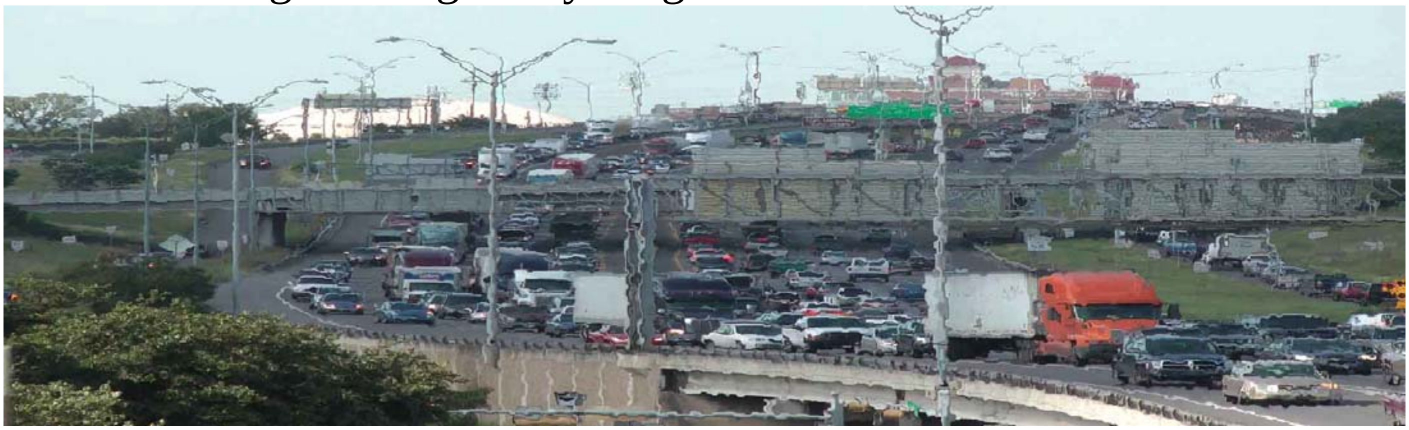
Climate Change: Doing Everything We Can – Or are We?



It's Cars, Not Coal: The New Paradigm of Climate Science

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The science has changed again. This time, things are really upside down. How are we supposed to know which target to shoot?

We live, we learn. Science goes on, especially climate science. There is an extreme need for more knowledge about our climate. This has been obvious to the climate scientists for years. The titles in the scholarly journals show just how rapidly climate knowledge is being discovered.

The amount of effort being put into the challenge is possibly greater than any learning event that has ever happened, including things like the Manhattan Project and the Apollo Project. The credibility of the science grows constantly as is shown by a recent paper evaluating over 1300 climate scientists.

The evaluation found that 97 to 98 percent of climate scientists studied, that supported man-made global warming science, were published more than twice as often in the scholarly journals than were the 2 to 3 percent of climate scientists who did not support man made climate change science (1).

In 2009, somewhere close to ten thousand times more climate discoveries were made than were made in 1990 (2). Too many of these discoveries showed that earth's climate was changing faster and with greater impacts than our climate scientists had previously realized.

Lord Nicholas Stern, World Bank Chief Economist (2000-2003) and Head of the Government Economic Service for the United Kingdom during the Blair Administration, wrote (in 2006) what is undeniably the most complete description of the global economic impacts of climate change. This incredible 700-page evaluation was ferociously shouted down by the non-climate science community.

In 2008, just two years later, Lord Stern published an update to his 2006 report. He said that the severity of his previous findings was vindicated by the 2007 Intergovernmental Panel on Climate Change (IPCC) Assessment. He also said "We underestimated the risks ... we underestimated the damage associated with temperature increases ... and we underestimated the probabilities of temperature increases".

