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# Mitigating Climate Change: Asking the Right Question

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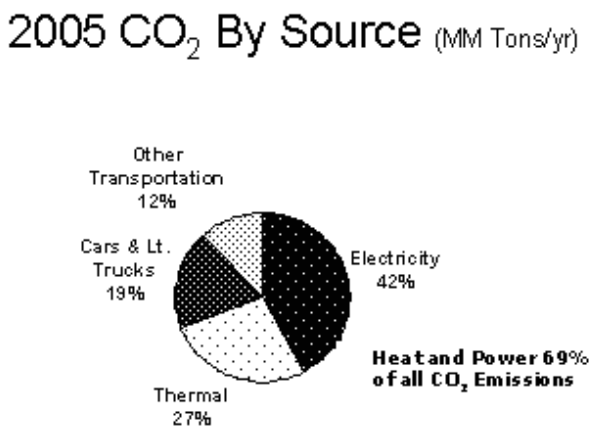
A noted scientist, Sir Henry Tizard (1885-1959), once said, "The secret of science is to ask the right question, and it is the choice of problem more than anything else that marks the man of genius in the scientific world."

How would Sir Henry view the current debate about mitigating climate change? Look at the typical questions in the political debate. How can we make society deploy more renewable energy? How can we develop new technology? How can we make cars that travel more miles per gallon? What size tax on carbon is needed to induce carbon emissions reductions? Are these the right questions?

The price of producing the main greenhouse gas – carbon dioxide – has tripled or quadrupled since 2002 with rising fossil fuel prices. Will market forces respond and de-carbonize the economy? Consumers pay a rising amount of money to warm the planet, and should be clamoring for cheaper energy services – for an increase in fossil fuel conversion efficiency. Markets show extreme efficiency in cutting costs, but only when open to competition and free of distorted price signals, regulatory barriers and anticompetitive practices.

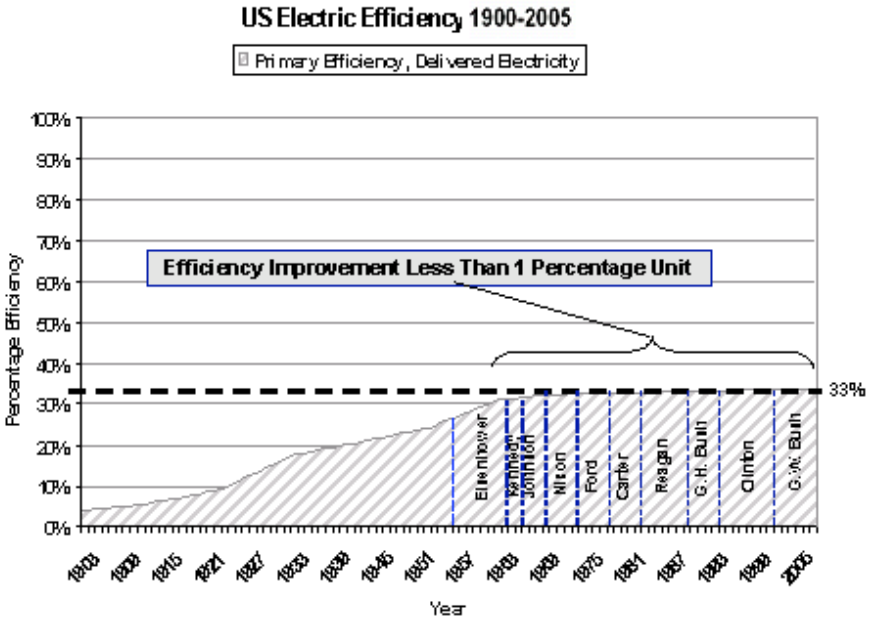
Two related facts suggest why market forces have not de-carbonized the U.S. economy.

First, note that 42% of the U.S. CO2 emissions come from the generation of electricity, and another 27% come from production of thermal energy. 69% of U.S. CO2 emissions come from producing heat and power versus only 19% from personal automobiles.




