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*by Max G. Bronstein**

Introduction

Humans have been disrupting the Earth's climate for hundreds of thousands of years.[1] Burning a piece of wood for warmth, cutting down a tree to build shelter, or even planting a crop are all ways that humans have interacted with and fundamentally altered the climate and the environment. New research has indicated that breakthroughs in agriculture as long as 8,000 years ago have played a major role in greenhouse gas emissions and may have even reversed a trend toward global cooling.[2] The widespread cultivation of rice in Asia, which first began 5,000 years ago, was followed by unnatural increases in methane concentration that some scientists believe may have averted another ice age.[3] Today, rice paddies cover 130 million hectares of the Earth's surface, emitting between 50 and 100 million metric tons of methane per year.[4] In addition, ruminants produce a significant amount of methane and, when combined with the emissions from rice, account for nearly half of the world's methane output.[5] Hence, human behavior that originated thousands of years ago continues to alter the climate today albeit on a much larger scale.

Deforestation was first recorded in 1086 AD when a survey of England indicated that humans had cleared upwards of 90 percent of the forests to make way for agriculture.[6] Between 2,000 and 3,000 years ago, humans also deforested wide swaths of fertile land near rivers in China and India to support quickly growing and increasingly dense settlements.[7] The scale of this deforestation deprived the planet of major carbon sinks.[8] Forestlands were often burned and then subsequently flooded to provide irrigation; both activities produce significant greenhouse gas emissions.[9] Today, forests are being destroyed at an unprecedented rate—every year, human activities destroy an area the size of Panama.[10] At this rate, the world's rain forests, the most bio-diverse portions of the planet, could disappear entirely in less than 100 years.[11] A recent study found that decreasing the rate of deforestation by 50 percent and maintaining that level for 100 years would reduce global fossil fuel emissions by the equivalent of six years.[12] These occurrences demonstrate that humans have historically caused significant climate disruptions and even modest changes in behavior—such as decreasing the rate of deforestation—can have a marked impact on carbon emissions.

Most people believe erroneously that humans did not begin to significantly alter the climate until the second half of the 19th century, which marked the start of the second Industrial Revolution.[13] Rather, the Industrial Revolution acted as a carbon multiplier by automating and scaling up the carbon-intensive activities that humans had already undertaken for thousands of years. The new technologies and innovations of this age required carbon-based fuels to power factories, automobiles, and the industrial machines that automated agriculture and deforestation. In fact, from 1850 to 1863, total world carbon emissions nearly doubled from 54 million metric tons ("MMT") per year, to 104 MMT. By 1900, world emissions had reached 534 MMT.[14] By 2006, the world was emitting 8230 MMT, an increase of 259 MMT from the previous year.[15]

For thousands of years, humans have been altering the climate and fundamentally remaking the environment at a local and planetary scale.[16] The behaviors driving such changes, like agriculture, deforestation, and transportation, are deeply ingrained hallmarks of civilization and are a core component of traditional development and economic progress. It should come as no surprise that policymakers have been struggling for over a decade to create a viable framework for limiting emissions and mitigating climate change.[17] Meanwhile, as our understanding of the impacts of climate change has sharpened, it is increasingly evident that failure to limit emissions will result in massive and irreparable damage to the environment and human welfare.[18] This realization has been one of the factors driving research and debate around geoengineering[19]—a "Plan B"—should policymakers fail to create a viable framework for mitigating climate change.[20]

However, the geoengineering solutions put forth by scientists are often untested, expensive, difficult to deploy, and ignorant of the non-technological barriers to implementation, such as policy and politics. Many of the so-called geoengineering "solutions" are overly reliant on advanced technologies that do not exist today and may require decades to deploy, which could only have a significant impact on the climate at an enormous financial cost. Effectively implementing such technologies on a meaningful scale would require an international framework and cost-sharing scheme that could be as complex and politically sensitive as the current climate treaty negotiations. If the nations of the world struggle even to reach an agreement to limit climate

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emissions in a timely manner, a future international resolution on geoengineering will face similar obstacles.

Rather than relying on untested and poorly understood geoengineering interventions, scientists and policymakers need to look toward tested and readily deployable mechanisms for regulating climate and mitigating the impacts of carbon emissions.

Many proposed geoengineering solutions aim to deflect the sun's energy, including proposals ranging from space-based mirrors to cloud whitening and cloud seeding using aerosol particles.[21] The goal of these approaches is to control the amount of solar energy striking the Earth by deflecting more of this energy into space.[22] If ultimately successful, the climate will cool because energy is being reflected rather than absorbed by the Earth and the atmosphere.[23] While these are intriguing approaches, some are exorbitantly expensive (e.g. space mirrors) and, although others are more affordable, they are relatively untested and could result in other irreversible, unintended consequences.[24] However, there are more affordable and practicable methods for increasing the Earth's global albedo or reflectivity. What follows is a low-cost, low-tech, low-risk, geoengineering plan that can be implemented on a local, regional, or national level without the need for a complex international treaty, which makes it more politically feasible than other proposed solutions.