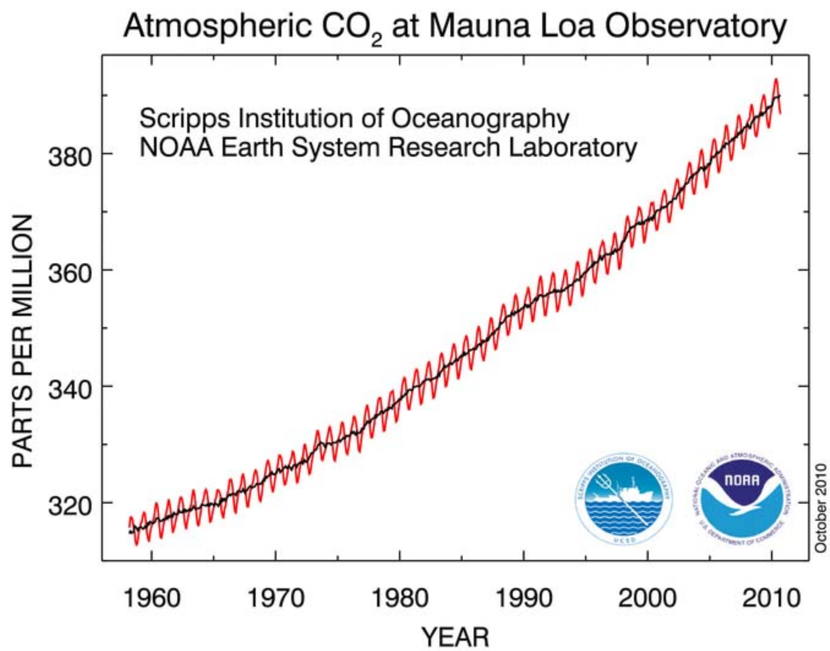
In June 2008, Stern said that because climate change is happening faster than predicted, the cost to reduce carbon below dangerous levels would be even higher. Instead of the one percent of global gross domestic product (GDP) per year assumed in 2006, it is now about 2% of GDP." (3)

In just a couple of years, because of new discoveries in climate science, the cost of mitigation has doubled. Are we doing the right things? Can we afford to be doing something that is not as efficient as possible? Do we have time yet to make mistakes? The answers may not be as obvious as we think.

A paper in the February 23, 2010 edition of the Proceedings of the National Academy of Sciences of the United States of America, written by a team of seven scientists led by NASA's Dr. Nadine Unger, has taken a new view of global warming pollutants that greatly alters our current world of climate change science.

There is really nothing new in this paper though. What has happened is that these scientists have gained a better understanding of the big picture of the climate impacts of air pollution.

The approach of the team was to define the net change to our climate from any given economic activity, considering both the warming and the cooling caused by air pollutants emitted from that specific sector. You see, some pollutants, like the smoke and gases from a volcanic eruption, or coal fired power plants or tropical forest biomass burning, can cool our atmosphere as well as cause it to warm.



We know a lot about greenhouse gases today. This knowledge has been accumulating for more than a century. But greenhouse gases make up only a portion of the pollutants emitted by any given economic sector. Many of the rest of the pollutants (air pollutants) are what are called aerosols.

What is an aerosol? Aerosols are defined as very tiny particles that can basically float (electro-static attraction) in the air. They are very similar to the stuff that comes out of a spray can.

Paint is an aerosol, as is the sticky liquid that makes hairspray work. Deodorant, air freshener, insecticides, anything that can be sprayed out of a tiny nozzle at high pressure can be made into an aerosol. Dust and smoke are common natural aerosols.

Aerosol particles are so small that they do not easily fall to the ground from the force of gravity. Smoke is an aerosol, as is salt spray from the ocean and much of what we know as smog.

Aerosols can be both 'light" and "dark". Dark aerosols are like greenhouse gases. They absorb sunlight and turn it into heat. Smoke is composed of both light and dark aerosols. Light aerosols however, reflect sunlight harmlessly back into space like ice and snow, resulting in a cooling effect.

