White Paper[1]

Verified Carbon Products for the Public:

The Missing Link between the Atmosphere and the Biosphere

"Beyond Clean/Green Tech to Planet-Tech"

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Summary

We argue here that to address climate change, to ensure a sustainable and hospitable planet for future human generations, we must catalyze direct public participation in greenhouse gas (GHG) emission reduction from across the planet with innovative economic frameworks. Consumers require new avenues to participation that make buying into carbon markets attractive, tangible, and financially sound. Likewise, corporations must develop economically viable new carbon products that attract consumers. Public consumer interest and purchase of carbon products based on verifiable emissions reductions and definitive environmental and economic returns are lacking. The purchase of verified carbon products by global public consumers will create a transactional link between the atmosphere and the biosphere and establish a foundation for effectively managing atmospheric gas concentrations. Consumers directly involved in the

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economic dimensions of climate change become accountable for their actions and can collectively influence the supply, demand, and pricing of GHG products. Innovative measurement-to-monetization business models for the management of atmospheric composition engages the public and requires large scale and magnitude to effect change in the global atmosphere; such endeavors reflect *planetary technology* (i.e., "*planet-tech*"), reaching beyond energy related industries in the "*clean- and green-tech*"[1] sectors. In this white paper, we propose that science-based, verified carbon products, and global public participation can be integrated in an overarching, scalable system, to address the management of atmospheric composition. We argue that humanity, now reaching close to 7.2 billion persons, is the ultimate scalar component in effecting changes to the atmosphere and biosphere. The world population is expected to reach approximately ten billion by 2100. In our view, if the global population does not engage now in managing atmospheric composition, the future will offer increasingly diminished opportunities for transformation. We conclude that, even though the management of atmospheric composition is in its infancy and is thus far ineffective, humanity has the means to reach out and effect change now and for future generations.

Introduction

The concentration of GHGs in earth's atmosphere continues to increase, with many projections estimating that if rates of emission do not stabilize by 2050, then the damage to the biosphere may be irreparable.[2] The current projected 2–3ºC increase in temperatures worldwide as the result of the increasing capacity of the atmosphere to trap heat (most commonly referred to as the greenhouse effect[3]) may result in a world with increasingly frequent devastating weather events, widespread ecosystem destruction, and other potential ramifications[4] affecting societies

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large and small. We depend on the biosphere for habitable living spaces, fertile soil in which to grow food, breathable air, clean water, and countless other resources that define our lives. Because of our dependency on these resources, we must not only reduce our emissions but also sequester greenhouse gases until we succeed in restoring a balance to the atmosphere, compatible with acceptable warming scenarios and management by future generations. A lack of public participation in carbon markets and of publicly accessible verified carbon products, however, poses a barrier to widespread civilian engagement[5] and represents the "missing" anthropogenic transactional link between the atmosphere and the biosphere.

The role of corporations in GHG and climate change mitigation is potentially large, but few validated GHG products are offered to the public by corporations; the majority are based on relative estimates that are likely inaccurate and are at risk of invalidation. Planetary Emissions Management, Inc.[6] provides carbon projects with directly measured GHG flux data, in real-time at the project scale, linking this carbon data to tangible carbon products. In this white paper, we recommend that new carbon products be created and made available worldwide, catalyzing public action for meaningful change, and empowering individuals to make choices that contribute to solving the problem of climate change and its effects on local and global scales.

The lack of public participation does not result from a lack of awareness of these problems. Over the past few decades, public awareness of the global climate crisis has grown tremendously, with more citizens than ever discussing or actively contributing to green causes.[7] This rise in awareness has nevertheless failed to produce the needed reduction in GHG concentration in the atmosphere, as evidenced by the unabated rise of atmospheric concentrations of GHGs.[8] The use of "climate change gloom and doom" rhetoric by scientists, governmental, and nongovernmental entities[9] does not offer a plan, strategy, or call to action, but

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rather produces ennui around the climate change problem,[10] a perception that can affect people's outlooks as they consider the state of the biosphere. Public policy across institutions has failed to effectively address the long-term impacts of climate change—in part because financial perspectives of long-term climate change policies continue to fall outside of the short-term financial goals of both the public and private sectors.[11] There are many examples of technology and policy efforts to mitigate climate change that, while well intended, have produced mixed results, demonstrating the difficulty of the problem. Several examples are discussed hereafter.

