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The Three Most Important Graphs in Climate Change

There's a lot of confusion about climate change out there, especially when it comes to finding viable solutions. How can we determine what solutions make the most sense, and where to focus our efforts? It turns out that starting with these three little graphs helps a lot.

Jonathan Foley Jun 3 · 11 min read

In the redwood forests of northern California. Photograph by Jonathan Foley © 2019.

When it comes to climate change, confusion is rampant.

Why? Many people might point to the lack of robust science literacy in America today. Others might point to the deliberate attempts by industry groups and their political allies to obfuscate the issue, sowing doubt and confusion. Others might criticize our media outlets, where facts and respectful dialogue are trumped by sensationalism, manufactured controversies, and shouting matches.

While this is all true, I think it might be more basic than that. Maybe it's because people literally can't *see* what we're talking about, so it's easy to be confused.

By their very nature, greenhouse gases like carbon dioxide, methane, water vapor, nitrous oxide, et cetera, are *invisible* to our eyes. That's the point. Solar radiation — and the visible spectrum of light our eyes see in — does not get absorbed or emitted by these gases. Sunshine goes right through them, allowing the sun's radiation to pass unencumbered, illuminate and warm the Earth's surface, and do it all without us seeing a thing.

Greenhouse gases cause a problem, of course, because they are *not* transparent in the infrared part of the electromagnetic spectrum, where the Earth's radiates back to outer space. So-called greenhouse gases absorb and re-emit that radiation, some of it back to the Earth's surface, making the planet's surface warmer than it would otherwise be. In other words, Earth has a *Greenhouse Effect*, something scientists have known about since the 1830s. (Yes, that's correct, the *1830s* is when we first started to understand the greenhouse effect.)

It's basic physics, it's simple, but it is something we can't actually see with our own eyes. So it's easy to ignore or dismiss it.

Moreover, I sense that people have a hard time thinking about polluting the *sky*. We can see landfills, plastic pollution on the beach, noxious chemical foams floating on the water, and it all makes immediate sense to our senses. But changing the sky with invisible gases? That seems so impossible to our brains, since the sky overhead appears infinite to us. And, for most of human history, it was seen as the realm of the gods, not us.

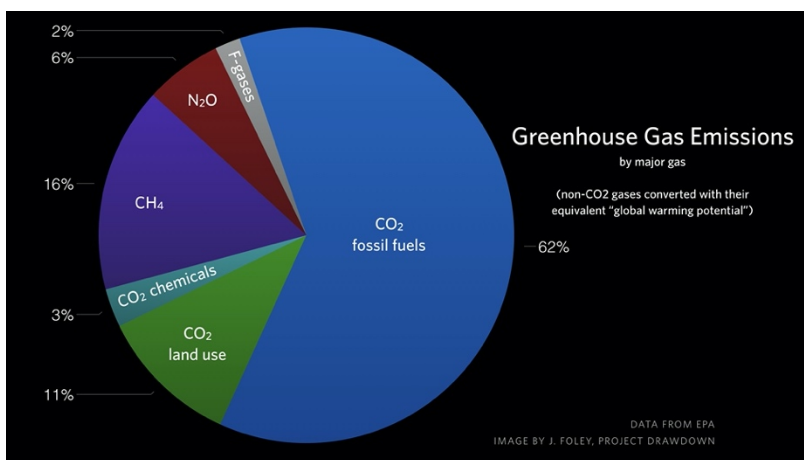
But that's not true. We *can* change the sky, and we have. Dramatically. As of this spring, the levels of carbon dioxide in the atmosphere rose to about 415 parts per million, shattering the highest levels seen in the last few million years — 270 parts per million. And it's still climbing, year by year.

The confusion about climate change gets even messier when it comes to solutions. The discussions usually don't start with facts or basic science; instead we can hear from numerous "experts" who want to tell you how they will solve climate change — usually with their favorite pet theory or business idea. Often with little data or scientific understanding to back it up.

Before debating the merits of different climate solutions, it's best to start with the basic science, and learn a little about how greenhouse gases actually work. Then we can have more informed debates and discussions about which solutions to climate change are the most viable.

