Carbon, Peak Oil, Global Warming and Biomass

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Two looming crises have now emerged in public consciousness, “peak oil” and global warming. These two interrelated and potentially aligned phenomenon are both signs of a larger phase-change in energy transport and atmospheric chemistry. Both represent risks to the continuity of the global system as it is currently constellated, and for that reason both represent the embodiment of evolutionary drivers, which will force the system to make adaptive transformations. Few recognize the full scope of the transformation required, and virtually no one has articulated the upside opportunity of these adaptive changes. In spite of the lack of general awareness, these adaptations are crucial. Given the inertia of the industrial infrastructure it looks like we may not have the time that we need to adapt. In any case we have very little time and the risks are increasingly clear.

For example, virtually all discussion of our response to global warming has cast the situation in terms of gradually reducing the growth in the overall output of greenhouse gasses. Yet, the consensus from the scientific community suggest that the effects we are already seeing have been brought about by releases decades ago and the effects of what we have already done in the intervening decades will be far more serious. This means that what must be at issue in coming decades will not be a just matter of slowing the growth in emissions, but of actively reversing the atmospheric level of CO2. We will need to intervene to remove carbon dioxide from the atmosphere to avoid catastrophe.

Even many of those who remain in denial about global warming have began to recognize the reality of peak oil. Peak oil is a relatively new term, at least to the mainstream, referring to the point in time when total world oil production “peaks” at its maximum production level. The problem is not that production will suddenly cease following that point; it will taper off for many years. But from that point forward the actual cost of producing the remaining oil will rise steadily, as it will require more and more energy and thus become increasingly expensive to actually extract oil from the remaining reserves. At the same time, the market price will rise simply due to global demand now sharply exceeding supply. Energy prices will continue to rise until conservation sufficiently reduces demand and/or other alternatives become cheaper and more abundant than oil.

There is considerable debate as to exactly when peak oil will occur, with estimates ranging from 2000 to 2037, but 2037 is an extreme outlier, and most estimates are in the range of 2010 to 2015. In addition, perverse incentives in the way the counting of oil industry reserves work makes it likely that each player has systematically over-counted their own reserves, thus inflating the overall global estimate.

Each oil company's share value is tied in part to its stated reserves, so management has an incentive to publish the largest and most optimistic possible reserve numbers. In addition, the only way to estimate the global situation is by doing meta-statistical analysis of the overall global rate of discovery of new fields over time. To do this all of the discoveries throughout the world must be added together in a huge statistical model. However, for this model to be valid it is important not to double-count new discoveries within already known reserves. But from each company's point of view each new discovery is a good PR opportunity for share prices, etc. So, there is a natural inclination not to include a new discovery within the context of any previously known reserve.

Add to this the problem that the actual amount of a theoretical reserve that can ultimately be produced will be reduced if the oil is extracted faster than a field can geologically accommodate. In other words, if you pump it out too fast, you will not be able to pump all of it out in the long run. Both the pressure on the gulf states and other producers from the United States government to keep oil cheap and abundant, and the pressure from shareholders to make high immediate profits as prices do increase, serve to induce both oil companies and oil producing countries to extract oil faster than their oil fields can actually support. The result will be that they ultimately will not be able to actually produce all of their stated reserves.

The alternative to oil in the minds of those who cannot see beyond fossil fuel is coal. While natural gas does produce less greenhouse emissions than oil, its supply is also limited, and it will peak soon after oil, if not before. Coal is abundant, but with such serious greenhouse gas emissions that it appears suicidal in the face of global warming.

This raises serious concerns about global warming for many observers as the advocates of coal within the current US administration appear to be in complete denial about the reality of global warming.