Black carbon and sulfate aerosols are the two biggies that come from everything that burns including coal and the wood fires used for cooking in developing nations. Black carbon is a warming aerosol. Sulfates are cooling aerosols. There are many other aerosols that occur naturally and that are generated from mankind's economic activities and they include nitrogen oxides and volatile organic carbons, as well as organic molecules from algae in the oceans and from trees and other plants on land.

Dr. Unger’s team’s paper takes all of these warming and cooling effects, adds them up for individual economic sectors, and then ranks them from bad to worse. It also does something else novel. Because different atmospheric pollutants remain in our skies for different lengths of time, the researchers looked at things in the short term (2020) and long term (2100).

I’ll get to this in a minute, but there are a couple of other basic fundamental tenets of climate science that have changed that need a little discussion first.

As we learn, our knowledge changes. We have been learning oodles about the different greenhouse gases in our skies, man-made and natural, for over a century. We also have a lot of knowledge about the way other things in our atmosphere, such as aerosols, dust and smoke warm or cool our planet.

One of the big new climate science discoveries is that the life of carbon dioxide in our atmosphere has changed. Our previous understanding of how long CO2 lasted once emitted was about 100 to 200 years. This is an understanding that has developed over generations as we have learned how the different things react with CO2, how they are absorbed by the oceans or respired by vegetation on land, or how they are trapped in the soil or ocean sediments.

Now we are finding that all of these things change as our planet itself changes with the warming. On a warmer planet, our oceans absorb less carbon dioxide (4).

Our forests have changed to. They now absorb less carbon dioxide because they are becoming less healthy as their environments warm beyond their evolutionary niches. NASA and numerous other researchers have shown that the carbon dioxide fertilization effect has already worn off as our forests succumb to stress from the warming. This has been documented across most of the world’s forests north of the tropics (5).

As our planet becomes warmer, these changes will become larger. Other things that the scientists have seen happening already will start to play an even larger role in the way our climate changes. Drier soils from ongoing drought cannot hold as much carbon dioxide from decayed organic material. Extensive peat lands across the world are also drying and have already changed into large sources of greenhouse gases (6). Melting permafrost releases greenhouse gases, under sea frozen methane is venting, ocean primary productivity is falling, and the list goes on.

When the big picture is completely digested, or as completely digested as our knowledge base can get it today, the 21st century understanding of the life of CO2 in our sky, based on research from Dr. David Archer at the University of Chicago is as follows: CO2 lasts for 300 years except for 25% that last forever (7). This is very much different from our previous understanding of the life of CO2 being 100 to 200 years.

Our knowledge about methane has changed too. When the big picture is recognized, methane has far more impact on our atmosphere than we once thought. Methane reacts differently with different things in the atmosphere at different times. These different reactions tell us the strength of the warming that then occurs. For example, methane decomposes after a dozen or so years, but the decomposition byproducts are CO2 and ozone, both greenhouse gases.

