THE AGE OF SUSTAINABILITY

THE SPACE RACE, DISRUPTIVE INNOVATION, AND ECOSYSTEM SERVICES

DENIS POMBRIANT

Chapter 7 Addressing the Challenges

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Straightening out the planet's environment could become the next paradigm or K-wave. Of course, a lot of things would have to go right and we all have an interest in making that happen. That's a good start.

If everything goes wrong and our planet faces a climate catastrophe, the next wave could look a lot more like the Middle Ages. World population would plummet due to starvation brought on by inadequate food and water supplies; diseases now thought to be under control would arise again; and in the competition for shrinking resources there would likely be wars over assets. Petty dictators would control small regions or fiefdoms with no government or administrative entity attending to the needs of society. There are countries that look like this today. You can imagine any number of scenarios in which one of those dictators, armed with nuclear weapons, could extort his neighbors. North Korea comes to mind, so does Pakistan, Syria, and possibly Iran, if it were to resume its nuclear program.

But if we decide to think and act rather than finger point or live in outright denial, there are solutions to even the gravest challenges we face, including population growth, pollution, and resource scarcity. In this chapter, we'll look at some possible solutions and as you'll see, not all proposed solutions live up to the booking but that's okay. Key to this analysis is provisioning enough energy so that we can take on some of the chores that nature can no longer do because our population has grown so big.

Potential solutions must be practical. When you examine some so-called solutions, they aren't solutions at all—at least not on a global scale. But that's good because it shows us where we are in the evolution of our thought process and we need to separate wheat from chaff. The things that don't work demonstrate why they aren't viable, and teach us what's needed in a true solution to a problem. It's all part of K-wave formation.

We learned from the Space Program what a motivated and well-funded people can achieve working on a big endeavor. But it also showed a glaring weakness. As we've seen, space never became a K-wave in the same sense as the Industrial Revolution or the age of steel and heavy engineering did. By putting a lot of money into circulation and stimulating the growth of sectors deeply involved in science, technology, engineering, and mathematics (STEM) the space race produced all the upside and very little down side associated with a 50 to 60-year K-wave. The upside transferred into the high-tech era that includes telecommunications and information technologies.

Space caused a very nice Keynesian economic stimulus but it didn't generate a self-perpetuating economic paradigm or an age, even though we happily gave it that designation. This time we will need a real K-wave, an economic paradigm that generates profits that will make the Age of Sustainability work. The profit motive will be essential to getting people and corporations to want to do what we all need to do to produce a sustainable world.

Space spending spun off private-sector industries that mostly supported space research but they didn't have breakout events the way that later technology industries did, for example, with the introduction of the Macintosh, the PC, the Internet, or the smartphone and many other new product and sector introductions.

But investments made during the Space Age enabled many of these private sector inventions to happen. The Space Age gave important early boosts to the nascent computer, software, and telecommunications industries that ignited the age we live in. The latest evolution can be seen in autonomous cars and a variety of semi-intelligent devices that have caused job creation, made life easier and in some cases eliminated old-sector jobs, a typical outcome of the second half of a K-wave.

Given the long gestation periods of advanced technologies, the most optimistic view of the 20th century's space effort may be that a true Space Age (with all the economic trappings of a K-wave) may still be in the future. Alternatively, space might later be seen as analogous to the machine tool industry, essential to several ages but not sufficient to form a K-wave of its own. The trip to the moon and all the shuttle flights simply may have been explorations that can be re-discovered or repurposed later as were the basic research efforts on steam engines, coal tar, vacuum tubes, or steel-making that went into so many other paradigm-building discoveries in earlier eras. Space research provided a lot of benefits to society, just not the economic benefit that comes from a true K-wave.

In the 20th century, space had one customer: Uncle Sam (well, two if you count the Soviets). Both nations' space efforts ended about the same, with funding cuts, a token orbiting laboratory now subscribed to by both former rivals, and a small private sector customer base. With government-sponsored manned flight space programs all but wound down, private industry companies like SpaceX, Virgin Galactic, and other contractors picked up the slack. So far, these companies, especially SpaceX, have focused on providing launch services for governments and private companies aiming to deposit things in orbit such as communications satellites.

A new space effort may become part of developing a new K-wave that produces an overall solution to our climate and energy challenges. For example, space-based solar collectors could generate a vast amount of electricity that would help reduce humanity's dependency on rapidly depleting fossil fuels. That collection will need some tending.