Now look at the efficiency of delivering electricity. The next graph shows the efficiency of converting the energy in fuel to delivered electricity over the past 105 years, using data from the U.S. Federal Power Agency. Note that only 6% of the potential energy in electric plant fuel arrived at consumers as electricity in 1900. Technology improved. By 1959, the delivered electrical efficiency had increased fivefold to 33% -- three units of fuel energy for each delivered unit of electricity.

In spite of phenomenal advances in knowledge and technology in the ensuing five decades, the electric power industry has failed to increase delivered efficiency by one full percentage point. Here we sit, 48 years later, ten U.S. presidents later, after a 570% increase in electricity consumption, and the industry continues to waste 2/3's of the energy it consumes.



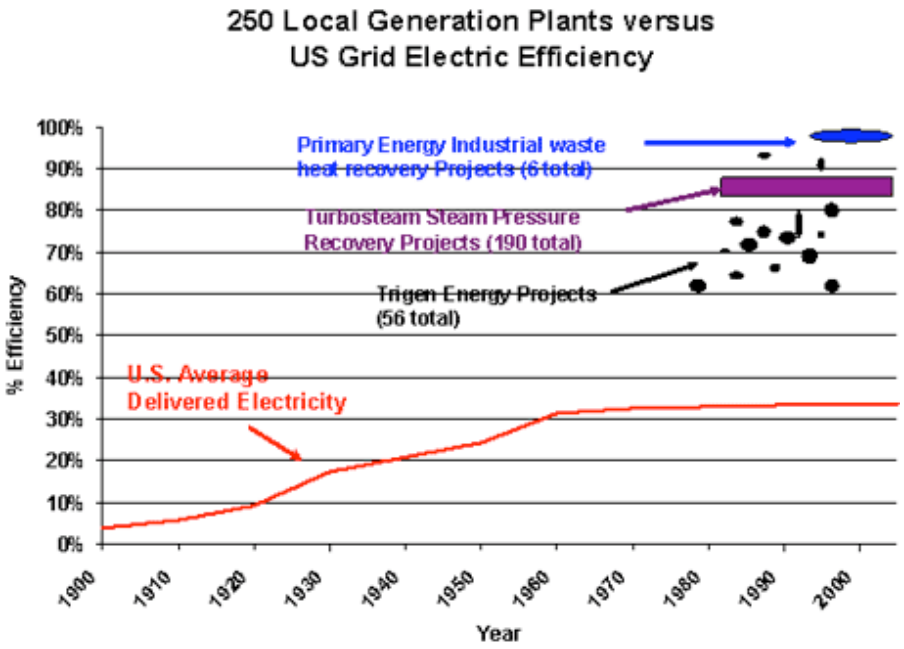

**What is the Right Question?**

We think the 'right question' about mitigating climate change is, "Why has the U.S. electric power industry failed to

improve delivered efficiency over the last five decades?"

The most discouraging answer would involve physical limits. Is there an Einstein like 'speed of light' limit? Is it impossible to convert more than 33% of a fuel's potential energy to electricity?

Happily, no. The next chart again plots the U.S. delivered electricity efficiency and adds representations of 250 local power plants built since 1977 by three organizations that developed local power plants capable of recycling waste energy streams. Note that the worst local power plant achieves nearly twice the net efficiency of the average central power plant.




Some of these local plants achieve 60% to 97% net efficiency by recycling the normally wasted heat, which is a byproduct of all thermal-based electricity generation. The low grade heat displaces boiler fuel, creating a second energy service. A second set of plants recycles exhaust heat, flare gas or steam pressure drop from industrial processes to produce heat and power. Central plants, located far from thermal users, cannot recycle their own inevitable waste heat, nor can they recycle heat from industry. Thermal energy simply will not travel that far. Furthermore, the grid loses 9% of the power these central plants generate, on average, as line and transformer losses. By contrast, locally generated power flows directly to users with almost no net line losses. Local generation and actually reduces grid losses to other consumers by freeing up the grid.

We invite readers to ask why the delivered efficiency of electricity has been stagnant for five decades.