Here's where a couple of simple graphs may help.

First, here's a chart of the *anthropogenic* (a fancy word which means "human generated") greenhouse gas emissions into the atmosphere.



Greenhouse gas emissions by major gas. Each of these gases is emitted by human activities, contributing to a warming planet. Carbon dioxide (CO2) is the most important greenhouse, *stemming from fossil fuel combustion, land use, and industrial processes. Methane (CH4), nitrous oxide (N2O), and fluorinated gases (f-gasses) are also important. Here we compare each gas on an "apples to apples" basis by averaging their "global warming potential" over a 100 year period. Data from the [EPA](), with adjustments to separate chemical and cement emissions of CO2 from fossil fuel combustion based on data from the [World Resources Institute]().*

This graphs shows us a few basic things.

First of all, there are *several* key greenhouse gases to consider — carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and so-called f-gases (mainly hydrofluorocarbons, chlorofluorocarbons, and other fluorinated gases). It's not just CO2.

Each gas behaves a little differently in the atmosphere, and we need to take that into account. For example, some gases trap heat much more effectively than others, because their molecular structure absorbs infrared radiation better, and they each last a different amount of time in the atmosphere. So to compare them in a consistent, "apples to apples" way, we often convert them into equivalent units by averaging their "global warming potential" over 100 years. (This is a standard tool to compare different greenhouse gases and their impact on climate change. But it does bury a few important points. For example, methane is far more powerful at trapping heat than carbon dioxide, but it doesn't last in the atmosphere very long. So, in the short term, say 10–30 years, methane is *extremely* important to climate change. But in the longer term, like a century or two, it's much less so.)

Of our greenhouse gas emissions, carbon dioxide gets most of the attention, and for good reason. It represents about 76% of our greenhouse gas emissions each year. And the lion's share of it (about 62% of total emissions) comes from burning fossil fuels, including our use of oil, coal, and natural gas. That's why a lot of the focus on climate change solutions is centered on replacing fossil fuels — it causes about 62% of the problem.

But a lot of carbon dioxide, and other greenhouse gases, *aren't* generated from fossil fuel combustion, and we need to look at those too.

In fact, it's a big mistake to equate greenhouse gas emissions with burning fossil fuels alone; you'd be missing about 38% of the emissions, and 38% of the opportunities to address climate change.

For example, about eleven percent of our greenhouse gas emissions stem from carbon dioxide released from land use, especially deforestation. Remember, burning trees, which are also largely made up of carbon, is like burning coal. They both release CO2.

And some carbon dioxide is released from chemical processing and curing cement. Those are significant sources too.

Then we have methane (CH4), which can be released from leaks from fracking and natural gas pipelines, landfills, and biomass burning. Another major source of methane comes from agriculture, especially from rice fields and cattle. (Funny fact: cattle mainly *burp* methane, not fart it.)

Nitrous oxide (N2O) is another greenhouse gas, mainly produced from overusing fertilizer in agricultural soils.

Finally, we have fluorinated gases (f-gases) such as hydrofluorocarbons (HFCs), chlorofluorocarbons (CFCs), and sulfur hexafluoride (SF6). These chemicals are typically used as refrigerants or in industrial processes.

There are other minor greenhouse gases, and something called "black carbon", that we humans emit into the atmosphere as well, but for the sake of simplicity, this is a good starting point.

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The bottom line is that the greenhouse gases that warm our planet include more than CO_2, and come from more than just burning fossil fuels. We need to widen our perspective to understand, and address, climate change.