Fixing the two chief problems humanity faces—capturing and storing carbon, or at least neutralizing its impact on climate, and developing alternative energy sources to replace the decreasing supply of fossil fuels—will take a big effort. More than that, it will have to run in a for-profit mode because large organizations will need to be created to take on these jobs, even if they evolve from existing businesses. These businesses will risk huge sums of capital and to do that, there will have to be an assurance that they will be able to profit from their risk-taking.

Purists may object to injecting the profit motive into saving the planet but the opportunity for profit will drive the free market to deliver effective and economical solutions—in fact, that's already begun too. However, many of the ideas floated so far lack a profit orientation, which shows in bloated designs for carbon capture that consume vast amounts of energy and would have trouble scaling to meet the demand regardless.

But alternative energy generation is becoming a real success story, although there is still work to do. The free market is already responding to the challenge and it will be a matter of how best to guide and assist the effort.

Sustainability revolution

In a November 14, 2016, speech at Stanford Graduate School of Business, former Vice President Albert A. Gore, author of *An Inconvenient Truth*, summed this up as a "sustainability revolution" sweeping the world, with "the speed of the information revolution and the scope of the industrial revolution."[1]

"Market forces are going to be very powerful. Some of the proposals [Trump] made [during the election, like bringing back all the coal jobs," Gore said, just won't make business sense, adding that, "Companies and homeowners are moving toward efficiency." He was signaling the abundance of available renewable solar power coming online—even from solar panels mounted on the roofs of homes.

This should be no surprise, because it's being driven by enlightened self-interest on the part of consumers and sound reasoning by businesses and investors. When renewable energy reaches grid parity, as it is doing right now in many areas, demand rises and capital begins to flow in a self-reinforcing virtuous cycle. But there's more left to do, especially in finding solutions that work and are scalable, and separating them from interesting ideas that aren't.

Frankly, fixing the climate problem is not one big job—it's two big jobs. The first job is removing some of the trillions tons of CO_2 from the atmosphere. The second job is developing new ways to make electricity and to use it in most applications that currently rely on fossil fuels. We'll talk about CO_2 first because it gets headlines and because it's very important, but it might not be the number one priority because you can't solve it with the current highly polluting energy paradigm. We need a solution to power generation first and we'll get to that.

Carbon dioxide is a problem with two dimensions: Taking it out of the atmosphere and then keeping it out. Most carbon solutions currently discussed aim for permanently removing CO_2 and storing it somehow. Storage is a tricky subject since it has to be permanent and foolproof. The last thing we'd want is a storage regimen that works for 1,000 years but then begins to leak. You don't know what the world will look like in 1,000 years and we have to be careful not to saddle that future with a time bomb. Another approach worth considering is approaching CO_2 as a chronic problem that needs attention into the foreseeable future. In that case we need an efficient and cost-effective solution so that we can continuously remove CO_2 and convert it to useful forms that don't pollute. Food is an example of carbon in a stable form that doesn't pollute. We're going to need food, too. Of course, food molecules get broken down to CO_2 and water, thus placing CO_2 back in the air. But there are approaches that keep at least some of it out of the air for long periods. After all, fossil fuels are another example of carbon that's been removed from the air for many millions of years.

The problem with CO_2

Estimates vary but according to the U.S. Energy Information Administration (EIA), there are between 5 and 6 trillion tons of GHGs in the atmosphere, most of them carbon dioxide. It's difficult to get an exact number because until recently it has been increasing and concentration fluctuates with the northern hemisphere's growing season.[2] Lately, with the replacement of some coal-fired power generation and other efficiencies, the rise in the quantity of CO_2 in the air has slowed, however we're still pumping between 35 and 45 gigatons of CO_2 into the air each year.

Because 5 trillion tons is such a big number, precision is less important than magnitude. More often, CO_2 is reported as a concentration in the air we breathe. The current CO_2 concentration is just over 400 parts per million (PPM) compared to about 280 ppm at the dawn of the Industrial Revolution. Simply put, this means that in an air sample containing a million molecules, 400 of them would be CO_2—not much but enough to cause significant climate change.

A trillion can also be written as one thousand billion, and taking one billion tons of CO_2 out of the air annually (as some have suggested) may be a worthwhile demonstration project, but it is really table stakes unless we can ramp up our efforts significantly.

