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Global Warming: The Real Options

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Summary

In contrast to the belief that there are "many things we can do" with respect to global warming, we in fact have only very limited options if we wish to respond **effectively** to global warming. To avoid the worst effects of global warming, we have only a short 40-50 year window of opportunity to change our energy systems away from fossil fuel, for this is the major part of the solution. To achieve this huge reduction in fossil fuel use, we will need to rebuild most of our energy extracting and consumption industrial base and change a large fraction of all the end users of energy. The short time to accomplish this change requires very aggressive action, and can only be achieved if we concentrate on already mature technologies to replace fossil fuel use, specifically, conservation and nuclear generated electricity. Contrary to what we might wish, most "green" options can only be very marginal in their benefits due to their various limitations and to the lack of technological and market maturity.

It is vital that we keep open the options we are very likely to need: specifically, a very large expansion of nuclear power, and the use of Yucca Mountain for at least temporary storage of nuclear waste. It is equally vital that we not endorse as "the solution" the relatively ineffective so-called "green" technological options (wind, solar, etc), but treat them for what they are: necessary but marginal contributors to solving the big problem.

Who am I?

I am a physicist who has worked in the government (U.S. National Institute of Science and Technology), has been elected to major public office (County Council, Montgomery County, MD), served as an appointed environmental department head (Montgomery County), worked for a think tank in energy and environmental issues (Mitre Corporation), and has run a small manufacturing business. I have no ties, past or present, to any nuclear or other industry interest.

Global Warming and Nuclear Power

Global Warming

To those of us who are skeptics (as we all should be), it has only been in the past several years that the data have become persuasive: global warming is real. To me, the biggest piece of evidence has been the compiling and analysis of the glacial ice record over the past thousands of years combined with the current glacial ice retreat measurements from many parts of the world. Less persuasive is the agreement of the various atmospheric climate models predicting warming as a result of greenhouse gases--these models are still very crude, and have relatively little verification.

Never the less, the conclusion must be that climate change, almost surely the result of human activity, is already occurring. How much and how fast it will occur, and with what geographic distribution, is still in question. However, it is virtually certain that the warming will be VERY significant in the next fifty years and will continue worsening if no or ineffective (e.g., Kyoto) action is taken. It is apparent that it is already too late to prevent global warming; however, while very late, it is not quite too late to greatly reduce its scale and duration. But only direct, aggressive, large-scale efforts will be effective in mitigating the effects.

Global warming will produce some winners as well as losers. However, even if winners and losers were in equal proportions, the overall effect is bad because the disruptions in the established human order will be severe, and the changes will happen quickly compared to how fast societies can modify their own balances.

Contrary to popular belief, the U.S. is not the major driver of global warming. While disproportionately large, our emissions even now are only 25% of the world emissions. As the third world (India and China) advance economically, their emissions will increase many-fold and will soon totally dominate the world emissions. All must be reduced--first world and third world.

Response to Global Warming

To avoid the worst of the global warming, the world (not just the U.S.) will have to reduce its fossil fuel emissions by 80-90% compared to the present day. This means that we must eliminate almost all present and future fossil fuel use. Over the last 100 years, the developed world has based most of its economy and industry on fossil fuels. Reducing the fossil fuel use by the necessary degree will require fundamental changes in a huge fraction of the installed industrial, commercial, and end use base in our economies.

Even with 80-90% of fuel emissions removed, there will still be substantial population and standard of living driven greenhouse gas emissions from agricultural activities (including animals), original forest harvesting, and other sources. Many of these sources are even less controllable than fossil fuel usage.

The major end uses of fossil fuel are space heating, transportation, and industrial processing. Most end uses will still be needed, so nearly all of these will have to convert to alternative energy. As discussed below, this would be in the form of electricity. In addition, present fossil fuel electric generation will also have to convert. While some electricity can be supplied by geothermal, hydro, or other sources, the only major source of non-polluting energy that is plausibly available (discussed below) is nuclear. In addition, new plants will need to be constructed to supply energy to the newly electrified end uses.