For us, the answer is obvious. Market forces are blocked or perverted by monopoly protection of electricity distribution, energy subsidies and financial guarantees of central generation and transmission. To further distort market decisions, governments have failed to tax fossil energy sufficiently to pay the associated health and environmental costs. Recent studies by Harvard and by the Ontario Medical Association found health and environmental costs of burning coal equal to 6 to 12 cents per kilowatt-hour, 100% to 200% of the delivered charges for coal-fired power. Finally, a vast tapestry of local, state and national energy regulations block or discourage the deployment of efficiency.

Once we have asked the right initial question, the subsidiary questions, are obvious. How can we modernize regulations to remove distortions, remove barriers to efficiency, send the industry the right signals, and open competition? Can we satisfy the original social purpose of each regulation in a way that does not also block

efficiency? Can we change environmental laws to reward instead of blocking efficiency and still improve air quality?

We think climate change mitigation is an enormous economic opportunity, if these questions are addressed. Removing the barriers would unleash a boom in capital investment, create many high quality jobs, lower manufacturing costs, improve balance of payments, and slash the emissions of green house gases. All is possible just from asking the right questions?

What are your answers?



## Readers Comments

| Date | Comment |
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| John K. Sutherland *11.29.07* | Thomas, you say:<br><br>'We think the 'right question' about mitigating climate change is, "Why has the U.S. electric power industry failed to improve delivered efficiency over the last five decades?".<br><br>Actually the right question first of all is 'Can we mitigate climate change?' And then even ask 'How much of an effect might we think we have?', and then 'do we want to try?' followed by lots of other questions and cautions.<br><br>It isn't so much the electric power industry that is at fault for not improving efficiency, its the end point consumer who wastes energy. |
| Len Gould *11.29.07* | "Central plant efficiency" is quite a broad definition, includes everything from nuclear facilities with an 80+ year lifespan to old coal-burners being operated on life-support to avoid needing to invest in pollution mitigation.<br><br>I definitely agree with your article's general thrust. It appears that we are at or near a significant change in how we think of energy with respect to a) Peak Oil b) World demand v.s. supply c) new technologies d) environmental considerations, particularly GHG's e) rapidly changing loci of international (read economic) influence.<br><br>Perhaps the right question is "Is this transition point a good time to evaluate from basics our entire regulatory structures regarding energy?" |
| Edward A. Reid, Jr. *11.29.07* | Tom,<br><br>Thoughtful, clear and cogent as always. I would suggest that the factor of 2 range you suggest for coal emission environmental externalities is one of the key reasons nothing has ever been done about internalizing externalities costs; the uncertainties are just too great, though James Hopf believes it could be resolved. I suspect the uncertainties with regard to the human contribution to global climate change are at least as great, scientifically if not politically.<br><br>John,<br><br>We (ALL of the globe's populations) could certainly mitigate the climate change which is occurring as the result of our fossil fuel use, by terminating the use of fossil fuels. Your second question is the better one, since it requires quantification of the fraction of the current climate change which is the result of human activity.<br><br>Len,<br><br>Any time, particularly any period of energy transition, is a good time to question our energy regulatory scheme. As we have learned over the decades, in the case of regulation, practice does not make perfect, it merely makes permanent.<br><br>Ed |
| Roger | It's perhaps a minor point, but it always irks me when CHP proponents claim "near 100% efficiency" of energy |