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Cool Materials Cool the World

The U.S. Secretary of Energy, Nobel Laureate Dr. Steven Chu, has frequently avowed the virtues of white roofs.[25] The theory underlying this solution is quite simple; lighter colors reflect more sunlight and therefore increase the planet's reflectivity, which, on a large scale, can result in global cooling.[26] This intervention would be most effective in urban areas, which only account for about one percent of the Earth's land surface, but if implemented on a large scale, could equate to a 63 kg CO_2 offset for every square meter of white roof.[27] Estimates have also shown that a "cool roofs" initiative could offset about 24 billion gigatons of CO_2—the equivalent of total annual global CO_2 emissions—over the course of the roofs' lives.[28]

In addition to increasing global albedo, white roofs keep buildings cooler. Cooler buildings reduce energy costs and in turn lower CO_2 emissions. Lower energy costs and a smaller carbon footprint help to minimize the "heat island" effect. The heat island effect is an increase in temperature in urban areas caused by warming of absorptive surfaces and infrastructure.[29] Temperature differences are most marked when compared to non-urban areas, which are 1-3 degrees Celsius cooler and on a clear, windless night the temperature difference can be as much as 12 degrees Celsius.[30] These higher urban temperatures result in an increased demand for electricity for energy intensive air conditioning.[31] In fact, one study estimates that the heat island effect alone accounts for 5-10 percent of the peak electricity demand for cooling buildings in cities.[32] Hence, mitigating the heat island effect through simple interventions like white roofs can be an effective way of reducing energy demand, cutting CO_2 emissions, and increasing global albedo.

In addition to roofs, roads are another component of urban infrastructure that can play a significant role in global reflectivity and mitigation of the heat island effect. Cool pavements, as they are commonly called, work on the same principle as white roofs. Urban pavement accounts for 35 percent of urban surface area whereas roofs only account for 25 percent.[33] Some calculations have indicated that a cool pavements initiative could offset as much as 38 kg CO_2 per square meter.[34] If extrapolated to account for all urban areas, cool pavements could offset up to 20 billion gigatons of CO_2.[35] Aside from the reflectivity and energy savings benefits, cool pavements can also enhance nighttime visibility and reduce the amount of street lighting needed during the evening hours, thereby further reducing energy demand.[36]

What is most appealing about these "cool" solutions is that there are low barriers to implementation, as they are largely cost competitive with existing approaches and the underlying technology is relatively mature.[37] Hence, these approaches have already been deployed in various urban areas across the United States[38] and have been shown to actually increase albedo regardless of color.[39] Cool roofs do not necessarily have to be white, but must contain composite materials that increase solar reflectance and thermal emittance.[40] In addition, experiments have even begun to test newly developed paints for cooler cars, which also cover much of the land surface in urban areas.[41] When combined, these "cool" approaches present a relatively low-risk, low-cost, and politically viable approach to geoengineering. Even simple policy interventions at the local or state level could have a marked impact on reducing the heat island effect, lowering energy demand, and ultimately decreasing CO_2 emissions. While this is an important approach to mitigating climate change, increasing the global albedo is only part of the solution. The planet also needs a strategy to sequester the vast concentrations of CO_2 already in the atmosphere.

Aggressive Reforestation

Forests serve as an enormous carbon sink and store more than double the amount of carbon than is present in the atmosphere.[42] In addition, forests store 45 percent of all terrestrial carbon.[43] However, deforestation is releasing that stored carbon on an unprecedented scale; every year a forest area the size of Panama is lost.[44] Deforestation can occur naturally through wildfires—which have been increasing in number with global warming—but deforestation is more commonly driven by the need for agricultural and grazing space.[45] In 2004, deforestation and decay of biomass accounted for 17.3 percent of total greenhouse gas emissions.[46] Hence, forests can act as both a sink and a source of carbon. The fate of the carbon in forests, however, largely depends on how humans interact with them.

There are several ways in which forests can increase uptake of CO_2: through reforestation that increases the carbon density of existing forests; through use of fuels from biomass; and by limiting deforestation and degradation. Calculations done by Canadell et al. have shown that, if all deforested land was converted back to forests, the sequestration potential would be 1.5 Pg C (petagrams of carbon) per year, which would reduce atmospheric CO_2 by 40-70 parts per million ("ppm") by 2100 (CO_2 concentration in 2008 was estimated to be 385 ppm).[47] Even reducing deforestation by 50 percent (a laudable goal), would offset 50 Pg C.[48] While reducing deforestation is socially and politically difficult, individual nations can take the initiative to reforest or increase the carbon intensity of existing forests. For example, in 2000, China used 24 mega hectares ("Mha") of new and old forest re-growth to offset 21 percent of emissions in 2000.[49]

Estimates have also shown that a "cool roofs" initiative could offset about 24 billion gigatons of CO_2—the equivalent of total annual global CO_2 emissions—over the course of the roofs' lives.

