4-2006

How Serious is the Global Warming Threat?

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19 April, 2006

Abstract

Global warming is the quintessential environmental scare. While the local effects of litter, chemical contamination, and aerosol pollution had dominated our environmental concerns in the 1970's and 1980's, we are now faced with a threat that is global in extent and predicted to be long-lasting[1]. The culprit is humanity's use of fossil fuels, which release carbon dioxide into the atmosphere when burned. Since carbon dioxide is a 'greenhouse gas', it affects the radiative energy budget of the Earth. While carbon dioxide is a relatively minor atmospheric constituent, with a concentration now approaching 400 parts per million (pre-industrial levels were about 280 parts per million), it acts like a 'blanket' for infrared (heat) radiation, warming the lower atmosphere, and cooling the upper atmosphere.

The direct warming effect of a doubling of carbon dioxide concentrations (doubling is predicted to occur late in this century) has been estimated to be only about 1 deg. C. While this is not a very worrisome level of warming, many computer climate models suggest warming levels of three or four times this magnitude. This extra warming is due to 'positive feedback' in the models. Positive feedbacks occur when the direct warming tendency of the carbon dioxide is amplified by changes in clouds, water vapor, snow cover, and sea ice in the models. The existence and magnitude of these positive feedbacks are at the heart of scientific arguments over how much of the current global warmth is due to mankind's activities, and therefore how much global warming we can expect in the future.

But even if predictions of strong warming, say 10 deg. F by the end of this century, are correct it is not at all clear what the best policy reaction to that threat should be. Because of the necessity of inexpensive energy sources for the health and well being of humans, it will be impossible to achieve substantial reductions in energy use through conservation. Instead, massive reductions in greenhouse gas emissions will require new energy technologies. Those technologies will likely be developed in the countries that can afford massive energy R&D efforts. Therefore, draconian, government-mandated punishment of fossil fuel use through taxes or carbon caps could very well hurt rather than help efforts to develop those new technologies.

1. Global Warming to Date

Globally averaged temperatures as measured by surface thermometers have warmed by about 0.6 deg. C (about 1 deg. F) over the last one hundred years (see Fig. 1).

There are three major features in this temperature record. The first is a warming trend up until 1940, which is believed by many to represent the end of the “Little Ice Age”. Then, a gradual cooling trend is seen from the 1940’s through the 1970’s.   This cooling could have been due to man-made aerosol pollution, which reflects sunlight, but this explanation is somewhat speculative.

Finally, stronger warming has occurred since the 1970’s up to the present. This warming is widely attributed to manmade greenhouse gases. It is this recent warming trend that is the most worrisome for many scientists, and has led to considerable media hysteria over the issue. Some believe that global temperatures are now warmer than they have been anytime in the last 1,000 years. (Year-to-year temperature fluctuations seen in Fig. 1, which can be quite large, are mostly due to El Nino, La Nina, and volcanic eruptions, the effects of which all last about two or three years.)