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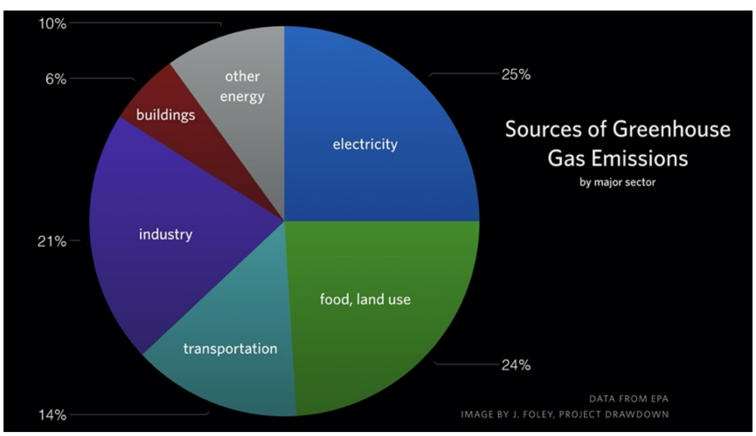
So where do all of these emissions originate? And what human activities causes them? That's where we can start to think of the most viable solutions to reduce their emissions.

In order to figure this out, we can trace the greenhouse gas emissions back to their different sources around the globe, and assign them to major economic categories. Here's a graph breaking them down at the global scale.



Sources of greenhouse gas emissions by major economic sector. It's important to note that these data are for the world as a whole, and each country has a different emission profile. In the United States, for example, food & land use are a smaller fraction of emissions, but transportation is higher. Data from the EPA.

What this graph shows is that there are *a lot* of different things that contribute to climate change — not just burning fossil fuels.

Globally, the two biggest sectors that contribute to climate change are electricity generation (~25%) and food & land use (~24%). In other words, burning coal, oil, and natural gas to generate electricity is the single largest source of global emissions, but the food & land use sector is nearly tied with it.

Some people are surprised by how important food & land use is to climate change. It turns out that food & land use release greenhouse gases for three major reasons. Deforestation and clearing other lands for food production is the largest source of these emissions. Methane production by cattle and rice fields is the second most important contributor of greenhouse gases from food & land use, followed by nitrous oxide emissions from overusing fertilizers on agricultural soils. Interestingly, the differences between local food and industrial food systems, and the differences in "food miles" they might involve, have only minor impacts on climate change. While local food systems may have a lot of other benefits, they are not crucial to reducing energy use and greenhouse gas emissions. Instead, we need to focus on deforestation, methane emissions from cattle and rice fields, and nitrogen fertilizer overuse.

The rest of the graph tells the whole story. Electricity (~25%) and food & land use (~24%) make up about half of the world's greenhouse gas emissions, and industry, transportation, buildings, and other sources make up the rest.

Six major sectors — electricity, food & land use, industry, transportation, buildings, and other emissions — are causing the problem. So that's where the opportunities to reduce emissions will largely come from too— by eliminating the sources of greenhouse gases where they originate.

There are some immediate lessons we can draw from these graphs. Most importantly, and I have stressed this before, is that climate change is *not* just an energy problem; it's about 62% an energy problem — food & land use are also crucially important — and so are leaking natural gas pipelines, landfills, cement, and refrigerant gasses. Several gases, and several emission sources, contribute to climate change, not just CO2 from burning fossil fuels. So, in the end, we need to look for solutions in many different areas, not just eliminating fossil fuels, although that is still *crucially* important. We need to look at the whole board.

At Project Drawdown — the non-profit environmental organization I help lead — we have examined 100 of the most viable solutions to climate change, ranking them against their climate impact and cost. And you can see them all by visiting Drawdown.org.

Many of the solutions we explored involve changing energy use, of course, but we also propose crucial solutions in land use, the chemical industry, cement, building construction materials, forests, and the food sector. I'll be writing about many of these in future posts.

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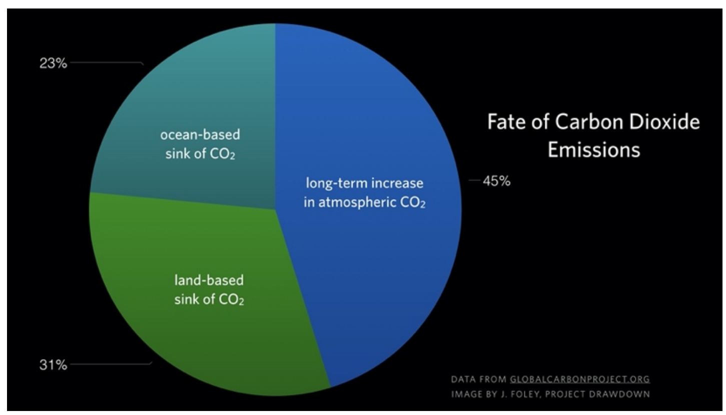
So far we have only talked about the *sources* of greenhouse gases to the atmosphere — what they are, where they come from, and the potential solutions to reduce them.