One example of an institutional failure to sustain an "avoided carbon emissions product" is Germany's *energiewende,* or energy revolution, heralded as a turning point for the expansion of wind and solar facilities at the expense of nuclear power and fossil fuels.[12] Despite the shift to renewable energies, Germany's emissions have risen by approximately 1.8 percent in 2013, making it the European Union's biggest CO_2 emitter. Meanwhile, coal-fired power plants are expanding, along with government subsidies required to maintain renewables at current levels, the costs of which are passed on to consumers.[13] Germany's energy policies could not accommodate the actual long-term costs of renewable energy because they are scaled to accommodate German residential and business sectors and are also subject to the larger global impacts of energy pricing variations that cannot be ignored.

The advance and retreat of large-scale biofuel production (i.e., a "carbon-neutral" carbon product) provides another example of the complexity of the energy-emissions–economics chimera. Less than seven years ago, KiOR[14] announced to the world that new technology to transform cellulose to biofuel would constitute a revolution that could compete with the oil and gas industry; unfortunately, it failed on both accounts.[15] KiOR filed for bankruptcy and was delisted from the NASDAQ, capping off failure by similar biofuel startups, despite hundreds of

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millions of dollars in financing. In this case, conversion of organic material was not economically viable at a commercial scale and thus could not reach consumers in the transportation sector. Biofuels are an elegant application of microbial decomposition, a globally distributed free ecosystem service; but as yet, this technology lacks efficient and economic scale to replace petroleum for the transportation sector.

The direct capture of CO_2 from the air is theoretically an appealing approach to reducing CO_2 concentrations in the atmosphere.[16] In this case, the largest challenge is in capturing, concentrating, and utilizing CO_2 from the atmosphere to create material products that will subsequently sequester the CO_2. The direct capture of CO_2 is the inverse problem of the production of biofuels by decomposition. Photosynthesis captures CO_2 directly from individual plants at global scales, converting carbon dioxide and water into energy-rich carbon compounds that eventually decay. Plants are highly efficient in capturing CO_2 as it comprises only about 0.04 percent (circa 400 parts per million) of the atmosphere. Direct capture thus requires highly efficient and cost-effective capture and concentration, typically employing chemical capture, however, this approach would have to be scaled across the landscapes of the planet to effectively reduce atmospheric CO_2. Currently, no known, full-scale, direct CO_2 capture facility exists anywhere on the planet. The costs of capture, concentration, and subsequent usage or storage appears to be prohibitive,[17] thus, initiatives of this type lack the scale needed to intervene in the rising concentrations of CO_2.

The examples above illustrate that scale is critical in considering management of the global atmosphere; without scale, many technologies would never make a difference in the concentration of atmospheric GHGs. The examples above are not failures, but simply part of the

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learning process—all of the approaches with further development of scale (amount sequestered and cost) may in the future become viable. In the meantime, we must explore other approaches.

While Thousands Marched in New York City, Atmospheric Composition Increased Unabated

How can we incentivize people and institutions to verifiably either limit GHG production or sequester already emitted gases from the atmosphere at local and global scales? How can popular support, such as that evidenced by activists in New York City,[18] be linked to verified carbon reduction markets? Popular support is important but of limited value if support does not translate into meaningful change of the GHG composition of the atmosphere. Regulatory approaches have been attempted,[19] but have not shown promising success as evidenced by the unabated increase in atmospheric GHGs over the last several decades, and the consistent failure of policy-makers to agree on specific actions that include pricing of carbon and performance accountability.[20] Most attempts to curb GHG emissions are based on legislation and/or nonbinding emissions reductions of carbon dioxide as an anthropogenic by-product, an idea embodied by a variety of "cap-and-trade" platforms.[21] Under cap-and-trade rules, companies receive allowances for emissions and enter a trading market to buy or to sell to one another as needed. However, practice has demonstrated significant issues with this governmentally restricted system, including carbon price volatility and cap leveling relative to economic conditions.[22] Current carbon markets continue to expand as trading-platforms but lack measurement of real-time carbon flow. Their reliance on inaccurate measurement and reporting tools cannot guarantee alignment with their goal of reducing GHG emissions. Transparency and

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equivalency across platforms is lacking reflecting the disarray of carbon markets that have fallen dramatically over the last year.

Large, established markets, such as the European Emissions Trading System (EU ETS),[23] have shown troubling signs of financial instability,[24] and some estimates evoke the trajectory of the Chicago Climate Exchange (CCX), defunct since 2010.[25] The current carbon market consists of governmental partners and primarily covers reduction of emissions instead of quantifying the removal of GHG from the atmosphere. As a result, regular citizens who express concern about carbon dioxide emissions cannot contribute to solving the global issue. Unless businesses offer carbon products that appeal to consumers and realize profits in climate management, carbon markets will continue to be dominated by compliance buyers, essentially barring the public from widespread voluntary participation in managing the earth's future. Without access to GHG markets, the public cannot participate in shaping the sustainability of the planet for future generations.