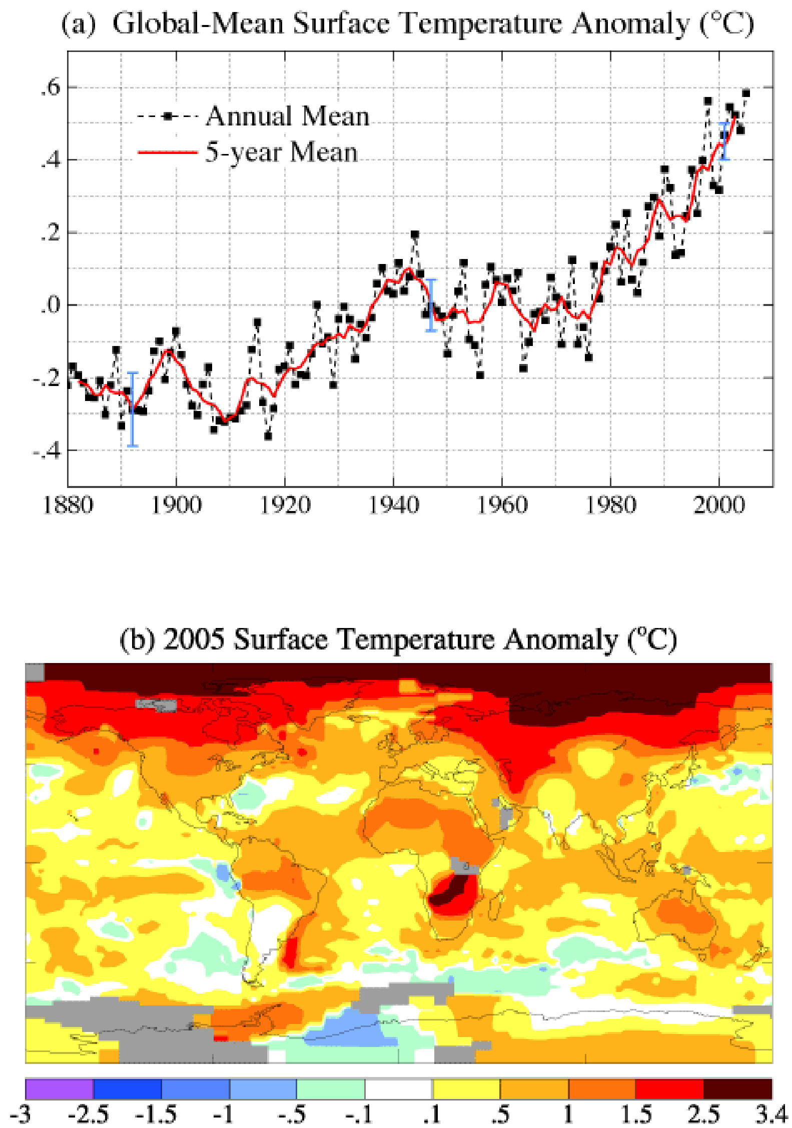

Fig. 1. (a) Globally averaged yearly surface temperature fluctuations measured by thermometers for the period 1880 – 2005; (b) the geographic distribution of those temperature anomalies for 2005 (Goddard Institute for Space Studies).

The claims that current temperatures are warmer than anytime in the last 1,000 years depend critically on proxy measurements – primarily tree ring data from a handful of locations that have long-lived species of trees. While I'm sure that most of the paleoclimate experts that perform this kind of research are fully convinced of the accuracy of these proxy estimates, many of the assumptions involved can never be tested and verified. Therefore, I view any conclusions based upon proxy data to be very suspect.

A central issue is how much of the present warmth is due to mankind's activities. While several climate modelers have indeed come up with assumed magnitudes for aerosol cooling and greenhouse gas warming effects that explain the current warming trend, these are by no means the only possible explanations. Since we really do not understand, and thus are unable to model, the decadal-scale natural climate variability of the climate system, we really can not know with any certainty how much of the present warmth is due to the burning of fossil fuels. For instance, due to a lack of sufficient observational data, changes in ocean circulation or cloud amounts could have occurred without being detected. But science can only deal with what is understood, not with what is unknown. So science has fallen into the bad habit of attributing most climate changes to the activities of man.

Anecdotal evidence such as melting sea ice and retreating glaciers would seem to provide convincing evidence. But thermometer measurements suggest that the Arctic region was at least as warm in the late 1930's as it is now. Since we only have reliable sea ice measurements since about 1979, when satellite measurements first began, we really do not know whether recent sea ice trends are outside the realm of natural variability.

Similar points can be made about the receding of glaciers. Glaciers respond to a variety of influences, especially precipitation. Only a handful of the thousands of the world's glaciers have been measured for decades, let alone for centuries. Some of the glaciers that are receding are uncovering tree stumps, indicating previous times when obviously natural climate fluctuations were also responsible for a restricted extent of the ice fields.

The bottom line is that, while we are indeed in a period of unusual warmth, it not at all obvious whether it is either unprecedented, or directly attributable to manmade greenhouse warming. While science has come up with suggested explanations for the current warmth that only involve manmade aerosol and greenhouse gas pollution, these are by no means the only possible explanations.

2. **The Earth's Greenhouse Effect**

The term 'greenhouse effect' really has two meanings. The Earth has a natural greenhouse effect that is mostly due to water vapor (about 90% of the effect), as well as and carbon dioxide and methane. It has been pointed out many times that the Earth's natural greenhouse effect[11] (again, primarily due to water vapor) keeps the Earth habitably warm. Indeed, were it not for this warming effect, life as we know it might not exist on Earth, as the surface would be too cold.