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| Arnold *12.1.07* | use, in contrast to the 33% efficiency of electricity generation, with the implication that CHP is making 3x better use of fuel.<br><br>Don't get me wrong; I like CHP as well, in cases where it makes economic and environmental sense. But different forms of energy are not all equivalent and interchangeable. In general, a joule of electricity is one hell of a lot more useful than a joule of low grade heat. Burning natural gas for low grade heat is a wasteful use of a high grade energy resource--for all that it *is* 100% efficient in converting the chemical potential energy in NG into low grade heat.<br><br>To be rigorous, CHP efficiency calculations should consider the temperature of the heat produced, and weight the heat energy according to the Carnot efficiency of an ideal heat pump. Thus, 100 joules of energy used to heat water to 140 F (60 C) from an ambient temperature of 50 F (10 C) would only count as 15 joules, since that's the mechanical energy needed in an ideal heat pump to pump 100 joules between those two temperatures. When efficiency is calculated in that manner, the spread between central power generation and CHP becomes a lot less impressive.<br><br>As to why efficiency for central power generation has been relatively stagnant, I'm not sure how much can be attributed to regulation, and how much is due to simple economics in the face of our failure to internalize the external costs of fossil fuels. Regulated or not, it's cheaper and more economically efficient to continue producing electricity in old coal-fired power plants at 33% efficiency than it is to build newer and more efficient plants.<br><br>Efficiencies for new plants *have* improved. Even relatively conventional coal-fired plants now use super-critical boilers to reach 40% efficiency, and CCGT units for baseload service now manage 60%.<br><br>It's possible to do even better, but it will require shifting to high temperature fuel cells as the "combustors" for combined cycle gas turbines. But that technology is very immature. In any case, the huge sunk investment in existing power plants creates an economic inertia that's hard to overcome. |
| Edward A. Reid, Jr. *12.1.07* | Roger,<br><br>Engine manufacturers, turbine manufacturers and fuel cell manufacturers all report efficiency based on lower heating value (LHV) of the fuel, ignoring the portion of the input energy their devices cannot use, as if it did not exist. Therefore, the 60% number you cite above is actually 54%, based on the total energy content of the fuel.<br><br>Also, the 40% efficiency is steady state performance for new equipment at rated power. The 33% number is fleet average for all equipment in actual use, including startup and off-design operation.<br><br>Finally, recovering a unit of energy which would otherwise be rejected to the atmosphere and using it to do a unit of work which would otherwise be done by using incremental primary energy is a good thing. Arguing that it is somehow less good because the unit of energy which performed the work could have been provided by some theoretical device which is not in common use for the application seems rather meaningless.<br><br>The water heating example you used is particularly instructive, since the water heating would otherwise likely have been done (in the real world) by a gas boiler using the 90% of the natural gas energy extracted from the ground which reaches the burner at an 80% efficiency; or, by an electric boiler using the 27% (including T&D losses) of the primary energy used to produce the electricity which actually reached the resistance element, at a 100% efficiency.<br><br>The (theoretically) perfect need never be the enemy of the practical good. |
| Roger Arnold *12.2.07* | Ed,<br><br>Thanks for the corrections regarding power plant efficiency. I know that the difference between LHV and HHV is substantial for hydrogen, but I think of it as not significant for fossil fuels. Which is true if the fossil fuel is coal, but not true for natural gas. The difference there is 10%, so your 54% instead of 60% is about right.<br><br>Isn't 20% loss in T&D rather extreme, though? I've read that 5% is a typical figure for off-peak hours, while losses during peak hours can reach 10% or higher. But my impression was that losses of greater than 10% were exceptional. So 33% in generation might drop to 30 - 31% at the service entrance, but wouldn't normally be as low as 27%. Perhaps I'm wrong, or what I remember is out of date. I guess average losses could have increased significantly as demand has outpaced increases in line capacity.<br><br>I certainly agree that making use of what would otherwise be waste is, in general, a good thing. As I said, I'm in favor of CHP when it makes sense. What I object to is the overstatement of the advantage of CHP that's implicit when its efficiency is claimed to be 3x higher than that of central power generation. |