Convergence of Atmospheric Composition, Business, and Public Participation

At the intersection of the atmospheric GHG composition and business lie these key questions: (1) How can GHG emissions become concrete, marketable products? (2) What if everyone could invest and earn profit from saving the environment and could verify reduction of emissions on a local scale? (3) Moreover, how can we incentivize businesses to create and individuals to buy carbon emissions linked products? Whether the product is verifiable quantities of carbon sequestered from specific projects or the avoidance of emissions of specified quantities of GHG, how could a corporate strategy of making emissions a more tangible product be effective in today's market? Can such a market catalyze atmospheric carbon reductions,

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commanded by public supply and demand? Widespread buying and selling of carbon products by the public and financial markets is a viable solution to the current GHG problem that has no precedent. It is yet undeveloped but has the potential for success at a global level through individual action. We emphasize that without tangible carbon products, the public *cannot* participate.

Science alone is not enough—we must engage the economics of business to ensure success in managing the GHG composition of the atmosphere. In some ways, our envisioned "public trading" is evocative of cap-and-trade models for carbon trading, which are predominantly perceived as regulatory methods as opposed to a feature of a free market. The foundational difference, we emphasize, lies in public participation and incentives as opposed to governmental spending and regulation. If the more than 400,000 individuals who recently marched through the streets of Manhattan to show their support for action on climate change issues became active participants in a market of offered, verifiable carbon products, management of atmospheric composition could be revolutionized. We suggest that if corporations contributing the most GHGs to the atmosphere demanded high-quality measurement data reflecting verified offsets to create carbon products in ways that benefited the atmosphere and their bottom line, the reduction of GHG concentration could be catalyzed.

To bring such a market to fruition, and recognizing that the current market we envision is lacking, we must first understand the way that individuals and companies view emissions from both human and financial perspectives, and determine the characteristics of carbon products that will be attractive to consumers so as to generate demand. With proper market incentives, GHG emissions could be effectively managed; much of the required technology, scientific knowledge, and desired consumer base are already in place. PEM posits that the buying public will embrace

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verified carbon products if it is confident of the investment's impact on climate change and on an economic return—when it is able to see and measure accurately the quantity of GHGs leaving the atmosphere. The familiar purchase of "offsets" for air travel, for example, and similar carbon credit footprint products, are widely regarded as ineffective,[26] and a clear case of failed carbon products that could be readily improved. We believe that the demand for new, innovative and verified carbon products will be high, and that corporations will embrace direct measurement of emissions if they have economic incentives.

Large-Scale Market-Based Solution for Managing Atmospheric Composition

PEM is developing commercial scale technology that can reliably, and accurately measure the flux of Carbon-14 (^{14}C), as carbon dioxide (e.g., $^{14}CO_2$) in real time. The isolation of ^{14}C, a naturally occurring radioisotope of carbon, is crucial for the differentiation of anthropogenically deposited carbon molecules from the entirety of the carbon flow of the atmosphere. *$^{14}CO_2$ is the only direct tracer for fossil-fuel CO_2 produced by humanity*, yet its measurement is insignificant relative to bulk carbon (e.g., $^{12}CO_2$) that flows naturally through the biosphere. High-precision measurements of ^{14}C across time and space will allow us to accurately determine how much anthropogenic carbon must be returned to the biosphere to restore carbon neutrality. PEM's technology consists of state-of-the-art, laser-based analyzers that separately quantify the amounts of human-produced and naturally occurring carbon dioxide (CO_2) in the air, providing for a radically new "two-carbon" based accounting and trading system.[27] PEM's two-carbon accounting can be linked to carbon rights differing from the carbon credit system of most governmental regulations. In theory, these carbon rights can be directly available to the public and to stock exchanges, providing the foundation for a data-based open market of verified carbon

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credits. The anthropogenic carbon cycle cannot be "observed" measured and managed without high quality and high frequency data for $^{14}CO_2$.