From this perspective the situation appears frightening if not verging on hopeless. On the one hand many observers are suggesting that peak oil will precipitate global economic upheaval and wars over control of remaining oil. We are apparently already seeing this in Iraq and may be just beginning to see it in the price at the pump. On the other hand, there are quite plausible scientific scenarios suggesting an immanent collapse of the atmospheric balance due to global warming. We are already seeing the first minor signs of this trend in the spate of hurricanes in Florida, record heat, cold and flooding in the UK and western Europe, melting of the North Poll sea ice, loss of glaciers and a major ice shelf in Antarctica as well as droughts and advancing deserts throughout the world.

Before outlining a little known cause for optimism around CO2, we should touch on one other larger long-term dimension of the situation. The industrial revolution and the so-called green revolution combined have actually caused two fundamental imbalances in the natural flow of chemical elements in the biosphere. It is now increasingly well understood that excess carbon dioxide released into the atmosphere is causing an imbalance. Global warming is a household word today. However, the other serious imbalance is far less widely recognized even though we have known about it for several decades longer. This is the imbalance of too little carbon in our soils due to the excess use of petrochemical fertilizer with the introduction of industrial agriculture in the green revolution. The resulting depletion of the soils could be as threatening to human civilization as peak oil, or perhaps even global warming, but for the most part does not make headlines as it is a slow pernicious condition, which few of the parties involved wish to acknowledge, much less call attention to.

The affect of human agricultural practices on both the atmosphere and the soil are tightly coupled as the first evidence of human effects on the balance of CO2 in the atmosphere appear not at the time of the industrial revolution, but all the way back at the dawn of agriculture 10 or 12 thousand years ago. When we first started reducing tree coverage in favor of open fields and increasing the rate of burning and decay, we began to increase the relative concentration of CO2 in the atmosphere. This clearly accelerated with the invention of fossil fuel combustion technology. Yet the act of tilling the soil is itself an act of combustion as the suddenly exposed soil is oxidized in a manner that it would not have been before, releasing excess CO2 in the process. What a chemist would describe as oxidation is the same as “burning,” i.e. exothermically removing cat ions with an oxidizing agent, in this case oxygen, which combines with carbon and hydrogen atoms to form CO2 and H2O. We can see that both industrial combustion of fossil fuel and agricultural activity, particularly when practiced with industrial equipment, rapidly accelerated the transfer of carbon into the atmosphere. In the case of agricultural practices this trend was also further exacerbated by the introduction of large amounts of urea based nitrogen fertilizer. While plants do need nitrogen, they also need a balance of healthy soil organisms to maintain a healthy aerobic balance and to prevent both erosion and compaction of the soil. When large amounts of nitrogen are added but with very little carbon from organic matter, and in conjunction with pesticides that kill not only harmful pests but also healthy soil organisms, the resulting dead, inert dirt can really no longer properly be described as soil.

Thus, we can see that just as industrial technology in general has created an imbalance in the concentration of carbon dioxide in the atmosphere, industrial agriculture has also contributed to that condition through mechanical tillage, by oxidizing carbon from the soil where it is needed, and creating even more atmospheric CO2 in the process. In addition, the vast amounts of concentrated nitrogen fertilizer applied to agricultural lands do not stay there, especially in the absence of healthy aerated soil with high carbon content, but instead wash off and leach out to become pollutants in waterways and even in the oceans. The nitrogen runoff in the water creates conditions for algae bloom and overpopulation of aquatic plants, while at the same time the excess nitrogen crowds out dissolved oxygen in the water causing fish die off in rivers and lakes and even the ocean.

The point is not to demonize industrial agriculture or industry in general, but rather to show that these modes of activity have natural limits beyond which the imbalances they cause become dangerous to the well being of the system as a whole. The fact that a large number of these trends are becoming super critical at the same moment can be seen as evidence that the system is reaching a point at which it needs to jump to a higher order of coherence. The exact nature of both the imbalance we face and of the characteristics of the new modes we must adopt may be understood by examining the cycles of exchange of the simplest chemical compounds in the atmosphere, soil and water.

Now we are ready to look at a fundamental new class of solutions, which are as yet almost completely unknown even to most experts in the field.