But the term 'greenhouse effect' is also used to refer to the manmade 'enhancement' of the Earth's natural greenhouse effect from our production of extra carbon dioxide from burning of fossil fuels. Thus, 'global warming' usually refers to the manmade enhancement of the Earth's natural greenhouse effect by the burning of fossil fuels.

A useful analogy for the Earth's natural greenhouse effect is that of a blanket. The blanket of water vapor, carbon dioxide, and methane traps infrared radiation and warms the lower atmosphere, while at the same time cooling the upper atmosphere. This effect is somewhat analogous to that of a blanket keeping warm air close to your body, while at the same time keeping cooler air away from your body. The thicker the blanket, the warmer it stays under the blanket, and the cooler it remains outside of the blanket.

While sunlight is what ultimately drives the climate system, infrared radiation is an equally important player. For the temperature of the Earth to remain roughly constant, the amount of sunlight absorbed by the entire Earth must equal the amount of infrared radiation lost to outer space. This is called *radiative energy balance*. Adding carbon dioxide, a greenhouse gas, changes the radiative balance of the Earth by not allowing as much infrared cooling to occur to balance the solar heating. The result is presumed to be a warming that proceeds until the higher temperatures push the outgoing infrared radiation intensity back up to where it, once again, balances the incoming sunlight.

This radiative balance (or the presumed imbalance) has not, however, actually been measured…it has only been inferred. NASA flies Earth-orbiting instruments that measure these radiative components, but the instruments are not quite accurate enough to reliably measure the sub-percent accuracy necessary to observe the expected imbalance between incoming sunlight and outgoing infrared energy. For all we know, the oceans might be giving up large amounts of heat that had been stored in centuries past, or clouds might have undergone recent changes, leading to natural radiative imbalances in the system. But instead, since we don't have enough information to conclude otherwise, most scientists simply assume that balance exists.

3. **Global Warming Theory**

There is a sound physical basis for the fundamentals of global warming theory. We know for a fact that carbon dioxide is a greenhouse gas, and that atmospheric concentrations of CO_2 are increasing. And as can be seen in Fig. 2, the atmospheric concentration of carbon dioxide has been steadily rising (routine measurements were started in 1958). Note that the atmospheric concentration is still relatively small as of 2005, only about 380 parts per million by volume.