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| | It's not just an academic issue. The micro-turbines typically employed for commercial scale CHP (as opposed to industrial) have an advertised efficiency for electricity generation of 26%, I believe. (Which is presumably 23%, on an HHV basis.) That's fine, for a site that needs a generous supply of low grade heat, and is producing electricity as a by-product to offset their electrical power needs. But heat pumps with performance coefficients of 4 to 5 do exist, and provide a viable alternative for supplying low grade heat. A COP 4.0 heat pump driven by grid electricity at 50% delivered efficiency will supply the same heat output as a CHP installation for half as much natural gas.<br><br>Heat pumps are non-trivial capital items, and economics may favor approaches with lower capital costs, even if they are less efficient in fuel consumption. But that's my point: factors other than raw energy efficiency do matter and need to be considered, in deciding what makes the most sense in an given situation. |
| Edward A. Reid, Jr.<br>*12.2.07* | Roger,<br><br>Here's the EIA AER I/O diagram. Note, however, that the 20% nuclear fraction is shown as electricity on the input side. We can split the difference and call it 30%.<br><br>http://www.eia.doe.gov/emeu/aer/diagram5.html<br><br>I reviewed a study several years ago which showed the 27% number; however, it is no longer available. I also had access to a proprietary study which documented on-peak distribution losses as high as 16% on some utility systems.<br><br>I don't argue that high efficiency heat pumps exist, or that they could be more widely applied. My impression is they ain't exactly "sellin' like hot cakes". Neither is CHP. |
| Rodney Adams<br>*12.2.07* | Roger and Edward:<br><br>Your give and take is very interesting and certainly not a trivial issue. Heat pumps are indeed widely used in both commercial and residential energy systems as central heating and cooling units. They are especially useful in temperate climates where the winter extremes are not generally much below freezing for any substantial period of time. In my experience, heat pumps cease being effective for human comfort when the ambient air is below about 35 F and they need electric resistance heating as a supplement.<br><br>In many cases, these units are also good sources of water hot enough for showers, baths and dishwashing though they have a limitation with the latter as well - commercial restaurants need water that is hotter than the 130-140 F water that you get from a heat pump system. That is to meet health requirements for dish sterilization.<br><br>In regions where the primary electrical power is generated using nuclear and/or coal, the price of electricity has been low enough so that all electric homes were very economical compared to those using natural gas heat over the past 10 years or so. I know - I live in one.<br><br>Unfortunately, my state recently experienced a dramatic shift in energy price based decisions. Our electricity price more than doubled on a per kilowatt hour basis, making my all electric home significant more expensive. Natural gas has been expensive in this area for a very long time, so it is not very widely distributed due to a lack of residential demand.<br><br>Interestingly enough, the COST of generating electricity has not dramatically changed here. We are still mainly depending on coal and nuclear power for the bulk of our electricity supply. What has changed is that the state changed the regulations on the monopoly electricity supplier so that it is now able to charge its customers based on the last kilowatt-hours generated instead of on an overall average cost basis. Since the last kilowatt-hours are generally produced in low efficiency/high fuel cost natural gas peaking plants those last kilowatt hours needed for a given demand load are quite costly.<br><br>What we need is some load following, low fuel cost nuclear heated gas turbines in our grid. That way we could continue using our high efficiency heat pumps without paying an economic penalty. (See, for example - http://www.atomicengines.com/engines.html)<br><br>Another good addition to the local energy mix would be high efficiency local nuclear Combined Heating and Power (CHP) systems that used modifications of the nuclear gas turbines with waste heat recovery systems. (See, for example - http://www.romawa.nl/welcome.html) |
| Bob Amorosi | I think Roger makes the most critical points. The exisiting power plants and the distribution grids were paid for with huge investments over time, so the economic inertia to replace them is overwhelming. It's clear that power |