These steps imply that in the developed world, the majority of the installed energy economy must be redesigned and replaced. The newly developing world will have to largely bypass polluting technologies (fossil fuels) for clean technologies.

And all this will have to happen in less than fifty years--a very short time for this scale of conversion. If we do not achieve this enormous reduction in fossil fuel use, the bulk of global warming impacts will occur. Marginal (i.e., minor) reductions in U.S. and current developed world emissions will be inconsequential in results even though they may be expensive and disruptive.

Because of the short time frame (40-50 years) to make major changes in the huge base of the world's installed energy systems, I suggest that there are only two technologies that can accomplish the bulk of this task: Conservation and nuclear power electricity to replace fossil fuel end uses.

New Technologies - The Problems

Many people see the "green" technologies as the answer to global warming, but these are hopes not supported by experience. Indeed, these technologies will, at most, be bit players. Wind power will be suitable in some areas, solar electric in others, geothermal in still others, and so on. But even in combination, they cannot meet the base needs of a developed country, nor many of the needs of third world countries.

Most all emerging technologies go through a similar cycle: the idea, a demonstration, an increasing understanding of the advantages of the technology, increasing support for its application, and only slowly, a more full understanding of the adverse effects and limitations of the wide application of the technology. Every new technology has downsides, often severe, but it takes a long time to see them. For example, we are now seeing the increase in food prices due to ethanol production, and as these problems increase, we will begin to see others (e.g., the effects of intensively cropping marginal farmlands). And this is still early in the ethanol development (even though ethanol as a fuel has been developing for about 20 years).

Each new technology has proponents (constituencies) who downplay the problems even as they belittle skeptics. But a fundamental characteristic of nearly all the "green" technologies is that none are widely used now, i.e., they are not fully developed and installed as major parts of our energy system. So while the apparent benefits are widely discussed, the real costs and limitations are not yet clear to society. Those costs, and the implied down-sides of the technologies, will not become apparent until much money and effort will have been spent, and then it will be too late to have a major effect on global warming. We will have squandered time and resources for little real benefit, while building constituencies that will make changing direction even more difficult. All the while, we will be diverted from applying the technologies that would be of significant effectiveness in reducing global warming.

In many proposed energy technologies, very significant technical problems also exist that raise the question as to whether the technology can ever be viable on a significant scale. For example, no one even knows how to make liquid fuels from cellulose on an industrial scale, yet this is widely suggested as a future energy source. No one has demonstrated CO_2 sequestering at a single full scale coal fired power plant.

Even more importantly, some highly touted technologies appear to have fundamental problems that have no solution. For example, just what is the energy source that would be used to generate the hydrogen for the so-called hydrogen economy? Unless this is identified, the "hydrogen economy" means little. And even if one learns how to capture the CO_2 from a power or gasification plant, where will you put the CO_2 (the equivalent of several full freight trains per day per power plant)? At best, like geothermal (itself a relatively mature technology) and other green technologies, CO_2 sequestering would appear at best to be feasible only in unusually suitable geographic locations.

Some of the new technologies, for example, wind and solar electric/heating systems, will be of benefit in some situations, but a fundamental problem remains: where is the energy going to come from when the wind has died or the sun is not shining (presumably from base-load power stations)? And just how willing is our society to lace the land with the transmission lines to move the power to the end users when it is available?

Wishing that painless, easy to choose, solutions are at hand does not make it so: we must move to more evidence-based policy planning.

Even if the benefits and costs were clear, and even if the major technical problems have been solved, it will inevitably take a long lead time to get a major new technology adopted into the many places required in a large, complex economy. People need to be trained in the design and operations of it, economic, financial, technical, and regulatory systems must be developed, and the older, competing technologies must phase out (usually by waiting until the end of their functional economic life). One can hope for ways to reduce this time, but every experience we have shows a rather consistent period approaching fifty years to get the job even 75% done when we are replacing vital, widespread, functional, but obsolete technologies with new, often less economic ones. It just takes time: even buggy whip manufacture continued for decades after the automobile appeared. Energy is a huge component of our economy: the energy "ship" cannot change direction quickly!