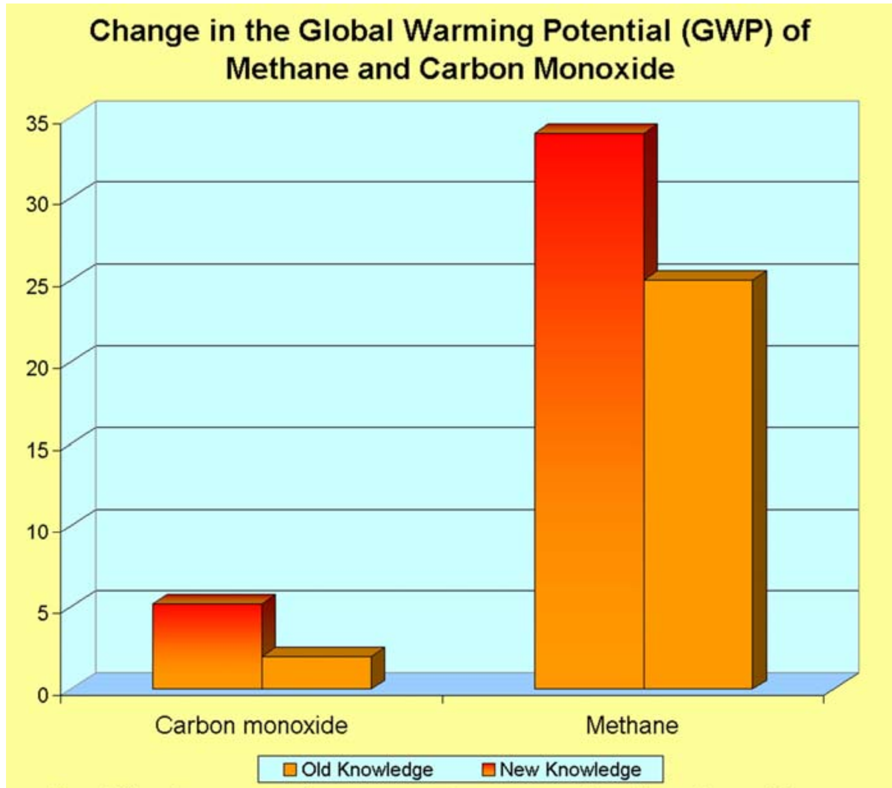
Other substances that are a part of the methane cycle are much more far reaching and include water vapor, volatile organic compounds, sulfur compounds, carbon monoxide, etc.

In the past however, our view was much more basic. We simply compared the warming caused by methane directly to the warming caused by carbon dioxide.

Today, we know that the warming from methane, like the lifetime of carbon dioxide, has changed relative to our knowledge of the 20th century. The IPCC Fourth Assessment report listed methane as having a global warming potential (GWP) of 25. That is, methane is a greenhouse gas that is 25 times more powerful than carbon dioxide.

This is basic 20th century knowledge. Even though the IPCC report was published in 2007, most of the knowledge in the report dated to two to five years (or more) prior to 2007. Science takes a lot of time to happen.

So our new knowledge then, about the GWP for methane, as published by Dr. Drew Shindell at Columbia University, considering all of the known reactions and interactions of methane with other atmospheric factors, is that methane is now 34 times more powerful than CO2. This is more than a third more powerful that we understood just a few years ago (8).



The ability of some greenhouse gases to warm our planet has changed because the chemical and physical processes on our planet are different today because of global warming already experienced. Shindell, et. al., Improved Attribution of Climate Change Forcing to Emissions, Science, October 2009.

So it has become obvious to the climate scientists, well at least the atmospheric chemists, that what is really happening in our skies is much different than what we thought.

Now, back to aerosols. We have learned a lot about aerosols in the 21st century. Aerosols generally cool our atmosphere instead of warming it like greenhouse gases and it turns out that aerosols have a play big role in what is going on in our sky.

So our team of scientists following Dr, Unger, considers how different economic sectors impact our climate based on the net impact from both warming and cooling pollutants created by those economic sectors.

These clever scientists have taken all of this information and put it in this nice little confusing piece of climate science art titled Impacts of Different Economic Sectors on Climate. The colored bars show the impacts from warming and cooling of different gases and aerosols. Cooling is on the left, warming on the right.