For several years there has been a great deal of interest in carbon sequestration—in how to get rid of the carbon after we get the energy we want out of fuels that contain it. Many even look at biomass this way. The assumption has been that if we want to correct the problems associated with global warming we will need to somehow stash a lot of carbon somewhere to keep it out of the atmosphere. The carbon comes off as CO2 gas from combustion, so the most simpleminded efforts have concentrated on injecting this gas underground—and essentially hoping the Earth doesn't fart…

In addition to being inelegant at best, many of these schemes would actually consume so much energy in the process of trying to sequester the carbon that they would make little sense in terms of the real physical economics of energy, much less in terms of the short term expediency we call economics. A better approach may involve combining the CO2 with calcium to make calcium chloride. This is essentially limestone, or the main constituent of cement, and may be a viable solution, though it is not clear whether the thermodynamics will allow it to be viable at the scale required. However, there is also a new set of technological solutions that offers a fundamentally different approach to the problem. These focus, ironically, on charcoal.

Here's some historical context. When the first Europeans sailed up the Amazon in the early 1500's, their first accounts told of cities of millions of people inhabiting parts of the Amazon basin. But when the next expedition returned two decades later they found nothing. The first visitors had apparently brought small pox and other virulent diseases previously unknown in the New World and within a few years these plagues had decimated a densely connected population devoid of any immunity to European disease. Yet until very recently the scholarly consensus on those first accounts had remained that they could not possibly have been true and must instead have been grandiose fabrications of a Spanish adventurer. This view was based on the assumption that the Amazonian soil was simply too poor to allow the agriculture necessary to support large populations.

However, in recent decades soil scientists and then a few anthropologists began to investigate the *Terra Preta* or "black earth" soils that still persist to this day in large patches throughout the area. These soils are clearly of human origin, containing dense deposits of pottery fragments and one key ingredient—charcoal. Once established, not only are these soils still exceedingly fertile five hundred years later, but they apparently grow back. In places landowners actually harvest them regularly as they regenerate themselves over a few decades if a layer is removed. Nobody really understands that part in detail, though soil scientists around the world from Japan to Brazil are now intensively studying the effect of charcoal on soil fertility. So far these early studies indicate that most soils can absorb at least 10%-15% charcoal with increasing fertility as a direct result as the concentration is raised up to that level. In addition, investigators have learned that the charcoal needs to be made at what by industrial standards is considered low temperature, less than 800 degrees centigrade. This appears to be due to the resulting physical characteristics of the charcoal which when made at low temperature contains tiny pores in its structure. These then act in a manner similar to a coral reef, creating a home for a complex eco-system of symbiotic bacteria and fungi which are beneficial to plant fertility.

The traditional method of making low temperature charcoal is to build a wet heap and use a slowly smoldering fire to heat wood in the absence of oxygen. This works to create the agricultural charcoal, but a few years ago an American researcher was given a USDA grant to work on this charcoal and chose to take a different approach. Danny Day had previous experience with producing charcoal under industrial conditions, so he chose to use a process called pyrolysis whereby a source of biomass, such as wood chips or peanut hulls, is heated in a closed vassal in the absence of oxygen. Otherwise relatively low temperature "waste heat" from another industrial process, such as a power plant, could ultimately be used as the source for this heat. The biomass will then give off a combination of a mixture of hydrogen (H2), carbon dioxide (CO2) and steam, (H2O) while converting most of the carbon into charcoal, which is virtually pure carbon (C).

Once we understand that charcoal can be used as a soil amendment, this process by itself is a valuable departure form other carbon sequestration approaches if used with biomass alone. Because by making charcoal most of the carbon from the biomass is locked up in a solid form, while the hydrogen can be separated from the gas phase and used by itself in a fuel cell, or recombined with some of the CO2 to make biodiesel or ethanol. However, what really makes this process exciting is the sequestration of CO2 from a fossil fuel source that can be achieved by adding an additional step.