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| *12.3.07* | generation technologies exist that could improve generation efficiencies, but it will take a very long time to gradually replace the exisitng infrastructure without governments imposing radical changes on society and the electricity generation and distribution industries.<br><br>The same can be said for forcing consumers to change their energy consumption choices and use habits. For example if governments taxed fossil fuels with draconian measures to force their (eventual) elimination, consumers and industry would obviously be excouraged to look for alternatives. But exisitng alternatives would only be adopted by consumers and industries if they are available and affordable, otherwise the taxes create nothing more than economic hardship.<br><br>One has to question why alternatives might not be readily avialable and / or affordable. This is where governments could do much more to make them economicly feasibl - through regulatory changes along with economic incentives for private investment to commercialize them. |
| Bob Amorosi *12.3.07* | Addendum to my last comment - consider an example of what it would take governments to make consumers and industry switch from say electric heating to natural gas or solar heating.<br><br>A tax could be imposed on the purchase of new electric heaters which would encourage consumers and industry to consider buying the desired alternatives. But, consumers would need far bigger financial incentives to replace their existing electric heaters especially if their heating equipment is nowhere near end-of-life yet. The result would be to encourage the alternative technologies only for the installation of heating equipment in new construction, or replacment of end-of-life equipment.<br><br>Another approach would be placing a tax on the energy all consumers use on electric heating. This is not practical though because it is not normally possible to accurately measure what portion of electricity a building uses for heating, since it is typically lumped into a utility company's energy bill with no easy way to separate it from the consumer's other uses of electricity.<br><br>Neither of these approaches are highly effective for a government because the first approach does not present a substantial immediate effect, and the latter is not practical.<br><br>However, providing consumers with a real-time in-home energy monitor display that can separate a consumer's energy uses into specific appliances would make taxing the energy used on electric heating feasible. If consumers suddenly were forced to pay an extra tax on their heating energy use, it wouldn't take much for anyone to calculate the economic pay-back period of switching to the alternative technologies, no matter what stage of life their exisitng heating equipment was in. And if the tax level was set such that this pay-back period happened in less than a year, the take-up by consumers of the alternatve technologies would probably be very substantial and immediate.<br><br>Unfortunately getting utility companies to provide real-time in-home energy display technology would probably require governments imposing regulatory changes on our utility companies, since currently they have no financial incentives to provide this technology to consumers. |
| James Hopf *12.3.07* | Ed (12/29 post):<br><br>My short answer to your point about the level of uncertainty (6-12 cents) is, "fine, I'll take 6!" Heck, I'll even take 3 (as even 3 would be enough to do the job in terms of making conventional coal non-competitive).<br><br>If the lower end of the external cost range were near zero, then we have something to argue about; something that we would have to resolve. But if even the lower end of the range is very significant (and enough to make clean sources competitive) then there is no point in arguing. Just take the lower-bound estimate and move on. If the range is 6 to 12 (for example), it is not reasonable to use that uncertainty as an excuse to stick with zero. |
| Gregory Elvestad *12.4.07* | John, your first question is the right one to ask. Can we as humans mitigate climate change? We can't accurately model the weather two weeks out, so how can we even come close to guessing what the global climate is going to be like years into the future? One problem is we haven't got a clue how much rain falls across the planet on a daily basis. It's impossible to know that variable, so any attempt to model climate change even on a regional basis is an exercise in futility. Without that, the audacitiy to claim causality between fossil fuels and climate is a best humorous and at worst sheer arrogance.<br><br>Ed, you patently say that fossil fuel use is causing climate change. On what factual basis do you make that claim? How can anyone truly make the claim when there is not agreement in the scientific community? The whole climate issue is simply another means of taxing the producing countries out of existence.<br><br>Warming is or isn't happening regardless of what we as humans do. Why, therefore, do we have to do anything |

