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Subject: Myhrvold and Caldeira: Study shows "no quick fix" for global warming

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Environmental Research Letters published a new study yesterday by Nathan and Carnegie Institution's Ken Caldeira. The study examines the transition from the current coal-based energy system to low-carbon technologies, and how that transition will affect global warming. In short, the study finds that there's no quick fix to global warming. Carbon already emitted into the atmosphere will continue to increase global temperatures through the first half of this century, and emissions created during the ramp-up to a low-carbon energy system will only exacerbate matters. To minimize the damage, the authors argue for a faster, larger-scale transition to extremely low-carbon energy sources like solar, wind and nuclear.

The full paper is available at <http://iopscience.iop.org/1748-9326/7/1/014019>, but a more detailed overview from Nathan is included below.

Nathan Myhrvold on his paper with Ken Caldeira

Greenhouse gases, climate change and the transition from coal to low-carbon electricity. Environ. Res. Lett. 7 014019 (doi:10.1088/1748-9326/7/1/014019)

"A few years ago I decided that to understand global warming better, I shouldn't just read about the science, I should do it. So I contacted Ken Caldeira with an idea about how to model the transition from our current high-carbon emitting energy system to low-carbon or "green" technologies.

This is harder than you might think. One reason is that the large computer simulations – known as coupled ocean-atmosphere circulation models – are difficult to use for studying small effects. So we had to develop some mathematical techniques which would be sensitive enough to measure the impact of moving say 1 TWe (terra-watt of electricity generation) from coal to say, solar.

Another reason this problem is tricky is that it takes energy emission to make a power plant. Solar photovoltaic plants need solar cells which require a lot of electricity to make. Generating that electricity causes emissions. It's a bit like building a hotel or office building. The builder borrows money to build the building. The day the building opens its doors, he is deep in debt and only then starts collecting rent. As the rent from the building comes in, the owner pays down the debt and hopefully make a profit, but it takes a while. When you build a clean energy plant, you also create a debt (emit CO₂ for the energy generated to build the plant), then you start getting benefit as the plant generates clean power you get benefit. Depending on how much benefit you get from ongoing operation, and how much "debt" it takes a while before you break even and start to see climate benefit.

We found that while lots of people (include us) advocate moving to cleaner energy generation, nobody had actually modeled the transition. So that's what we did. It took a couple years, but today Environmental Research Letters published our paper. Our conclusions are pretty interesting, and are likely to be quite controversial.

First, no matter what low-carbon or green technology you switch to, it is very difficult to have much impact on temperature increase this century. The total temperature increase through 2100 has some pretty tough lower bounds – it's already baked in the cake. Moving to very low carbon sources has benefit, but not as much as you'd think, or as soon as you'd think. The reason is that CO₂ persists in the atmosphere for a long time. Even if the world went on a crash course to replace every coal plant on earth with clean energy technology, the accumulated CO₂ from the coal that you would need to burn during the transition lingers. We modeled transitions ranging from replacing every coal plant on earth in just one year (clearly unrealistic, but it provides one extreme), to slowly replacing them over 100 years (another extreme).

This range covers just about any transition that one could make, and the somewhat depressing news is that they all have problems.

Even pure conservation – simply turning off coal plants over a period of time and not replacing the energy – leaves you with surprisingly large temperature increases. As a society we have overindulged on CO₂ emissions, and we're going to get quite a hangover even after we stop drinking.

One big surprise is that there is virtually no benefit from replacing coal with natural gas. Natural gas emits about a factor of two less CO₂ and other greenhouse gasses than coal (give or take), but a factor of two is much too small to have an impact. Replacing every coal plant with natural gas would only show a tiny decreasing in global warming versus coal – even if you wait 200 years or more. Climate change is about nonlinear effects, and the only way to have an impact in the next 100 years is to *dramatically* reduce the emissions. A factor of two isn't even close to enough to make a meaningful impact in a century or two. This is doubtless going to come as a disappointment to the gas company, and the people who want to use cheap natural gas from fracking to combat climate change.

A very similar situation exists for CCS (carbon capture and storage). At present no CCS plants are operating at scale anywhere in the world, so we took published estimates of the emissions that a CCS plant would make and modeled them. Most CCS schemes claim that they capture 90% of the CO₂ due to combustion. That sounds pretty good, but a total life cycle analysis of the emissions needs to include the CO₂ emission cost of the reagents used in the CCS plant, and the emissions for mining coal (or extracting natural gas) to fuel the plant. We took published life cycle costs for CCS, and while it is a bit better than natural gas, it too does not make a significant impact on global temperature increase this century.

What if technology improves over time? There is lots of talk about a "Moore's law" for solar cells, and other technology. Unfortunately this is a lot more hopeful than realistic. No energy technology has anything that remotely approaches Moore's law for semiconductor price/performance. Moore's law is a factor of two every 12-18 months – an improvement of 60% to 100% per annum. Most energy technologies have more like 3% to 6% improvement per annum. But we modeled technological improvement anyway, and a lot of other scenarios. Improvement helps of course, but it doesn't help all that much.

The stark reality is that switching to green energy is not a quick fix, which only underscores the importance of improving our energy generation infrastructure."