**[ERIC DREXLER](http://www.edge.org/3rd_culture/bios/drexler.html)**Researcher; Policy Advocate; Author, [Engines of Creation](http://www.amazon.com/exec/obidos/tg/detail/-/0385199732?v=glance)

KNOWLEDGE SPREADING

Human knowledge changes the world as it spreads, and the spread of knowledge can be observed. This makes some change predictable. I see great change flowing from the spread of knowledge of two scientific facts: one simple and obvious, the other complex and tangled in myth. Both are crucial to understanding the climate change problem and what we can do about it.

First, the simple scientific fact: Carbon stays in the atmosphere for a long time.

To many readers, this is nothing new, yet most who know this make a simple mistake. They think of carbon as if it were sulfur, with pollution levels that rise and fall with the rate of emission: Cap sulfur emissions, and pollution levels stabilize; cut emissions in half, cut the problem in half. But carbon is different. It stays aloft for about a century, practically forever. It accumulates. Cap the rate of emissions, and the levels keep rising; cut emissions in half, and levels will still keep rising. Even deep cuts won't reduce the problem, but only the rate of growth of the problem.

In the bland words of the Intergovernmental Panel on Climate Change, "only in the case of essentially complete elimination of emissions can the atmospheric concentration of CO2 ultimately be stabilised at a constant [far higher!] level." This heroic feat would require new technologies and the replacement of today's installed infrastructure for power generation, transportation, and manufacturing. This seems impossible. In the real world, Asia is industrializing, most new power plants burn coal, and emissions are accelerating, increasing the rate of increase of the problem.

The second fact (complex and tangled in myth) is that this seemingly impossible problem has a correctable cause: The human race is bad at making things, but physics tells us that we can do much better.

This will require new methods for manufacturing, methods that work with the molecular building blocks of the stuff that makes up our world. In outline (says physics-based analysis) nanoscale factory machinery operating on well-understood principles could be used to convert simple chemical compounds into beyond-state-of-the-art products, and do this quickly, cleanly, inexpensively, and with a modest energy cost. If we were better at making things, we could make those machines, and with them we could make the products that would replace the infrastructure that is causing the accelerating and seemingly irreversible problem of climate change.

What sorts of products? Returning to power generation, transportation, and manufacturing, picture roads resurfaced with solar cells (a tough, black film), cars that run on recyclable fuel (sleek, light, and efficient), and car-factories that fit in a garage. We could make these easily, in quantity, if we were good at making things.

Developing the required molecular manufacturing capabilities will require hard but rewarding work on a global scale, converting scientific knowledge into engineering practice to make tools that we can use to make better tools. The aim that physics suggests is a factory technology with machines that assemble large products from parts made of smaller parts (made of smaller parts, and so on) with molecules as the smallest parts, and the smallest machines only a hundred times their size.

The basic science to support this undertaking flourishing, but the engineering has has gotten a slow start, and for a peculiar reason: The idea of using tiny machines to make things has been burdened by an overgrowth of mythology. According to fiction and pop culture, it seems that all tiny machines are robots made of diamond, and they're dangerous magic — smart and able to do almost anything for us, but apt to swarm and multiply and maybe eat everything, probably including your socks.

In the real world, manufacturing does indeed use "robots", but these are immobile machines that work in an assembly line, putting part A in slot B, again and again. They don't eat, they don't get pregnant, and making them smaller wouldn't make them any smarter.

There is a mythology in science, too, but of a more sober sort, not a belief in glittery nanobugs, but a skepticism rooted in mundane misconceptions about whether nanoscale friction and thermal motion will sabotage nanomachines, and whether there are practical steps to take in laboratories today. (No, and yes.) This mythology, by the way, seems regional and generational; I haven't encountered it in Japan, India, Korea, or China, and it is rare among the rising generation of researchers in the U.S.

The U.S. National Academies has issued a report on molecular manufacturing, and it calls for funding experimental research. A roadmap prepared by Battelle with several U.S. National Laboratories has studied paths forward, and suggests research directions. This knowledge will spread, and will change the game.

I should add one more fact about molecular manufacturing and the climate change problem: If we were good at making things, we could make efficient devices able to collect, compress, and store carbon dioxide from the atmosphere, and we could make solar arrays large enough to generate enough power to do this on a scale that matters. A solar array area, that if aggregated, would fit in a corner of Texas, could generate 3 terawatts. In the course of 10 years, 3 terawatts would provide enough energy remove all the excess carbon the human race has added to the atmosphere since the Industrial Revolution began. So far as carbon emissions are concerned, this would fix the problem.