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| | about carbon sequestration and the like? There is no reason to try to go farther than we already have to lower carbon output. To borrow from Iacocca, "How much clean air do we need?" Human and animal breathing causes CO2 output. Beer fermentation causes CO2 output. Shall we kill all humans, animals, and stop making beer? Probably not going to happen. Yes, it's not a bad idea to make our generation facilities as efficient as possible, because it only adds to the bottom line. But to force industry and consumers to do so is tantamount to communism.<br><br>Taxation to cause behavior change is not capitalism. It is socialism. Never in the history of the world has a civilization taxed itself to prosperity. In fact, taxation kills productivity every time it's tried. We're the freakin' United States of America, for crying out loud! We're the greatest nation on the face of the planet, and the greatest nation to have ever existed. How do you explain the fact that in less than 300 years, fewer than 400 million people have created the greatest economic engine the world has ever seen? Capitalism and freedom have done more to benefit the world than any tax has ever done. Just turn us loose and watch what happens. Nobody wants dirty air or water. Nobody wants to poison people in the name of research or profits. Get the government off of industry's back and watch what happens. |
| Ian McQueen *12.4.07* | Your guest wrote: "What size tax on carbon is needed to induce carbon emissions reductions?" |
| Ian McQueen *12.4.07* | Your guest wrote: "What size tax on carbon is needed to induce carbon emissions reductions?" Despite all the reports, etc., etc., etc., from the IPCC, the propaganda of Al Gore, the statements of "environmentalists", and so on, there is no scientific proof that global climate is controlled by carbon dioxide. Without this connection there is no sense in taking the called-for heroic measures to cut carbon emissions. And there is no correlation. Temperatures have gone up (slightly).....then down.....then up....and have levelled off since 1998. All the while, the level of CO2 has steadily risen (to all of 0.00038 of the atmosphere). There is no correlation. The world has been warming since about 1850 and that ended the Little Ice Age. Total warming since then: about 1 degree F / 0.6 degree C. We are being guided by glorified video arcade games. So quickly we forget GIGO. Garbage In, Garbage Out. If the Kyoto Accord had been put into effect, the effect on global temperature would scarcely be measurable in 50 years. Before our eyes a giant and magnificent edifice of carbon credits, carbon trading, and the like is being constructed on a flood plain of sand. When the flood of reality hits, this edifice will collapse, spectacularly. Let us hope that our governments will not have caused money to be wasted trying to mitigate a large-natural process. Let them spend money where it is needed- on health, education, and the like.<br><br>Best regards.<br><br>Ian L. McQueen Glenwood, NB |
| Edward A. Reid, Jr. *12.4.07* | Gregory Elvestad,<br><br>"We (ALL of the globe's populations) could certainly mitigate the climate change which is occurring as the result of our fossil fuel use, by terminating the use of fossil fuels. Your second question is the better one, since it requires quantification of the fraction of the current climate change which is the result of human activity."<br><br>"Ed, you patently say that fossil fuel use is causing climate change."<br><br>No. My apologies for not being clear enough. To the extent that our carbon emissions may be resulting in climate change, we could mitigate that climate change by eliminating further carbon emissions. My point to John was that the better question was the extent to which our carbon emissions are causative. If our carbon emissions are not causative, we can likely do nothing. If they are causative, we are certainly capable of ceasing the causation.<br><br>I believe the jury is still out on causation. |
| Bob Amorosi *12.4.07* | Gregory Elvestad, in case you haven't noticed, our utility companies have a monopoly on distributing electricity to consumers and industries. They have no competition, nor do they have any financial incentive to provide new technology to consumers to allow consumers to make themselves more energy efficient. In fact when a utility company promotes energy conservation and energy use curtailment, it takes AWAY from their bottom line. So if governments do not force them to change, please explain how your pure capitalistic country of the United States will do so.<br><br>Bob Amorosi, Resident of Canada |
| Roger Arnold *12.4.07* | Before we turn this thread into (yet another) debate about whether global warming (a) is real and (b) is anthropogenic, I strongly recommend all comba.. er, readers, to visit http://www.aip.org/history/climate/co2.htm and read a bit of the history and science behind the issues. It's an outstanding example of good science writing: |

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| | well researched, technically rigorous, but very accessible.<br><br>I won't try to address matters that are well covered at that web site, but there's one particularly annoying meme that Gregory is passing along that I'd like to stomp on here and now:<br><br>> We can't accurately model the weather two weeks out, so how can we even come close to guessing what the global climate is going to be like years into the future?<br><br>That's *exactly* like saying "we can't accurately model the flow of air particles in the turbulent wake of a moving vehicle, so how can we even come close to guessing what the drag coefficient for the vehicle will be"? Weather is a chaotic phenomenon--exhibiting "sensitive dependence on initial conditions" and therefore inherently unpredictable on a long-term basis. Climate is statistical--a matter of patterns and averages. Beyond basic physics, weather prediction and climate modeling have virtually nothing in common. |
| Jim Beyer<br>*12.4.07* | This link is also not too bad. Some might find it too "pro-AGW", but I think it addresses some of the non-issue myths fairly well. (I hope I got my link logic right; this site could use a preview mode.....)<br><br>http://www.climate.org/topics/climate-change/debunking-climate-change-myths.html<br><br>Also, hear hear on Roger! I've seen that meme around as well. I would also like to counter it with: "In December, I know it's going to be cold. In June, it will be hot. So, I'd say that I CAN predict the weather more than two weeks out." |
| Jim Beyer<br>*12.4.07* | darn.... almost. At least the link works..... |
| Don Hirschberg<br>*12.4.07* | The original question seems to have been lost. It was the efficiency of generating electricity, not ways to use low grade heat. Roger Arnold's early post got to the issue. He hit the nail on the head.<br><br>"... it always irks me when CHP proponnents claim 'near 100% efficincy' of energy , in contrast to 33% efficiency of electricity genereation. with the implication that DHP is making 3X better use of fuel." |