Here's a summary of the chemistry involved: By taking about 70% of the hydrogen and all of the charcoal that came from the biomass in pyrolysis, plus some ammonia extracted from the air, and combining them in the presence of CO2 gas, such as found in the flue gasses from a coal fired power plant, all of these ingredients will combine and precipitate as a solid ammonium bicarbonate fertilizer. The ammonia is made by fractional distillation of nitrogen from the air using already well-understood technology, such as the Haber process, common in the fertilizer industry. However, unlike the conventional urea based petrochemical fertilizers commonly used today, ammonium bicarbonate fertilizer returns a large amount of carbon to the soil. In fact, when used with a fossil fuel source, such as coal, the overall process returns more carbon to the soil than was taken out in the biomass used. This is possible because part of the carbon comes from the CO2 flue gasses scrubbed from the coal plant. This extra carbon returned to the soil represents net carbon removed from the atmosphere. In addition, the process also scrubs the NOX and

SOX (nitrogen and sulfur compounds) from the flue gasses, turning these pollutants which are otherwise responsible for acid rain from coal power plants if released into the air, into useful additions to the solid fertilizer. They contribute additional nitrogen, and a small amount of sulfur, to the fertilizer where they are actually beneficial. The only remaining pollutants from the coal plant are the small amounts of mercury and other heavy metals that must first be scrubbed using activated charcoal, which is already a well-understood technology.

To summarize, this new technology offers a smooth pathway to retrofit existing power plants use coal and oil as a transitional fuels for many decades, while actually removing CO2 form the atmosphere in the process. The new biomass infrastructure technology that will be built up at the same time, as part of this transitional process, does not deplete the soil as it can actually return more carbon than it removes from the soil when used in conjunction with fossil fuel. The whole process extracts hydrogen as an energy source thereby also creating a smooth transitional process to establish the long-term hydrogen infrastructure. The same trajectory also smoothly builds out a new biomass-based infrastructure as the source of hydrogen that will be used in the sustainable long-term closed loop energy economy. The fossil fuel plants continue to produce electricity for the existing electrical grid as well as cement and steel where the same retrofit can also be used to reverse the carbon impact of these industries on the atmosphere. Of course, wind, tidal and ultimately solar will all offer other growing energy sources as components of the long-term truly renewable energy mix. Another nice transitional pathway with this biomass-based approach is biodiesel. The European vehicle fleet is almost half diesel powered at this point, and next generation diesel technology offers exceedingly clean emissions. For the coming decades clean diesel powering lightweight hybrid vehicles may offer the best transitional pathway for much of the vehicle fleet, and this may remain true in the agricultural and trucking sector for many decades, if not indefinitely. It is the ability to implement a transitional set of solutions that can at once incorporate exiting capital equipment and infrastructure, while actually removing CO2 from the atmosphere and restoring needed carbon to the soil, that are the key features that separate this approach from all others under consideration.

The preceding explanation is still described within the context of our current worldview. However, we can also see the transition to this new integrated carbon cycle technology in a larger context. It represents the analog of the carbon cycle in nature for human industrial technology. That is, it represents a truly closed-loop relationship between energy transformation and transport, soil chemistry and atmospheric chemistry that resembles the elegance found in the carbon cycle in nature. This is profoundly important as it represents the basic criteria that any truly sustainable human energy technology must attain. At the same time, like the carbon cycle, this characteristic is a good indication that virtually all human chemical energy transport technology will share these basic pathways. This is not to say that the exact design of the infrastructure to facilitate these pathways will not continue to evolve and change to achieve a growing level of sophistication. But like the carbon cycle, involving photosynthesis and respiration, which have remained relatively constant while being embodied in a wide and ever-changing spectrum of organisms, it is reasonable to expect that the basic chemistry of energy exchange will remain similar to this set of chemical pathways. There is simply nowhere else to go with the spectrum of the smallest simplest chemical elements, and no need to. We have, within that realm arrived at the dawn of the truly sustainable climax technology.