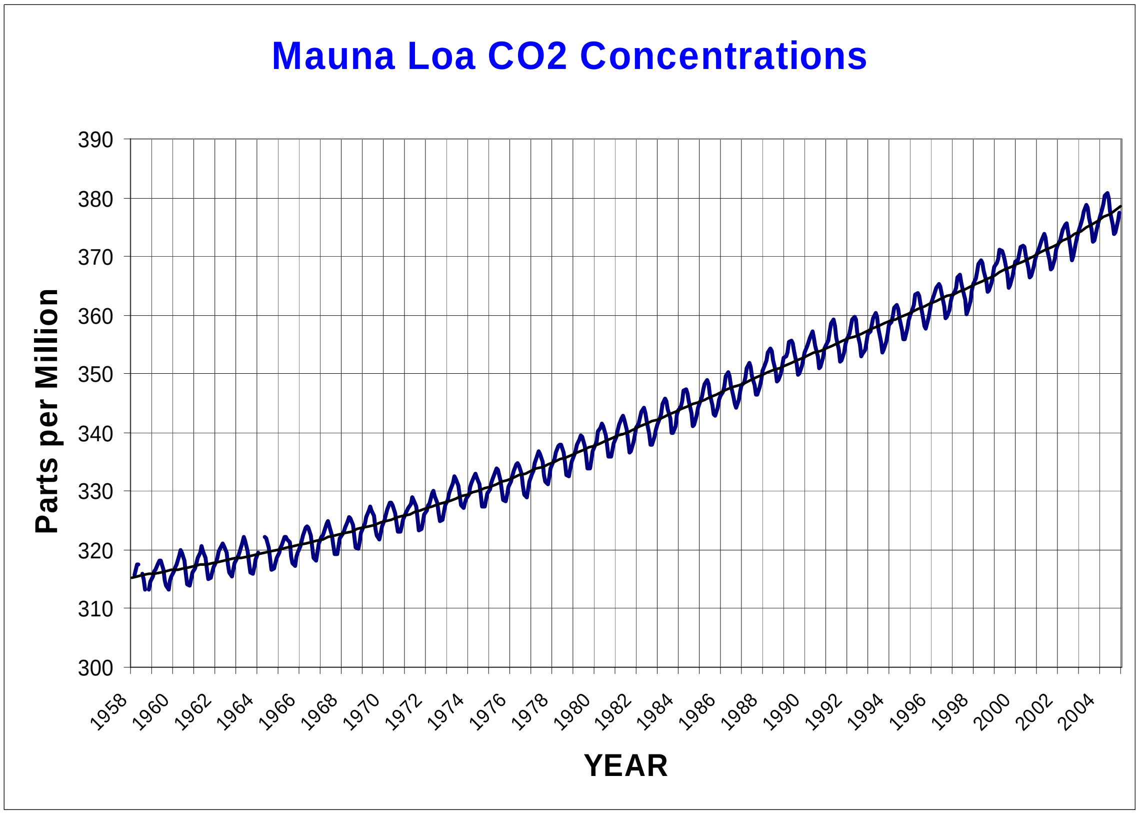

Fig. 2. Atmospheric carbon dioxide concentrations for the period 1958-2004 at Mauna Loa Observatory (based upon data collected by NOAA Climate Monitoring and Diagnostics Laboratory).

Based upon *theoretical calculations*, and assuming that no natural radiative imbalance exists, a current manmade imbalance of about 0.85 Watts per square meter has been inferred by one study.[5] For reference, this can be compared to an estimated average value of about 340 Watts per square meter for both incoming and outgoing levels of radiation at the top of the atmosphere (globally averaged). If not for the current global warmth, the calculated imbalance would be even larger since some of the imbalance has presumably been alleviated by increased global temperatures.

The accuracy of the (0.85 watts) calculation, however, depends upon assumptions about many variables, such as global water vapor and cloud distributions, that are really not measured accurately enough to give this level of precision. In other words, this small imbalance assumes all the natural forcings in the climate system are in balance. This, I believe, is unlikely to be true. Because of the ability of the ocean to store or release huge amounts of heat without large temperature changes, it would be the first suspect. Indeed, we already know that large radiative imbalances exist locally and over regions, for this is what drives much of our weather.

My focus on these potential *natural* sources of global imbalances does not by itself prove that the manmade portion of any imbalance is unimportant. I only point them out as an example of how we assume climate stability is tied to radiative balance, when in fact climate stability (say, as measured by the average surface temperature of the Earth) might well exist even in the face of substantial radiative imbalances – imbalances that climate models have not been tuned to deal with.

Despite all of these uncertainties, we *do* know that the extra carbon dioxide does indeed cause an extra trapping of infrared radiation, resulting in a warming *tendency* in the lower atmosphere (and presumably in the ocean). The warming due to a doubling of carbon dioxide *alone*, without any other changes in the atmosphere (an unlikely assumption) would amount to only about 1-2 deg. F. This doubling of CO_2 is expected to occur late in this century, and if this was the expected level of warming by then there would be relatively little worry.

Instead, the concern over how much warming will occur in the future is not so much because of the *direct* warming effects of the extra CO_2. Instead, the worry is that various weather processes might change in *response* to the warming tendency from the extra carbon dioxide in such a way that amplifies that response (positive feedback). For instance, a decrease in low clouds in response to the warming tendency would be a positive feedback, since it amplifies the warming by letting more sunlight reach the surface.

Similarly, an increase in water vapor (the Earth's dominant greenhouse gas) would also amplify the warming. Indeed, water vapor is believed by many climate scientists to be the dominant positive feedback in the climate system[13]. A warming tendency should evaporate more water from the surface, which by itself would cause further warming, which causes more evaporation, etc. This is why water vapor feedback is generally believed to amplify the warming due to carbon dioxide alone, by at least a factor of two.

In computer model simulations of the climate system, which are simplified mathematical representations of the most important weather processes, the net feedback is usually found to be positive[13]. In a few models, it is strongly positive. This is why some climate experts talk about a potential threat of temperature rises of 10 deg. F or more in response to a doubling of carbon dioxide. These large values occur because positive feedbacks combine in such a way that they tend to amplify each other.