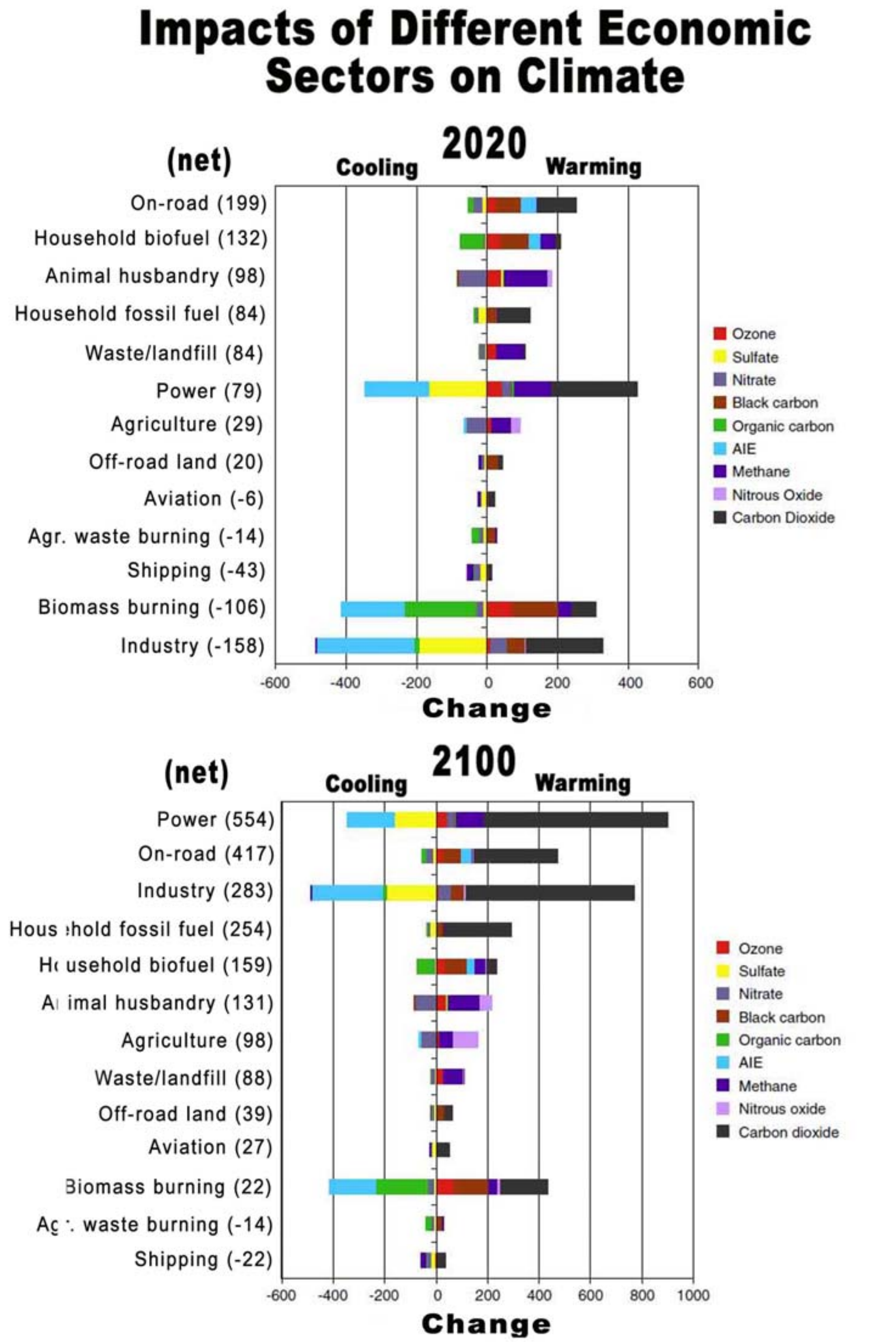
Focus on the top image labeled 2020 where the economic sectors are considered in the short term. “On-road” (which is transportation) ranks highest with a score of 199 watts of warming. This is in great conflict with what we know as the worst offender of greenhouse gas emitters. “Power”, better known as dirty coal, has a warming of 79 watts.

(Watts of warming is in watts per square meter relative to preindustrial times. This is the same comparison that the IPCC makes.)

So transportation warms the planet two and a half times more than coal, in time frames that matter to us humans.

How can this be? The greenhouse gas emissions of dirty coal are certainly the worst of the bunch. This is a well-established fact and is validated by the number one ranking position of “Power” in the long term graphic labeled 2100.

However, in the short term it is the cooling impacts of aerosols that make On-road (transportation) the worst offender.



