s announced plans for constructing seven to twelve nuclear power plants in the 600-1000 MW range each caused international concern because of the archipelago’s location on the geologically unstable Pacific ‘Ring of Fire.’) (Habibie 1994). However, the production of power with nuclear technology does not generate greenhouse gasses; hence it can be argued that use of nuclear power clearly supports the FCCC. It is under international security agreements, particularly the NPT, that nuclear power hits its biggest negative. In the interest of limiting the spread of nuclear weapons, the international movement of all nuclear technologies and materials is strictly controlled and may be denied to nations with declared intentions of using it only for peaceful purposes if the international community deems otherwise (the recent discussion of the sale of Russian technology and equipment to Iran is a case in point).

**Existence or absence of established infrastructures.** Nuclear power requires a grid; there are no distributed power options. Hence, nuclear power as an energy supply option encounters the same concerns as fossil in this context with no mitigating technologies such as diesel generators or small gas turbines. In terms of knowledge infrastructures, while knowledge of nuclear power technologies is fairly well developed, its dissemination is controlled due to (among other reasons) non-proliferation concerns. As a result, there also is an element of ‘technology fear’ connected with nuclear energy that may not be present with fossil energy knowledge.

**Relationship of the choice to sustainability.** Nuclear energy has the potential to show favorable marks in this column if the waste problem can be solved in a fashion that meets environmental concerns but does not threaten international security as does (some believe) current reprocessing techniques, and if the public can accept a level of risk at least comparable with if not better than fossil fuel-fired plants. As the state of the art currently stands however, nuclear energy must be given a negative here.

The big negatives for nuclear energy are in the international security and environment/sustainability columns, both of which have led to increased regulatory requirements which have had a negative impact on economics. Also unfavorable for developing countries is the requirement for a grid. Positives are in nuclear energy’s contribution to energy independence and the leveraging of an existing knowledge infrastructure which has had a positive impact on economics.

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*Figure 6: Summary of Nuclear Energy as an Energy Fuel Option*
We still don’t have an energy option which is attractive in the context of the emerging consumers (the developing nations, including China and India) which will see significant increases in the amount of energy consumed particularly in rural areas, generally do not have a grid structure in place to service these new consumers, are seeking energy independence to avoid slipping into dependencies of ‘neo-colonialism,’ and which may be politically unstable enough to pose potential proliferation concerns. Finally, the burgeoning world population is stimulating serious concerns about global sustainability, which neither fossil nor nuclear energy addresses favorably.

**Renewable Energy and Factors Driving Choices**

Rounding out our picture of available energy supply options, we now turn to a consideration of renewables. The analysis shows that, while negative in some columns such as cost of production, renewables do show positives in areas missed by fossil and nuclear, such as sustainability. This raises the suggestion of a portfolio of options, and suggests that a conscious, deliberate, and well-considered global energy strategy might require investment by both government and private sector in different parts of the energy supply mix.

**Economics.** The economics of non-hydro renewables generally are unfavorable, particularly when compared with other energy supply options. The costs of production generally are high, although they have decreased significantly over the last 15 years and are approaching comparability with fossil fuel-generated electricity.

![Renewable Energy Costs Declining - Realizing Our Goals](image)

**Figure 7:** Cost of electricity for renewable options


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1 The economic viability of non-hydro renewables has recently been challenged in a report by the Center for Energy and Economic Development that concluded that renewable energy will be unable to contribute significantly to the US’s electric power needs in the next 15 years without massive federal subsidies. The report was strongly rebutted by the US Department of Energy in a response prepared by the National Renewable Energy Laboratory (cf The Energy Daily 1995).

2 In the discussion referred to above between the US Department of Energy and the Center for Energy and Economic Development, the Center claimed that cost per kWh of renewables would level off at today’s cost; the Department of Energy argued for a continued decline (see Figure 7).
However, if environmental costs, currently treated as externalities in fossil and nuclear fuel costs, were internalized, the costs of renewable-generated energy would be much more competitive. Furthermore, renewables are very competitive with distributed power options such as diesel generators in certain niche but important off-grid applications. Finally, financing is often difficult to obtain for renewable energy projects, because technologies are immature and unproven, the up-front installation costs can be higher than alternatives, although system life costs may be competitive because there are no add-on fuel costs, and because of certain environmental considerations, particularly those caused by hydropower’s large footprint.\(^3\)

**Energy independence.** Renewables place high here, as every country can do some sort and some amount of renewable energy production.

**International agreements.** Production of energy with renewable sources such as water or the sun does not generate greenhouse gasses; hence renewables comes up positive against the FCCC. However, there are some serious environmental concerns associated with some renewable deployments, such as the Three Gorges Dam in China - in this case, concerns associated both with the large footprint required and the destruction of habitat and changes in water flows occasioned by the dam. Renewables raise no concerns regarding international security.