We are easily misled when we see a successful demonstration or even full scale plant into believing that the job of getting a new technology into service is thus well advanced. We do not see the decades it will take to refine the design, build the industries that can replicate it, install and learn how to operate new plants, and remove older plants from service. Even fifty years is none to long for this process, and that is assuming one begins with technologies that are already widely installed and understood.

To sum up, there is not time before global warming is past the point of no return for this process to include more decades of working our way through multiple possible technologies (wind, solar, etc). If we are to prevent the worst effects of global warming, we can only do so by aggressively using presently known, proven, already widely adopted technologies. And the only two that meet this need are conservation and nuclear.

Conservation

Conservation techniques are widely known and applied. Conservation is sometimes easy, cheap, and painless. However, as the demand rises for deeper reductions in fossil fuel use, not only does the cost and pain increase, but so does the technical difficulty. Solutions must be tailored to an end user activity, thus requiring not only technology tailored to the situation, but also social, political, and economic programs to achieve. Conservation efforts can and will function in both developed and undeveloped world, and both are needed. While difficult, effective conservation has been proved on a large scale and is accepted in the market place. To expand conservation on a large scale will require aggressive building on the political support that is present in many places, and will require aggressive research and development.

Although I do not go into detail concerning conservation, it should be noted that actually implementing effective, wide spread conservation in the U.S. will not be simple. There will be a large variety of economic, social, technical, political, and regulatory hurdles. However, there is at least wide spread agreement, at least in principle, that conservation is needed and feasible.

Nuclear Electrification

To eliminate 80-90% of our geenhouse gas emissions requires that we reduce our use of fossil fuels by a similar amount. We use fossil fuels (mostly as liquid and gas fuels) in end uses-transportation of all types, space heating, and industrial processes. And we use it to generate electricity (mostly as coal, and increasingly, as gas). Virtually all of this must cease.

There are two parts to achieving this goal: (1) electrification of the economy, (2) conversion to nuclear electric generation.

We know how to convert most fossil fuel end uses to electricity. Electric transportation (including mass transit both rail and road based, electric railways, battery operated cars and trucks), electric driven heating and cooling, and electric industrial processes are all feasible and most are widely used, fully mature technologies. They are not all equally easy, and in some areas (e.g., battery development) major work needs to be done. We also know how to build nuclear electric power plants--the only large-scale source of energy that does not generate greenhouse gasses.

It must be noted that some uses of fossil fuels have no apparent alternatives. Fossil fuels will continue to be used for chemical feedstocks (e.g., plastics) that are (or can be) very small sources of CO2 emission. However, other uses such as long distance airplane flights and ocean shipping, will almost certainly require fossil fuel and associated emissions (shorter distance flights can be replaced with high speed electric ground transport, as can long distance trucking.)

In developed countries, much (but not all) of the electric infrastructure is in place. However, the developing world will need to move away from and bypass fossil fuel based economies and go directly to electrification and nuclear. Ironically, the undeveloped world is likely to be where "green" technologies will have the most impact as a bridge to converting to electric economies (i.e., where intermittent operation of energy sources may be more tolerable).

Nuclear power combined with electrification of the economies of the world can displace (with conservation) virtually all fossil fuel use (which is what it will take to reduce emissions by 80-90%). The technology is developed and in place and can be replicated.

We should note: electricity is by far the most efficient means of transforming and transmitting energy sources, and is crucial to allow as much flexibility as possible in integrating a variety of energy sources. While some people criticize centralized electric production, there is no escaping that only central production is able to supply large scale reliable power, both for direct production and as a backup to variable sources (wind, solar, etc).