Short Term (2020) impacts are different from long term (2100) because aerosols are short lived compared to other greenhouse gases. Change is measured in watts per meter squared since 1750. AIE is aerosol Indirect Effect. Aerosols fall out of the sky in days, weeks or years and they have chemical reactions that change their characteristics (indirect effects). From: Unger, et. al., Attribution of climate forcing to economic sectors, PNAS, February 2009.

The reason for this new counter intuitive development is that in the past, in considering the climate impacts from a particular economic sector, we have only considered the impacts of warming from greenhouse gases. The cooling that we realized from the aerosols just was not added into the equation.

Could this be a "Duh!" moment for scientists? Well, er, yes *and* no. Of course there are many researchers out there that *have* been studying this issue, but the general state of the science does not consider both warming and cooling when looking at individual economic sectors.

We have only recently learned enough about aerosols to really sink our teeth into them when it comes to actually comprehending the big picture, so the climate scientists get a break this time. We are always learning.

Dr. Unger and her team have concluded that our society needs to change its priorities for climate change mitigation. We need to pay more attention to transportation, and maybe not so much to coal.

What you say?! It's not that we should stop our efforts at mitigating for the greenhouse gases emitted by coal, certainly not. But because of the issues with climate change in the short term, policies need to change. Unger's paper states:

"The combined direct and indirect effects of aerosols exert a net cooling that may have masked about 50% of the global warming by greenhouse gases (9,10)"

Current, as well as historic air pollution control strategies have focused on aerosols because they are bad for human health. This is why we in the western world no longer have such tremendous problems with smog – we have learned to control our aerosol emissions to an extent.

But developing nations are struggling with traditional air pollution control strategies. This is but one of the big reasons why aerosols are hiding a tremendous amount of warming and that our policies towards the climate crisis need to change.

We also understand that tipping points are game changers in our climate challenge. This concept of climate tipping points is the keystone of this new knowledge: *Why does the short-term matter more than the long term?* If we pass a tipping point, our challenge to keep our climate within the evolutionary limits where our civilization has evolved will suddenly become much more complicated. Climate scientists use the term irreversible for a reason.

These tipping points or thresholds can be compared to the process of accidentally tipping a canoe. Everything is fine until the tipping point is crossed, then something radically different happens, especially if one does not know how to swim.

Tipping points are everywhere: water freezing to ice, rain beginning to fall, flu epidemics, the increase in popularity of the Hula-Hoop phenomena, traffic jams, mercury poisoning, species extinction, fainting, a stampede, a dam failure, the fall of the Berlin Wall, hurricane formation, fruit rotting, fish kills, a thermostat, the collapse of the Saharan grasslands, microphone feedback …

The Arctic sea ice threshold has almost certainly already been crossed. The health of our world's coral reefs has likely crossed a tipping point. Caribou populations, permafrost, and forest health of the Rocky Mountains are all on the candidate list as likely to have already crossed thresholds.

In the last 100,000 years, we have experienced approximately 23 tipping points as our climate flip-flopped through abrupt climate changes. These changes general happened in tens of years or maybe a hundred years or a little more, but sometimes they occurred in less than a decade and possibly even as little as a couple of years.

The temperature, at least in Greenland, changed 10 to 20 degrees during these events and 5 to 7 degrees across the planet. These abrupt climate changes basically mark the difference between the depths of the ice ages and temperatures nearly as warm as they are today.

And just for the record, the snowball earth and the Venus syndrome are both the results of climate tipping points. We have experienced snowball earth several times on this planet.

Most climate tipping points are reversible however. This is the good news. The bad news is that time frames involve thousands, tens of thousands and hundreds of thousands of years.

The Venus Syndrome however, where out atmosphere and our oceans evaporate into space because of runaway warming, is an irreversible tipping point, to say the least.

