Getting to 350: What It Will Take to Fix Global Warming

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By Peter Montague, Truthout | News Analysis

An international day of action on climate change brought hundreds of thousands onto the streets of New York on September 21, 2014. (Photo: Tony Savino / Corbis via Getty Images)

In 2017, scientists for the first time spelled out what it will take for civilization to survive global warming. Simply ending the use of fossil fuels isn't going to do it; we must *also* extract billions of tons of carbon dioxide (CO2) out of the atmosphere and store it somewhere forever. The world has been edging toward this momentous conclusion for a long time, but in 2017, scientists finally laid out the details.

At least as early as 2001, a few scientists started saying atmospheric CO2 could not safely exceed 350 parts per million for very long. The world snoozed. Then, in October 2009, huge, noisy crowds of young people jammed the streets in 4,300 synchronized demonstrations in 188 countries, to publicize 350 parts per million (ppm) as a climate goal. The world began to wake up.

Now, thanks to climate activists (and many scientists), the 350 goal is firmly fixed on the global agenda. However, few people still have any real idea what it will take to achieve 350. In 2017, though, climate godfather James Hansen and his colleagues laid it out for us.

From 1981 to 2013, Hansen was director and chief scientist for the National Aeronautics and Space Administration's Goddard Institute for Space Studies. In 1988, it was Hansen who first told Congress that global warming was upon us. Some scientists scoffed, but today all the world's major scientific organizations acknowledge that he was right. After another 20 years studying global warming, in 2008, Hansen published his disturbing conclusion that global warming promises "irreversible catastrophic effects" if we allow CO2 to exceed 350 ppm past the end of this century.

The natural amount of CO2 in the air is 280 ppm, but by 2016, it had risen to a dangerous 404 ppm because of humans burning coal, oil and natural gas. It's now rising a bit more than 2 ppm each year and the rate of increase is accelerating. As everyone now knows, CO2 acts like a blanket in the air, warming the planet and changing the climate.

Why It Matters

Hansen is a physicist, and his argument is based on physical evidence from Earth's rocks and ice, which contain a record of past CO2 levels, temperature, climate and sea levels. We are now living in a warm period between ice ages -- a balmy epoch known as the Holocene, which began about 11,700 years ago. During this warm period, humans invented agriculture, formed villages and towns, then cities, creating modern civilization.

Today, everyone on the planet is dependent upon Holocene conditions -- moderate temperatures, steady sea levels, abundant sea life, manageable storms, predictable patterns of rain, snow, snow-melt and river flows, plus plenty of food thanks to regular seasons, abundant pollinators, ample fresh water and moist, temperate soils. If those things change -- especially if they change rapidly, as they are now doing -- hundreds of millions of people will find themselves short of food, fresh water or tolerable temperatures, and will migrate into someone else's territory, creating conflict, war and social upheaval. If present warming trends continue, the foundations of civilization will crumble.

The Science of 350

Hansen's argument goes like this: In the last warm period before the Holocene (in an epoch called the Eemian) the global average temperature peaked about 1.8 degrees Fahrenheit warmer than the Holocene average, and two things were hugely different from today: 1) sea level was 20 to 30 feet higher, and 2) coastal storms were much larger, producing waves that could push 1,000-ton boulders out of the sea onto the land.

Global average temperature today is already warmer than it was during the Eemian. If it remains so for long, polar ice will melt away, sea level will reach Eemian levels, and the world's coasts will be swamped. Since 1750, the global average temperature has risen about 2.07°F and additional warming of about 1°F is "in the pipeline," meaning the heat has already entered the ocean and will be warming the atmosphere in the next several decades, no matter what we do. *In sum, we have already overshot safe CO2 limits* and polar ice is already melting faster than most scientists thought possible.