Nuclear Power

Unlike conservation that has at least received the support of lip service, in much of the western world we have spent the past 30 years trashing the whole concept of nuclear power. While many of the opposition arguments have had at least some validity, at this point there are few options to deal effectively with global warming. As with an impending hanging, our minds must become more focused so as to choose among alternatives. Global warming changes the equation, and it changes the way we must look at alternatives. If there were really good alternatives, they would have long since been implemented--indeed, the economies of the world already would have adopted them. Instead, as in other parts of life, with impending global crisis, we must choose among less attractive but more realistic alternatives, and accept some risks or costs that we would not otherwise have chosen. If one is faced with cancer, to achieve the overriding goal of life we do accept the injection of poisons into the body and the consequent costs. We must face the real alternatives.

Probably the highest visibility issues with nuclear power are (1) safety and, (2), what to do with nuclear waste. Before discussing that briefly, we should note the state of the nuclear power technology.

In the past 30 years, the industry has greatly improved the operations and safety of plants, now routinely achieving 90% availability and greatly lengthened plant life. So the technology is here, proven, and widely used. However, there are more very significant improvements to design that can and should be made, in safety and other characteristics, and especially to put in place reactors that breed a higher fraction of their own fuel.

Safety remains a public issue, and is a legitimate concern. To put nuclear safety in perspective, present plants have in fact been safe (only Chernobyl has killed any citizens) while coal plants kill roughly 20,000 Americans per year from emissions. It is little known that the actual radiation emission from a nuclear plant is about 1% of that from a coal plant (which releases radioactive materials as it vaporizes so much fuel).

However, in contrast to a coal plant, a current design nuclear reactor contains a large amount of stored energy that requires active operational management. In a coal fired plant, if a conveyor belt breaks the fire simply goes out. However, if a critical component fails in a reactor, the energy release does not promptly stop by itself--control rods must be inserted, and the continuing heat being produced must be removed. That is, mechanical or human intervention is required to maintain a safe condition. Failure of this response is possible, as Three Mile Island showed. Safe design reduces the probability of the occurrence or the consequences of failure, but cannot eliminate it. However, in the past 30 years, several new reactor designs have been developed that literally are almost fail safe, i.e., almost any imaginable failure leads to an automatic shutdown without human or even mechanical intervention. These design principles are clearly desirable.

Another aspect of safety is terrorism. While almost anything is conceivable, many risks that have been cited (e.g., terrorists stealing nuclear waste to make a bomb) are probably not as likely as some believe, and can be greatly reduced. However, some of these are risks we will likely have to guard against, but ultimately accept (just as we accept other risks in all our decisions).

With regard to fuel and nuclear waste, we must note that the U.S. in the 90s decided to terminate nuclear fuel reprocessing. This policy decision (driven by politics and fears of proliferation) has enormously increased the waste quantity to be disposed and has reduced the long-term nuclear fuel supply (because we are throwing away unburned fuel). However, unlike almost any other power source, nuclear reactors now on line actually generate some (e.g., 25%) of their own fuel by converting some of their passive fuel materials into fissile materials. Reactors deliberately designed to increase this fraction are called breeder reactors, and with a high breeding ratio ultimately need little more than an initial charge of fuel and then can produce virtually all their own fuel over their operational life. Breeder technology will enormously extend our nuclear fuel reserves (x100), but probably the biggest benefit will be to greatly reduce future nuclear waste quantities and greatly simplify their handling and storage. Several breeder reactors have been built and operated around the world demonstrating that the basic concepts and engineering are valid. The U.S. canceled a major advanced breeder in the late 90s: we need to reactivate the technology. If pushed hard, such plants can begin penetrating the market in the next 20 years. Breeder reactors are, in fact, a "sustainable" energy source.

In the meantime, however, we have our existing nuclear plants and those similar plants to be built in the next several decades that produce the high level waste (and wasted fuel) characteristic of most of the present reactors. It is the waste from these that is a major issue.