The basic unit of trade, the carbon dioxide equivalent of a metric ton (tCO_2e)[28] is the same as that used in existing carbon markets. PEM's approach is to create markets with this system by using big-data analytics to quantify GHG emissions in specific projects and areas, providing client companies with climate mitigation strategies, and creating a link between the buying public and a portfolio of carbon products. These carbon products are linked directly to carbon sequestration or other consumer-desired data in an accountable and tangible way. With this technology and innovative methods of monetizing carbon for consumer exchange, PEM creates an “overarching system of systems” that simultaneously ties carbon sequestration performance to business growth. The “system of systems” is simply an integration of specific activities and processes that, once connected, provide a viable, GHG consumer-based transactional system. The “system of systems” illustrated below shows the essential elements, one to six, consisting of: (1) a defined GHG reduction project (e.g., CO_2); (2) a direct measurement of GHG flux; (3) verification of data and data products; (4) creation of GHG products (e.g., sequestration of CO_2 by forests); (5) the public sale of these products worldwide; and (6) performance verification of sequestration over the lifetime of the project. Public access to the purchase of verified carbon products links the atmosphere to the biosphere at large scales and establishes a method for effectively managing atmospheric GHG concentrations.

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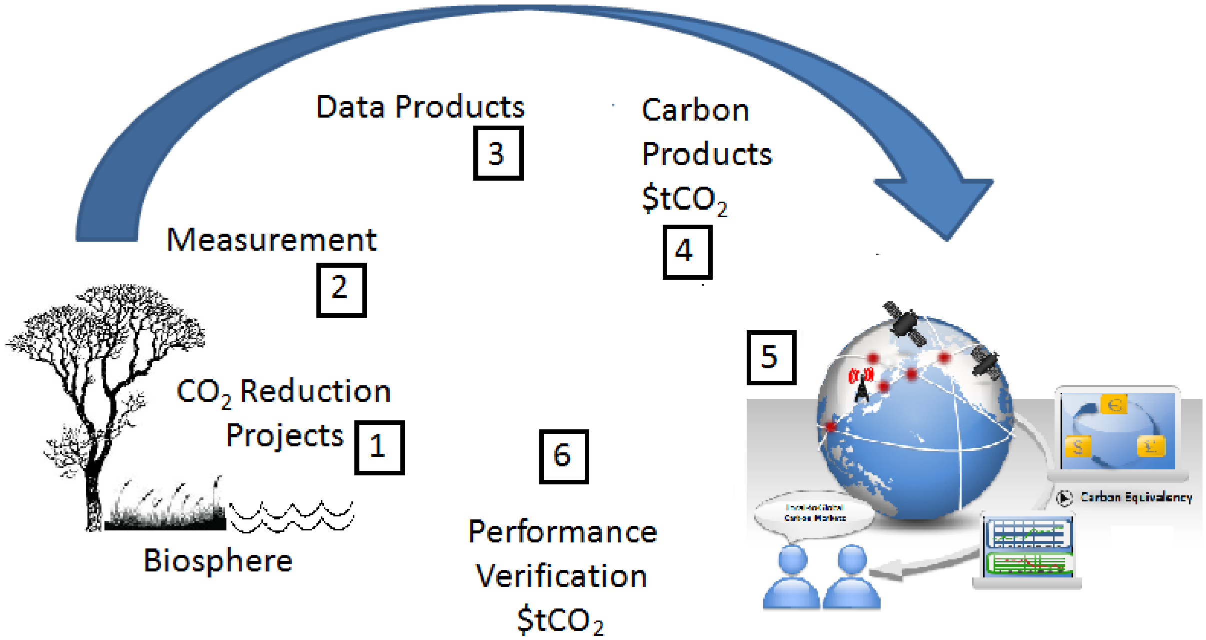
PEM System of Systems



<u>Case Studies: PEM's Carbon Management in Action</u>

<u>African Grasslands</u>: PEM is working with the nonprofit Rangeland Solutions[29] to maximize the number of cattle grazing in a specific field location while sustaining the field's capacity to support an equal or greater amount of cattle grazing there the subsequent year. This provides a model for sustainable income generation for Kenyan pastoralists by increasing the productivity of both the land and the livestock while simultaneously supporting sustainable land management. Using carbon measurement tools, PEM will link real-time carbon measurement of grassland carbon exchange (e.g., measurements of $^{12}CO_2$, $^{13}CO_2$ and $^{14}CO_2$) on a seasonal basis, enhancing pastoralists' ability to analyze when and where their cattle should graze. This approach maximizes efficient carbon usage and avoids overuse in specific areas, in turn improving future grass availability and allowing an increase in herd sizes. By using real-time carbon measurements, PEM will aid Rangeland Solutions pastoralists to sustain and grow

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businesses while protecting arable land quality in a way that was previously either inefficient or impossible. The "system of systems," in this case, originates from the measurement of grassland carbon dynamics and ends with the sale of meat to consumers in nearby cities. A feedback loop reinforces the system because, as more land is conserved, there is greater potential for pastoralism. Also, the more effective use of resources benefits the ecosystem and the livelihoods of pastoralists. The carbon products offered by Rangeland Solutions and PEM might consist of carbon sequestered by grassland pastoralists (e.g., Kenyan Pastoralist Carbon: tCO_2e) for compliance buyers (in the region or elsewhere), and improved management of pastoralist sequestered carbon (e.g., Kenyan IM Carbon: tCO_2e) for areas that require grassland restoration for pastoralist use.