The Speed of Melting Matters

From the geologic record, we learn that sea-level rise can occur abruptly -- 13 feet to 15 feet in a century. Because of the unprecedented speed of recent warming, Hansen believes a 20- to 30-foot rise could occur within 50 to 150 years. Even the more optimistic estimate -- a 20-foot rise in 150 years -- would average 16 inches every decade, which even wealthy, low-lying cities could not accommodate for long. "The economic and social cost of losing functionality of all coastal cities is practically incalculable," Hansen writes.

How Many People Live on Low-Lying Coasts?

Worldwide, an estimated 145 million people live three feet or less above sea level. Even a three-foot rise this century would bring economic chaos.

In 2007, the world's low-elevation coastal zone (less than 33 feet above sea level) was home to about 700 million people (then about 11 percent of the global population), and millions more have moved to the coasts since then. About two-thirds of the world's cities larger than 5 million people lie at least partly in this endangered zone. "It is not difficult to imagine that conflicts arising from forced migrations and economic collapse might make the planet ungovernable, threatening the fabric of civilization," Hansen writes.

What Will It *Really* Take to Get Back to 350?

Getting back to 350 isn't as simple as it may seem. As we extract CO2 from the air, it will be replaced by CO2 seeping back out of the ocean and the land. Therefore, almost all of the CO2 that humans have emitted since 1750 must be sucked out of the air and stored somewhere forever. Hansen's latest paper, for the first time, calculates the size of the task.

Three Things We Could Do

1. We could initiate a "concerted global-scale effort" (Hansen's phrase) to remove carbon from the atmosphere and store it in soil by "improving agriculture and forestry practices" worldwide. He offers an estimate -- which he calls "ambitious"

-- that we could remove about 370 billion tons of CO2 from the air this century by such a global effort.

2. Simultaneously, we could rapidly reduce CO2 emissions from fossil fuels -- modifying all power plants, industrial operations, buildings and vehicles. How fast we reduce emissions will determine the necessary size of step three, which is...

3. We can build machines to extract CO2 directly from the air. Even with maximum CO2 removal by improved farming and forestry, and even with rapid, steady decreases in fossil fuel emissions, CO2 would still exceed 350 ppm in year 2100, threatening civilization. Therefore, direct removal of CO2 from air is essential, Hansen calculates.

In his 2017 paper, Hansen describes two practical CO2-removal scenarios: 1) reducing CO2 emissions 6 percent per year for 80 years (2020 to 2100), or 2) reducing emissions only 3 percent per year for 80 years.

Hansen shows that if we choose the 6 percent per year reduction, then we must capture and store 560 billion tons of CO2. If we reduce emissions only 3 percent per year, we must extract 870 billion tons of CO2 and store it forever.

Two Ways to Store CO2

There are two basic ways to store CO2: 1) permanently solidify the CO2 by combining it with basalt rock, creating carbonate minerals, such as limestone; 2) compress the CO2 gas into a liquid and pump it a half mile or more below ground, hoping it stays there forever. This second approach has several problems. For one thing, pumping billions of tons of liquid CO2 underground will almost certainly cause earthquakes, which are destructive, costly and frightening. Second, if the CO2 ever leaks back into the atmosphere, it defeats the purpose. Third, liquid CO2 is dangerous -- if much CO2 leaks to the surface abruptly, it could kill all living things near the leak. Therefore, people are likely to oppose a CO2 burial site anywhere near them.

The Cost

Turning CO2 into stone seems the better option if it can work on a grand scale. The chemistry is simple, but the technology remains largely untested. The few researchers currently doing it aim to get the price down to $100 per ton of CO2. If they succeed, the 6 percent-per-year reduction plan will cost $700 billion per year for 80 years. (For comparison, the proposed US military budget for 2018 is around $640 billion.) At $100 per ton, the slower 3 percent-per-year emissions reduction plan would cost about $1.1 trillion per year for 80 years.

Of course, the $100-per-ton estimate could be wildly optimistic. The American Physical Society (APS) -- the professional association for physicists -- has estimated that air capture and storage of CO_2 will cost at least $610 per ton. If this APS estimate held true, then a 6 percent-per-year reduction would cost $4.2 trillion each year, and 3 percent-per-year reduction would cost $6.7 trillion per year, every year for 80 years. Those are large sums.