But are these feedbacks really understood well enough to believe the predictions of climate models that include those feedbacks? Is our climate system really that sensitive to a small increase in greenhouse gases? At some point, climate modelers must depend upon faith…faith that they know the sign and magnitude of these feedbacks, and that the model forced by these feedbacks is behaving in a realistic manner.

Now you can begin to see why global warming theory depends upon assumptions as much as it does on scientific observations. How much of the current (or predicted) warming a scientist believes is due to mankind ultimately comes down to how much faith that person has in our present understanding of what drives climate fluctuations, the computer climate models that contain that understanding, and ultimately, faith in how fragile or resilient the Earth is.

4. **The Earth's Thermostat**

There is a simple aspect of the climate system that I have not yet mentioned that I believe argues against substantial future warming. It has been computed that, even though the natural greenhouse effect 'tries' to increase the surface temperature of the Earth to about 140 deg. F, 75% of that warming is prevented from ever occurring[14]. Weather – clouds, rain, wind – all are the result of the atmosphere's response to the warming rays of the sun, short-circuiting the Earth's natural greenhouse effect and greatly limiting surface warming.

Thus, even though water vapor (through its greenhouse effect) keeps the Earth habitably *warm*, the same water vapor also represents *heat removal* processes that also keep the Earth habitably *cool*. In other words, the characteristics of water moderate and stabilize the climate against large temperature fluctuations.

The heat absorbed by the water vapor is carried by convective air currents that transport the extra heat and water vapor upward, eventually causing clouds to form. This further cools the climate by shading some of the Earth from the sun. Some of the condensed water in the clouds returns to the Earth as precipitation, replenishing the surface water so that the whole process, called the hydrologic cycle, can start all over again. As a result of all of the cooling processes associated with weather systems, the average surface temperature of the Earth is about 55 deg. F, rather than a scorching 140 deg. F[14].

These processes are, however crudely, are indeed included in climate models. My main point is that the *net effect* of clouds, water vapor, precipitation – in short, weather and the global hydrologic cycle – is to substantially cool the surface of the Earth below what the natural greenhouse effect would cause it to be for a given amount of incoming sunlight. So, without firm evidence that the net atmospheric feedbacks are indeed positive, I would say there is still substantial uncertainty about mankind's influence on global temperatures.

But how could climate models that predict large amounts of warming all be wrong? First, let us look at a feedback that is believed to be well understood: positive water vapor feedback. It is true that if the surface warms, there will be more water evaporated from the surface, and water vapor is the Earth's dominant greenhouse gas. But the average amount of water vapor in the atmosphere is not simply due to how much water is evaporated from the surface….that is only half of the story. If evaporation was to occur unchecked, the global atmosphere would become totally saturated with water within a matter of days or weeks. This does not happen. Instead, the average amount of vapor in the atmosphere is the result of a *balance* between the vapor *source* (evaporation) and the vapor *sink* (precipitation). Therefore, one can not determine how atmospheric water vapor will change with warming without understanding precipitation systems[15,16] and their response to warming.

And how will precipitation systems change in response to warming? No one knows. A minority of scientists (like me) contend that, until we understand how precipitation processes respond to warming, we really do not know whether water vapor feedback is strongly positive, weakly positive, or zero. Yet water vapor feedback is considered by many scientists to be a "solved" problem.

Clouds, in contrast, represent a feedback that everyone agrees is uncertain[17]. It has been calculated that only a couple percent increase in low clouds would offset the warming effects of a doubling of atmospheric carbon dioxide from fossil fuel use. And since all of these processes (evaporation, clouds, precipitation) are interconnected, it really is misleading to treat them as separate feedbacks anyway. They are all intimately tied together, and probably must all be addressed together, not individually.

5. **Global Warming Predictions as Faith**

I hope that the above discussions will help you realize how much faith is required to extrapolate our current level of climate understanding to predictions of future warming. Climate models are, their creators will admit, relatively crude representations of how the atmosphere works. Just because the models do a reasonably good job of replicating the seasons (which are forced by huge variations in the energy source, sunlight) does not mean that they respond properly to the warming tendency of a minor greenhouse gas, carbon dioxide.

Nevertheless, a majority of climate modelers and climate scientists have sufficient faith in the models to argue for their use as predictive tools. Unfortunately, the historical track record of scientific predictions of massive environmental changes of any kind has been poor. This has led to a public distrust, mostly deserved, of scientific predictions of catastrophe.