Forests: The PEM Forest Legacy Carbon Initiative[30] provides a new and innovative approach to land conservation, or *reverse deforestation*, by using PEM's unique measuring technology and monetization approach. The measuring devices offered by PEM allow landowners to accurately verify that their carbon capture and sequestration efforts are resulting in real changes to the carbon content of the targeted project lands. In areas of existing forestland, where the conservation of these lands is the primary goal, PEM's technology is especially useful in measuring the outcomes of efforts to enhance carbon sequestration, such as through improved forest management. Using PEM's new tool, landowners are able to accurately value their investments within the land, allowing for land conservation to become a tangible and monetary accomplishment rather than an abstract nonrevenue success. PEM's new tool can be applied in any forest setting, including current mature forests or newly grown forests in urban environments. PEM's approach to forests can be applied to small parcels of approximately one thousand acres to up to several million acres of land. The forest carbon products in this case

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could consist of improved management (e.g., Forest IM Carbon: tCO_2e) and urban forest expansion (e.g., Urban F Carbon: tCO_2e). Carbon-linked products are also foreseeable; sample measures of biodiversity based on inventory linked to expanding forests could be offered as a carbon-linked biodiversity product.

These case projects illustrate the potential impact of PEM's carbon measurement tool on carbon optimization in both economic and environmental terms. In a fully realized "system of systems" PEM would pay a client (e.g., landowner, project owner) for the rights to the carbon at each of these sites. With those carbon resources, PEM would create innovative carbon products to reflect the real impact on carbon flux and climate change, and this would be sold to any party interested in offsetting its emissions or contributing to climate change mitigation.

<u>From Clean/Green Tech to Planet-Tech: Skills Required to Manage Our Planet</u>

The underlying science and technology to monitor, verify, and create carbon products effective in managing the composition of the atmosphere are within reach for entrepreneurs and established businesses. Planetary craft, or skill, is required to guide efforts to ensure that GHGs are actually returned to the biosphere for lasting benefits to the environment and to humanity. PEM's "system of systems" provides an architecture of components that ensures the connection of measurement to monetization and a return of GHGs to the biosphere. The approach described here is particularly suitable for mitigating deforestation and the loss of natural habitat at local and global scales, a trend that is not easily "fixed," as our knowledge of ecosystems is insufficient to allow for their re-creation in a short time span. The direct measurement approach that is the foundation of the "system of systems" will also provide new information on the

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response of the biosphere to changing climatic conditions and humanity's response to those changes.

The processes described here are often categorized under the umbrella term "clean-tech and green-tech"; however, the goal of change at the scale of the atmosphere is *planetary* and more appropriately described as "planet-tech." We suggest that this term be added as an investment asset class within technologically based business sectors. Moreover, the initial vision and promise of clean/green tech has not flourished. One distinction is that scales of economy and global atmospheric composition are linked by performance accessible to the global public. Planet-Tech, for example, could span many industry verticals organized by GHGs, including the six greenhouse gases covered by the Kyoto Protocol—carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). When verticals are organized by gas type, industries can be compared relative to features of the industry, including potential scale, public accessibility, and impact on atmospheric composition. Clearly, a new vision is needed to guide planetary scale mitigation of atmospheric GHG composition.

Conclusion

The challenge of managing the GHG composition of the atmosphere is like no other experienced by humanity. To date, the public has been excluded from directly participating in GHG markets that offer innovative products of economic and verified value to consumers and producers. In simplest terms, management of a system requires measurement of key variables. Direct measurement of GHGs, including direct tracking of anthropogenic CO_2, enabled by the analysis of $^{14}CO_2$, is within our reach. The science of measurement of GHGs is sufficiently

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developed to deploy at small and large scales, revealing the quantity of each gas. A measurement-to-monetization approach, with the public as consumers, has the potential to effect tangible change to natural and human systems. Given the lack of visible atmospheric progress to date, this approach is worthy of consideration. Future generations deserve and demand effective management of atmospheric composition to ensure a sustainable planet for all. PEM's "system of systems" addresses solutions needed to manage emissions reductions on short- and long-term scales (e.g., one to one hundred years), across continents, and with the active participation of individuals worldwide. The ultimate result will benefit future generations.

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