Now to put this in perspective, there's no need to take 5 or 6 trillion or so tons of CO_2 out of the atmosphere. Simple math suggests that on the order of 3.85 trillion tons of CO_2 have been introduced into the environment by the consumption of fossil fuels since the Industrial Revolution. It would be inadvisable to remove all carbon dioxide from the air because green plants need it right where it is if they're going to do the job of making food for the rest of the world. If we could remove just one trillion tons of CO_2 from the air though we'd see an appreciable improvement in climate quality. But even with that reduced ambition, if we could only take a billion tons of CO_2 out of the air per year it would take 1,000 years. We will need a faster solution.

We could look at the natural process of photosynthesis, for instance, to see what's possible. Today green plants, including food crops, grasses, trees, mosses, and tiny sea creatures like algae and phytoplankton, capture solar energy at an annual rate estimated at 130 terawatts, which equals more than 6 times the power consumed by human civilization. Green plants turn this solar energy into biomass equal to between 100 and 115 billion tons—again, not all of it is food.

So here's a suggestion: If we could find ways to double the photosynthetic output on the planet and if we could prevent even some of that biomass from decaying back into its starting products, including CO_2, we'd have a solution that could remove one trillion tons of CO_2 from the air in about a decade. If our effort went slower we could still save the environment, after all, we've been adding carbon to the atmosphere for more than 250 years and the fact that we'd be moving in the right direction counts for a lot. But the scale of any effort needs to be in the many tens of billions of tons per year, not a just one billion.

This is purely hypothetical since we don't have the arable land, fresh water, or as-yet unspecified storage capacity for that much biomass. Still, the idea is thought provoking because it at least lets us conceptualize the need, and with that concept as a goal we can perhaps iterate toward a solution.

Let's take this a step further. We could double or even triple photosynthesis on the planet by making large amounts of fresh water for irrigation from seawater using electricity generated by non-fossil fuels. There's enough dry land that could come under cultivation if we could irrigate it. Think of North Africa, the Middle East, and most of Australia as places to start. Each is close to the sea and each has ample sunlight for making electricity and if we were to get really creative we could place solar panels in orbit to collect and supply those regions with even more electricity.

We could also consider enhancing the amount of photosynthesis taking place in the oceans by promoting the growth of phytoplankton. These microscopic green plants form the bottom of the marine food pyramid and as we'll see in Chapter 8 phytoplankton have played an important part in building the petroleum reserves we have today. Encouraging more photosynthesis in the oceans has several advantages. It uses free sunlight as an energy source (so does agriculture on land), it requires no additional land to achieve its goal, and doesn't require the step of making fresh water for irrigation. Best of all, it provides a food source for marine life, including commercially valuable fish species.

Setting goals for enhancing photosynthesis across the planet would completely change the conversation from reducing emissions, which is hard and expensive, to removing carbon, which doesn't have to be either.

Add another thought provoking idea: carbon dioxide is the main problem, not carbon per se. Carbon that's been reduced (a technical term) by adding hydrogen to it to make simple sugars doesn't contribute to pollution or warming. Green plants make simple sugars from CO_2 and water in the presence of sunlight. Sugars are then combined into polymers like starches for food and also wood and other fibers, which form structural plant materials like husks, stems, leaves, roots and more. Plants and microbes also turn captured carbon into cell walls and fatty structures—the most important of which are membranes. Once carbon dioxide is captured in this way it is out of the atmosphere, no longer contributing to global warming.

As a practical matter, living things from us to the smallest microbes and fungi are continually breaking down plant materials to extract food energy, which sustains life. This produces a back-and-forth movement from organic carbon found in living things to oxidized carbon, or CO_2—that's the Carbon Cycle. Of course, any process that captures CO_2 is useful and if those processes outpace the processes that return carbon to the air, the net effect is an atmospheric reduction of carbon. Photosynthesis is especially important because it happens with no addition of energy other than sunlight, provided you have a place for the green plants to grow.

Other Greenhouse Gasses

As we know, carbon dioxide is only one of the GHGs in the atmosphere but its concentration is the highest. The U.S. EPA estimates that 76 percent of GHG in the air is carbon dioxide but also present in high concentration is methane (at 16 percent) and (nitrous oxide) at 6 percent. Other GHGs make up two percent of the pollutants in the atmosphere.[5]

But we should also consider that all GHGs are not the same in their effect on climate. For instance, releasing 1 kg of methane (CH_4) into the air is equivalent to releasing 25 kg of carbon dioxide while 1 kg of nitrous oxide (N_2O) is about equivalent to releasing 298 kg of CO_2. So, gasses found in lower concentrations still have significant impact.[6]