Again, for perspective, the quantity of waste from a nuclear plant is perhaps 20T per year vs 5 million T/year for a coal plant. Of course, the nuclear waste is highly radioactive, though the radiation levels do decrease rapidly with time (0.1% remaining after 40 years). Some components of the waste remain radioactive for several thousand years, but at rather low levels--above regulations for safe exposure, but not particularly deadly. Of course, the toxic components of the wastes from coal plants and other processes normally remain chemically toxic forever--they don't decay at all. Even the gaseous waste CO2 emitted from fossil fuel burning remains in the atmosphere for many decades. So the nuclear waste must be handled carefully, but it would appear that the waste disposal/storage problem is not so much a technical challenge as it is a political and social challenge.

Ironically, no other technology in man's history has had to meet the kinds of demands that we place on the issue of nuclear power. And it is fair to say, that no other major technology could have been developed and adopted that had to meet such tests. Could the internal combustion engine been developed if the originators had had to say how greenhouse gases would be handled? Could we even develop vaccines if the doctors had to say where the food was going to come from to feed the saved patients?

A Technical and Political Solution

If we are to be effective in avoiding the worst of the global warming effects, we have few real options:

- Begin the conversion of fossil fuel end uses to electricity
- Recognize that we must immediately begin the conversion to nuclear electric generation by installation of new generation light water reactors such as other countries are now deploying, first replacing existing fossil electric plants then building additional plants to provide the energy as fossil fuel use decreases
- Develop and shift to lower waste producing (and even safer) breeder reactors as quickly as possible
- Open the storage facility at Yucca to temporarily accommodate present and near term waste, with the waste to be removed and reprocessed into fuel as the breeders come on line

This program will be expensive, difficult, and will present stupendous political challenges. There is an alternative. We can recognize that the U.S. can probably weather the global warming effects better than most countries--we have vast technical and financial assets. We can also recognize that any large-scale response to global warming will be very expensive, and would likely reduce our financial assets just when we need them. If we compromise between those advocating a strong response, and those pressing for a minimal response, we will achieve the worst of both worlds: an expensive, disruptive program that does little to solve the problem. That is the course we are now on--an increasingly expensive series of efforts that nibble on the edges of the problem, that generate a sense of achievement without the substance, and that build ever-stronger constituencies for the status quo.

However, continuing the present course is dangerous: there is no guarantee that we will not have worse climate effects than we expect, and we can be sure there will be ever more painful but unforeseen political and security effects from the global warming and its geopolitical effects. No response, or an ineffective one, is a very dangerous choice (and one that is arguably immoral).

The economic opportunity for the U.S. from a strong program is obvious: even though we start from behind due to our lack of work in the past decades, we should be able to dominate the conservation, electric, and nuclear industries around the world. We have the depth of education and the capital to take advantage of this market: no other country has it.

The national security effect is equally clear: we will be able to disconnect from foreign fossil fuel sources that so dominate the world's and our security, and the equally dangerous transfer of our wealth to repressive governments.

To accomplish this shift will be extremely difficult, and very costly (though not without profit!). Ironically, the cost for the US would likely be less than the cost of fighting the Iraq war, while generating real profit, and real benefits. The biggest challenge will be to develop the political will to frame a practical program, then implement it over the long run. Given the past 30 years of misdirection and largely wasted effort, this will require great statesmanship.

The political situation is similar to that which Franklin Roosevelt faced in the late 1930s. It was obvious that a war was coming, yet the country was isolationist. He undertook a series of graduated, politically calculated (but politically costly) steps to prepare the country for war. Even so, he was almost too little, too late. The U.S. response to global warming must be similar. There needs to be a series of steps to ratchet down the opposition to existing technologies (especially nuclear), to focus the nation on the practical alternatives, to reduce demagoguery, and to lay the basis for long term effective solutions. And there needs to be leadership.