This is not to say that substantial global warming is out of the question. Instead, I would argue that, both in terms of threats to humanity as well as to the Earth, there are usually unforeseen checks and balances in place that prevent the predicted threats from ever materializing. This statement, I admit, involves faith as well. But it is grounded in past experience, whereas catastrophic global warming beliefs are founded more in fear, conjecture, and a myriad of assumptions (both explicit and implicit).

6. **Benefits from Warming**

If I was forced to predict the future, I would side with a level of future warming that is relatively modest, due to stabilizing mechanisms within the climate system. The benefits of such a modest amount of global warming are seldom discussed. There is comparatively little government research money available to investigate possible benefits, and the media would rather report predictions of gloom and doom anyway.

The largest positive impact could be in agriculture. Based upon estimates of global energy use, the current rate of rise in atmospheric carbon dioxide concentration in Fig. 2 is only 50% of what it should be. The other 50% is apparently being absorbed by the biosphere, which uses it for food. This fact alone has led some plant physiologists to conclude that some of the increase in agricultural productivity in recent decades is likely due to the increased fertilization of crops from the extra carbon dioxide. Of course, most of the vegetation on Earth is non-agricultural, and it, too, is being increasingly fertilized. Much research has been performed into the combined effects of extra warmth and extra CO_2 on various kinds of plants, with the bulk of the results showing net benefits to plant health, growth, and sensitivity to drought[18].

7. **Policy Implications**

Even if global warming ends up being a serious problem, is not at all clear what should (or even can) be done about it. If it was easy to switch to fuels that produce little or no carbon dioxide, it would be stupid not to, given the potential risks of a 10 deg. F rise in global temperatures by the end of this century. But policy changes invariably involve weighing costs and benefits. They also necessarily involve assumptions about where our future sources of energy will come from, and whether there will be any countries left that can afford to fund new energy technology R&D if we mandate CO2 reductions by fiat.

The main difficulty in "doing something" about global warming is the fact that inexpensive energy helps drive economic growth, human health and well being. Historically, those countries that build wealth through efficient use of natural resources have the lowest levels of pollution and population growth. The poorest countries have the worst environmental problems, and their high rates of population growth put additional pressures on the environment.

The concern that the richest countries of the world have the least sustainable environmental practices is contrary to the evidence that the 1991 Environmental Sustainability Index is positively correlated with per capita gross domestic product when both variables are plotted for 117 nations of the world (ref).

Since alternative fuels are, at least for now, more expensive, mandating their use through governmental controls will come at the expense of other portions of the economy. If there were alternative sources of energy that were cost-competitive with petroleum and coal, they would already be in widespread use, at least in those economies that, like the United States, have free markets. Any resulting economic downturn as a result of the punishing of fossil fuel use will affect the poor first, since those are the people who are living on the edge, from paycheck to paycheck. While the wealthy can absorb the extra cost of, say, a $2 increase in the cost of gasoline, many of the poor can not.

Even if global warming ends up being a serious problem, it is not at all clear what should be done about it right now. Nevertheless, environmentalists today seem only interested in reducing fossil fuel use *immediately*. The fact that they are unwilling to consider approaches (e.g. intensive research into new energy technologies) that might actually accomplish the greatest reductions in the long terms suggests what many have suspected for a long time: that the environmentalist movement is, fundamentally, anti-technology.

8. **Conclusion**

While catastrophic global warming is theoretically possible, such a conclusion depends critically upon a myriad of assumptions contained in computer climate models being substantially correct. These assumptions, taken together, represent faith on the part of many climate modelers that the climate system is fragile, and very sensitive to small perturbations, particularly our production of carbon dioxide, a relatively minor atmospheric greenhouse gas.

I have argued that there is just as much reason to have faith that the climate system is relatively insensitive to a doubling of carbon dioxide, which is expected to occur later in this century.

But even if predictions of strong global warming are correct, it is not clear how to avoid this eventuality from a policy point of view. Inexpensive energy is necessary for human health and well being. Punishing the use of energy through caps or taxation will be unpopular and relatively ineffective. To me, technological solutions to the problem seem to be the only long-term option. Since only the wealthy countries of the world can afford the R&D to bring this about, it could be counter-productive to finding those solutions by hurting economies with carbon caps and taxes.

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