Whatever it finally costs to get back to 350, based on historical CO_2 emissions the US would be liable for 26 percent of the total cost -- somewhere between $182 billion per year and $1.1 trillion per year, using the cost estimates given above.

These are painful but perhaps manageable sums in a growing global economy, but there's another way to measure the size of the required CO_2-capture effort: by comparing it to the global oil industry. In 2015, refineries processed 4.4 billion tons of crude. Notably, it took over 120 years to build that processing capacity. If we reduce CO_2 emissions 6 percent per year, we'll need to build the equivalent of today's global oil industry in 72 years. That is arguably doable with a major, concerted, global effort.

On the other hand, if we reduce CO_2 by only 3 percent per year, we'll have to build a CO_2 storage industry the size of today's global oil industry in 26 years, and within 80 years, we'll have built a CO_2 processing system three times the size of today's oil industry. This seems beyond human capacity, which tells us we need to reduce global CO_2 emissions faster than 3 percent per year.

The 6 percent per year reduction rate (or close to it) could be feasible if we had a global agreement on that goal. Belgium, France and Sweden each reduced CO_2 emissions between 4 and 5 percent per year for more than a decade when they switched from coal to nuclear power in the 1970s. (Today only Sweden remains fully committed to nuclear power. In France, a decades-long cover-up of construction flaws has undercut confidence in the nuclear option, and Belgium is phasing out the technology. In the US, greying advocates of nuclear power hope against hope that a new generation of "small modular" atomic reactors will arrive in time to revive the industry. However, serious unresolved safety issues -- and the disaster-scarred track record of the technology -- continue to repel investors and the public. Many new, exotic nuclear reactor designs have been proposed, but all suffer to one degree or another from ruinous unsolved problems, including weapons proliferation, radioactive waste disposal, extreme technical and managerial complexity, terrorist threats, long construction times, public mistrust and high cost. Far cheaper, simpler and safer renewable energy systems are already available off the shelf, and investors know it.)

What's Politically Possible?

If a 6 percent annual emissions reduction using renewable energy seems technically doable, then we can ask whether it's politically possible. So long as the sky is a free toilet for waste carbon, there's a strong incentive to continue emissions as usual. In the US, to reduce emissions 6 percent per year for 80 years, we'd have to impose a carbon tax on coal, oil and natural gas, to be collected at the mine mouth or well head and distributed uniformly to every citizen. (Such a tax would improve, not diminish, economic prosperity.) Worse, governments worldwide are presently subsidizing fossil fuels to the tune of $5.3 trillion per year, or $10 million every minute, 24/7. Those subsidies would have to end.

Making Corruption Illegal

Naturally, before we could end massive subsidies and impose a tax on carbon in the US, we'd have to get private money out of our politics. Our system of perfectly-legal corruption allows the fossil corporations (and their lawyers, consultants and subcontractors) to buy Congress. As a result, in 2016, 180 of the 535 members of Congress (34 percent) simply denied climate science. It pays to do so. On average, the 38 Senate deniers have each received $732,788 from fossil fuel interests while science-believing senators each got only $182,902. On average, each House denier has received $272,536 from the fossil corporations while science-believing members each got only $80,095.

Obviously, fixing corruption in our politics is an *essential* reform that must happen before global warming can be brought under control. But it's a reform that could appeal to *all* issue-oriented people. *It is the one reform that makes all other reforms possible*. You might think that a gigantic coalition of concerned residents and activists from *all* issue-groups would join together to make it happen. But so far you would be disappointed. Can we still make it happen? Yes, we can.

PETER MONTAGUE

Peter Montague is a historian and journalist whose work has appeared in Counterpunch, Huffington Post, the Nation and many other publications. He has co-authored two books on toxic heavy metals.