A quote from another of Unger's papers, this one from June 2010 in Environmental Science and Technology, titled *Short-lived non-CO2 pollutants and climate policy*, puts tipping points into an uncommonly used frame of reference for an academic publication:

"Concerns about anthropogenic forcing of the climate system beyond an irreversible tipping point coupled to the important role that the non-CO2 effects play in global climate change, urgently call for the development of new metrics that would appropriately quantify the non-CO2 effects relative to CO2."

So, most scientists understand that we are close to climate thresholds if we have not already initiated them (Arctic sea ice.) The "urgent" viewpoint of Dr. Unger is certainly not an uncommon sentiment among climate scientists.

We know that the Greenland and Antarctic ice sheets have tipping points, that methane clathrates have melt thresholds, that our oceans have a threshold for CO2 absorption called the saturation point, that marine organisms have a point where ocean acidity increases can kill because of carbon dioxide absorption.

We know that rainforests have thresholds beyond which they collapse, and that temperate forests, as I speak even, have passed a threshold where a native pine beetle pandemic has killed 70 million acres in the North American Rockies and the climate scientists and forest professionals see no reason why this epidemic will not continue across the North American continent.

So, once again, why are we concerned with the short term? Reason number two: because the long term is about slow things happening.

It is not only likely, but very likely that in the next 90 to 100 years we are going to learn how to deal with atmospheric carbon dioxide in a relatively efficient way. This will make it "easy" to get that extra carbon dioxide out of our atmosphere. This is a "slow thing" relative to a climate tipping point.

But if we cross a threshold (s) in the meantime, the task will become immeasurably harder because we will have lost functionality in one or more earth systems. The earth scientists call these systems "ecosystem services".

For example: Ocean primary productivity is really important to our planet. Ocean primary productivity consists of all of those single and multi-celled ocean organisms that have tiny calcium carbonate shells that sequester carbon dioxide and that create oxygen as a byproduct just like trees.

If we cross an ocean acidity threshold where we vastly deplete the primary productivity of our oceans (which has decreased 40% in the last 50 years across 8 out of 10 oceans (11)) we will not only lose the ability of this planet to sequester somewhere around half of the CO2 in our skies, but we will also lose the ability to create half the oxygen that is created on this planet.

This example of "ecosystem services" that our planet provides is one we can no longer take for granted. Our innocent pollution of our atmosphere with greenhouse gases has put life here in jeopardy unless we take responsibility for our actions. Understanding the new knowledge about climate change impacts of different economic sectors and using this knowledge to the greatest extent feasible is paramount.

So now we have this new knowledge. The extra smoke and sulfates, those bright aerosols, and the different reactions that they have in our skies, and even the ways that clouds respond to these aerosols, make the net short-term warming from coal about two and a half times less than the emissions from transportation. Gas and diesel are simply much cleaner than coal, so they are responsible for more warming. They produce less smoke and sulfates which, in total, cools our planet less.

The smoke and aerosols from burning dirty coal counter-balance the warming from the carbon dioxide in what could be the greatest policy blunder of the climate change challenge. What we have previously understood as the "most important climate change economic sector" – power generation from dirty coal – in time frames that matter, is actually nowhere near as important as transportation.

What then, is the meaning of this new knowledge? It means we have to change the way we think about mitigating for climate change. We have to reprioritize our strategies to maximize our efforts in the short run.

This is not a "personal" reprioritization – this policy paradigm is fundamental at the highest level. It is international in scope. It impacts everything that we know about mitigating for climate change.

We can't stop trying to reduce greenhouse gases; they still accumulate over time and compound the warming. But the long-term is not our priority concern. We have tipping points that must be considered. Dirty coal is not the most important climate change challenge any longer.

We have to focus on the most efficient means of limiting global warming to minimize the risks from tipping points. Just to be clear, we cannot simply ignore carbon dioxide from coal. But the game is now more complicated. The highest priority strategies need to involve the global economic sectors responsible for the most warming *in the short term*. This new prioritization needs to be addressed with the greatest amount of resources.