But we can also look to ways to *remove* greenhouse gases from the atmosphere through so-called "*sinks*". A sink is a process — typically found in land-based ecosystems, in the oceans, or possibly in an engineered device — that removes greenhouse gases (especially carbon dioxide) from the atmosphere.

This may sound far-fetched at first. What could possibly remove pollution from the atmosphere at a scale that would matter to climate?

Well, it turns out that nature *already* does this, and does a great deal of it every year for free.

If we focus on carbon dioxide, it turns out that only ~45% of the annual CO2 emissions stay in the atmosphere, contributing to climate change; the other ~55% is basically soaked up by the oceans (~23%) and land-based ecosystems (~32%).



The fate of annual CO2 emissions from human activities. About 45% of the emissions stay in the atmosphere, contributing to climate change. But the remaining 55% are absorbed by the oceans and by land-based ecosystems. These natural carbon sinks have greatly reduced climate change from what it would have otherwise been, absent these carbon absorbing processes. The question is: Can we somehow enhance these natural sinks, or add to them with engineered devices? Data from the Global Carbon Project.

That's important to reiterate: Over half of our annual CO2 emissions are immediately absorbed by land-based ecosystems and the oceans, dramatically reducing the impact of our activities on climate.

And it might be possible to *enhance* these natural sinks — on land and in the oceans — so that they absorb *even more* carbon dioxide. Planting large areas of new forest, restoring carbon rich soils under our agricultural and degraded lands, restoring coastal ecosystems, and protecting natural ecosystems under current threat are all ways to do this right now. And there are many others.

(A side note: To me, it's very interesting to notice the central role of land use and our food system in greenhouse gas emissions, as well as their potential role in creating additional carbon sinks. Land-based solutions are crucial to reducing emissions, and they are crucial to enhancing sinks. This area deserves much more attention in the research, policy, and funding communities.)

It is also conceivable that we can design technologies to act as *supplemental* sinks, with devices that remove greenhouse gases through industrial and chemical processes. So far, machines that can remove greenhouse gases at scale are just a dream, and I'm quite skeptical of them. I'd rather help Nature do the job, with a proven track-record of results, but we may want to keep an open mind here.

In short, we have to address the *sources* of greenhouse gases, immediately, but it is also important to recognize the potential importance of *sinks* as well.

In the end, we need dramatic, rapid, and informed action to address climate change.

We should always cut emissions first, which come mainly from fossil fuels, land use & food, and industrial processes. Again: CO_2 from burning fossil fuels is *crucial*, but *not* the only issue.

I think we need a portfolio approach to address climate change, and not put all of our greenhouse eggs in one solutions basket. I'd focus on several issues to start, including enhancing energy conservation, scaling up renewable electricity generation, reducing food waste, shifting diets to less damaging foods, improving agricultural systems, electrifying transport where possible and using sustainable fuels where not, constructing and retrofitting buildings for extreme energy efficiency, and electrifying heating and cooling systems. We should also target methane, and so-called super-pollutants, as soon as possible, to help us buy time to do the rest.

And we should look for ways to *remove* greenhouse gas emissions (especially those emissions that will take time to eliminate at the source) through the development of safe carbon sinks. I strongly recommend natural carbon sink solutions, like replanting forests, increasing "carbon farming" on agricultural lands, and restoring coastal ecosystems, as an excellent "no regrets" strategy to start.

Addressing the climate crisis is *possible*, but it won't be easy. We will need to transform policy, business practices, capital flows and infrastructure, and personal behaviors on a massive scale. It will be a huge transformation of our world. But we must do it, and I believe we can.

But, first, we have to understand where the key issues are, and where the best opportunities might be to address climate change. And starting with a little background science might be a helpful place to begin.

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