So as a practical matter, the job of stabilizing and reducing atmospheric carbon requires three actions:

1. Stop adding to the problem. If we stop adding roughly 40 billion tons of CO_2 to the atmosphere each year, the job gets so much easier. This means finding alternatives to fossil fuels as soon as possible and ramping them up to commercial scale. Carbon dioxide remains in the atmosphere from one to three hundred years before being reabsorbed or radiating into space, so what's there now will stay there for the lifetimes of any people on the planet today, as well as for their descendants unless something is done. Therefore, during the interim period between being completely reliant on nonpolluting energy sources and our current energy paradigm (and beyond), we must seek out and use approaches that actively remove carbon from the air and oceans.
2. Reduce the future threat on a time scale that matters. In practical terms, aim at one trillion tons of carbon removed from the air in a 10-year timeframe. The remediation needed has to happen on a human time scale.
3. Scale up a new energy paradigm for the new K-wave that will provide clean and virtually inexhaustible supply of electricity. We can get this energy from the sun and earth in forms that include solar, geothermal, and wind, to name the most obvious sources. We'll also need a distribution system that will vastly expand on the electric grid we now have. At the same time, we need to find new and better ways to reduce energy demand to make it easier to reach the goal of self-sufficiency in non-polluting energy. Finally, and very importantly, we'll also need some of that new energy to drive ecosystem services like delivering clean water.

Oceans

Having these goals is great, but it's not time to pop champagne corks yet. As we've noted, a great deal of carbon is dissolved in the oceans causing them to acidify and killing delicate sea creatures like coral while making it harder for fish to successfully spawn. An equilibrium between the ocean concentration of CO_2 and atmospheric concentrations means oceans absorb CO_2 from the atmosphere and act as a buffer to slow escalation of atmospheric CO_2 concentration. We should therefore expect that taking carbon out of the air would cause the oceans to give up some of their CO_2 back to the atmosphere, with the result that we might not see improvement in atmospheric concentrations right away. Another way to say this is, if you want to check the progress on removing carbon from the atmosphere, first monitor the oceans.

How much carbon should we take out?

But let's go back to a fundamental question: How much carbon should be removed from the atmosphere? Global population in 1750 was only 791 million people and it could reach 8 billion by 2025, a ten-fold increase in less than 300 years. We'd need to figure in enough atmospheric carbon to support our agricultural needs for feeding so many people.

Also, photosynthesis needs a minimum concentration of carbon dioxide in the air to operate. Experts say that the minimal concentration of carbon dioxide in the air to support conventional photosynthesis is around 150 PPM, and given the need to feed such a large population, the minimum amount will be much higher. So, it's hard to come up with a precise number given the Earth's population and the needs of green plants. Most, but not all, of the carbon dioxide in the air right now will need to circulate with green plants in the natural carbon cycle to ensure adequate food supply for a growing population. That's why keeping carbon out of the air is a sufficient goal and sequestering it is not absolutely necessary.

A plan

Perhaps an all-out effort at recapturing CO_2 through artificial means may not be the best approach to the climate challenge. To be sure, there's a lot of carbon in the air and oceans causing harm—even if it's only measured at 400 PPM—and a realistic goal of carbon reduction will require three things.

1. A multigenerational timeline to support an expanded carbon cycle. Think of it like building a medieval cathedral. There was certainly a plan for most cathedrals, but the tools of the day made progress grudgingly slow, so slow that building one was a task handed down from father to son. Stonecutters learned their trade working on cathedrals and taught the next generation. Solving the carbon challenge could be a multigenerational effort.
2. A profit motive. Cathedral construction was paid for by faith and the people who built the structures lived short, malnourished, and disease-prone lives. The workers in the Sustainability Age will need to be paid well and given meaningful work, all things that a profit motivated effort will ensure.
3. The knowledge that failure is not an option. Fixing the climate problem isn't just about finding alternative energy sources and first restricting the amount of

additional carbon that gets into the air and ultimately eliminating it. It's also about understanding the carrying capacity of the planet. Carrying capacity is simply the number of people that can inhabit this world without overusing its natural resources. We've already overshot the planet's carrying capacity in many ways from provisioning energy and water to overloading waste disposal paradigms. Using new forms of energy can help improve earth's carrying capacity but it's a number we need to know and monitor so that we can intelligently plan our future and that of our kids.

Let's begin the search for a solution by looking at the Virgin Earth Challenge, an early effort.