Even more important may be the risks posed by reducing aerosol pollutants through the reduction of energy produced from coal. What are the ramifications? How much of the hidden warming will be revealed? What will be the effects on tipping points? And how will the developing nations of the world change the big picture as they address the health impacts of smoke and other aerosols?

We do not know all of the answers yet, we are still learning. We do know that some serious work must be done on the direction of the policies that we are pursuing in this great atmospheric chemistry experiment that we call climate change.

And always remember, we have found ourselves in this situation innocently, there is no need for blame or guilt, unless we fail to act responsibly on the knowledge that we have learned, and the knowledge that we continue to learn.

(1) Anderegg, et. al., Expert Credibility in climate change, PNAS April 2010.

(2) A Google Scholar search for "climate change" in the title for the year 2009 returned 70,100 hits. The same search for 1990 returned 7,900 hits. Google Scholar is similar to Google except the data base is not the World Wide Web, but all of the scholarly journals where scientific publications are published. There is some bias in this query methodology. A good number of new journals have been created to accommodate the crush of science coming from our climate scientists. This creates some opportunity for the same discoveries being published in multiple journals. But this opportunity existed in 1990 as well, so the real impact is unknown without an in-dept evaluation. It is just as likely, without that in-depth evaluation, that today there are fewer scientists publishing their discoveries in multiple journals. There is also a possible bias in the query term. There are certainly more papers about climate science being written than have the words "climate change" in their title. Again, without an in-depth evaluation, it is unknown how this search definition impacts the results. The real issue however, is the rate that the number of hits have increased in the last 20 years. Looking at the numbers from each year, the yearly discoveries are increasing rapidly, meaning that we are still ascending the learning curve. This means that we still do not know more than we do know. If we had already passed the midpoint of the learning curve (learning curves assume a bell shape), the yearly number of hits for new scientific discoveries that include the words "climate change" in their titles, would be decreasing.
See this article in the magazine Science for a discussion relevant reference (1) Anderegg 2010, and relevant to scholarly searches using the Google Scholar Database.

(3) Stern, The Economics of Climate Change, American Economic Review: Papers and Proceedings, 2008.

(4) Ocean acidification – another undesired side effect of fossil fuel-burning, European Science Foundation, http://www.esf.org/research-areas/life-earth-and-environmental-sciences/news/ext-news-singleview.html?tx_ttnews[pointer]=2&tx_ttnews[tt_news]=439&tx_ttnews[backPid]=1117&cHash=e24ee9ab5e

(5) NASA Earth Observatory: Forest on the Threshold
   a. http://earthobservatory.nasa.gov/Study/BorealThreshold/boreal_threshold.html
   b. Goetz, et. al., Satellite-observed photosynthetic trends across boreal North America associated with climate and fire disturbance. PNAS, 2005.
   c. Angert, et. al., Drier summers cancel out the CO2 uptake enhancement induced by warmer springs. PNAS, 2005.

(6) Van der Werf, et.a l., CO2 emissions from forest loss, Nature Geoscience, November 2009.

(7) Archer, Fate of fossil fuel CO2 in geologic time, Journal of Geophysical Research, volume 110, 2005.

(8) Shindell, et. al. October 30, 2009, Improved Attribution of Climate Change Forcing to Emissions, Science.
(9) Koch D, et al. (2009) Distinguishing aerosol impacts on climate over the past century. J Climate.
(10) Ramanathan V, Feng Y (2009) Air pollution, greenhouse gases and climate change: Global and regional perspectives. Atmos Environ.
(11) Unger, Short-lived non-CO2 pollutants and climate policy, Environmental Science and Technology, June 2010.
    a. http://pubs.acs.org/doi/pdf/10.1021/es1012214\
(12) Unger, et. al., Attribution of climate forcing to economic sectors, PNAS, December 2009.
    a. http://www.pnas.org/content/107/8/3382.full.pdf
(13) Boyce et. al., Global Phytoplankton decline over the past century, Nature, July 2010.