**Existence or absence of an established infrastructure.** Here, again, renewables come out both positive and negative. There are many renewable technologies that are highly suitable for distributed applications, and hence to not require development of a grid. The nature of the feedstock also means that there are no transportation issues with which to deal. However, the installation, repair, and maintenance knowledge infrastructures are in their infancy, perhaps raising concerns of intellectual dependency (neo-colonialism) in some developing countries.

**Relationship of the choice to sustainability.** It is here that renewable energy options shine. Properly implemented, they will act as effective closed systems, generating little or no waste and consuming little or no irreplaceable resources.

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 & Economics & Energy & International & Infrastructure & Sustainability \\
 & Production & Financing & Independence & Agreements & Phys. Knowledge & \\
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Fossil & + & + & +/- & - & -/+ & + & - \\
Nuclear & +/- & + & +/- & +/ - & - & +/- & +/- \\
Renewables & - & - & +/- & + & + & - & + \\
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**Figure 8: Summary of Renewable Energy as an Energy Fuel Option**

Although they are improving, the economics of renewables are still unfavorable, particularly when compared with other energy options. Costs per kwh are high, although

\(^3\) The Clinton administration recently announced that it opposes credit from the US Export-Import Bank for companies seeking to participate in China’s Three Gorges Dam project. Opposition was due to “environmental concerns,” according to White House press secretary, Mike McCurry (The China Energy Report, 1995).
they are rapidly decreasing and would look much better compared to other options if environmental externalities were considered in all energy pricing. The up-front cost of system installation can be high, making renewables an unattractive option for financing systems that require a near-term return on investment and so favor smaller loans as well as loans directed at grid-connected applications which can generate a much higher cash flow than can off-grid connections which generally target rural consumers. However, for this same reason (grid independence) renewables speaks well to developing countries without established infrastructures, and also supports energy independence, although the absence of the knowledge infrastructure does raise fears of dependence. Renewables also show positives in key columns which speak to the needs of the global community - sustainability and international agreements.

Implications of Energy Choices for Global Quality of Life

The geopolitical distribution of the bulk of new consumers of energy - in the developing countries, most particularly China and India - say that we all will have to do something about such long-term and systems problems as planetary sustainability. As we showed earlier with the projections on CO₂ production, this must indeed be a joint effort: the industrialized nations cannot do it alone. However, given that the factors influencing choices among energy supply options generally are manifest in ways that favor industrialized nations (the most clear example being that of financing, where the system has made it most difficult to obtain financing for that energy application where developing countries need it most - rural electrification), it is most likely that our future energy supply mix will look very similar to that which we have today. I would like to make a few suggestions that may alter that mix, and then leave you with some questions.

How to Improve the End Game

If our analysis is reasonably accurate, it would suggest that the best global energy supply mix would be just that - a mix or portfolio of energy options, providing affordable energy when and where needed, offering a hedge against unforeseen geopolitical events that might radically alter the flow of energy feedstocks around the globe, protecting against the acquisition of nuclear weapons knowledge by ‘bad actors,’ and doing all this in a fashion that will allow planetary longevity. As our global mix currently stands, renewables are the weak element in our portfolio. However, with a judicious mix of government and industry investment, we can significantly strengthen the offering. Government can play an important role in financing the R&D that is needed to make the technologies market-attractive, at which point the private sector should pick up the ball. A relatively small investment in education and outreach programs, again on the part of the government, will develop the knowledge infrastructure required to disseminate renewables into remote areas of developing countries, areas to which they are eminently suited. Finally, we collectively need to change our paradigms, to think long-term, inter-generationally, in terms of sustainability. Such a paradigm shift would have natural fall-out in the global financing system, internalizing what are now ‘environmental externalities’ and suggesting a life-time view of energy systems that would incorporate fuel costs, particularly for fossil fuel-based energy production systems. If we can do these things, we can, for a relatively small social cost, develop an ‘energy insurance portfolio’ that would help improve the global quality of life without compromising key social goals. And a viable renewable sector is key to that portfolio.

Now for the questions. The US has very effectively build a defense industrial base to assure our national ability to respond to aggression and to defend us against any other country’s attempt to detract from our life, liberty, or pursuit of happiness. We should see
the energy industrial base in the US as the equivalent in its importance to preserve these rights for Americans and to respond to the global economic market that is going to develop in the next two decades and that should spread some of these opportunities to others. The US has made a number of (aborted) attempts to take this high ground, but it has regularly failed. What is the root cause of these failures? How do we deal with them? Are they all economic or are they political and competitive? Are other countries responding to this market and moral message and leaving us behind?

We all - whether we live in industrialized or developing countries - have a common investment in the future of our planet. Renewable energy as a significant part of our global energy portfolio can help make a real contribution to sustainability. The energy sources will be continuously available: exploitation of them is limited only by our imagination. We must see beyond our current paradigms, move beyond international competition to a concerted global effort, and use the closed system concepts of industrial ecology to begin development of a reasonable and considered response to this problem. Should we fail to assume this responsibility, we will consign it to our children and grandchildren who will have to address it in less time and with fewer resources.
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