However, it is important to point out that creating new forests is only the first step in this process. In order for such offsets to be permanent, the forests must have proper protection and stewardship to prevent future deforestation or degradation that can lead to carbon emissions. Hence, in order for reforestation to create a viable carbon sink, it requires not only a short-term planting period, but also a continued investment in forest stewardship. Stewardship is especially challenging in light of the negative impacts associated with climate change. The frequency and intensity of forest fires is expected to continue to rise as is the number of insect outbreaks that can destroy healthy forests.[50]

Reforestation not only alters carbon concentrations, but can also have a significant impact on global albedo.[51] On one hand, dense forest canopies can actually decrease albedo, thereby absorbing more solar radiation, which can cause an increase in temperature.[52] On the other hand, forests also play an important role in the water cycle through evapotranspiration, the migration of water from roots, through leaves, and into the atmosphere.[53] This moisture can ultimately seed clouds that can increase global albedo and therefore lower the amount of solar radiation warming the planet.[54] The extent of the impact of these competing forces is unclear and varies by region. For example, as forest canopies substitute for snow-covered ground in boreal regions, this would result in a net decrease in albedo.[55] However, in tropical regions, more forests would result in increasing cloud formation, which would have a positive impact on albedo.[56] This evidence suggests that tropical regions would be most suited for reforestation and stewardship programs.[57]

Policy Implications & Implementation Mechanisms

Compared to other proposed methods of climate engineering such as space mirrors, artificial trees, or ocean fertilization, reforestation and albedo management are two simple, relatively inexpensive, and effective methods for mitigating climate change. Reforestation not only increases albedo in certain regions, but more widespread and healthy forests act as a natural carbon sink, provide innumerable ecosystem services, and create new habitation space in areas that have traditionally been threatened by human development. Using novel roofs and roads provides a cost-effective mechanism for deflecting the sun's energy and decreasing the heat island effect, which can ultimately lower energy usage and the requisite carbon emissions. But, for these solutions to be viable, they must be implemented on regional and national scales and must involve a variety of stakeholders. The following recommendations outline a U.S. reforestation and albedo management program.

The President should establish an office of Climate Change Mitigation within the Environmental Protection Agency ("EPA") by executive order. Establishing this office via executive order would bypass Congress, because this program needs to be implemented as soon as possible in order to maximize impact and effectiveness. The office would be responsible for drafting, implementing, and enforcing best practices for developers and civil engineers to mitigate climate change through the use of reflective materials. Specifically, the office would establish requirements and regulations for using reflective materials in the construction of civil infrastructure. Roads are constantly being repaved or maintained and, as a result, it would be relatively straightforward and expedient to phase in the use of reflective and cooling materials. Developers in the private sector need incentives to implement these best practices in both new buildings and existing structures.

While this initiative could be effectively seeded at the federal level, proper implementation and execution would require trained agents working at the state and local levels. This would require buy-in from these stakeholders and could be achieved through additional training. A brief educational program should be developed that illustrates the benefits of cool materials for energy consumption and mitigation of climate change. This material could then be disseminated to state and local departments of transportation and to public planners.

In addition to establishing a new office at the EPA, the federal government should fund more research into development of cost-competitive advanced materials that can have an even greater impact on reflectivity and global albedo. Recently, the Technology Innovation Program at the National Institute of Standards in Technology ("NIST") released a call for proposals.[58] One of the topic areas was in civil infrastructure, but it made no mention of reflective or cool materials that could replace current infrastructure and mitigate the impacts of climate change.[59] The fiscal year 2010 solicitation should call for research and development proposals on cool materials and should give funding priority to proposals that demonstrate potential for commercialization. Emphasizing development could enable late-stage projects to become viable in the market and ultimately be sold to meet the increased demand that could be expected to follow the release of new EPA regulations and best practices.

Throughout U.S. history, wide swaths of the country's forest have been cleared to make way for development or harvested as a natural resource. As a consequence, there are vast areas of vacant and uninhabited rural land that could be reforested with relatively little investment. Over time and with periodic maintenance, these areas could give way to new, healthy forests. The U.S. Forest Service has the expertise to take the lead on such an initiative, but lacks sufficient resources to have an impact on a scale that would significantly offset emissions. As the climate bill is currently being discussed in the Senate,[60] this is an opportune time to lobby for a reforestation provision that could spearhead a nationwide initiative. The costs of the program could be funded through revenues generated by the cap-and-trade scheme and a nationwide program would assist the United States in reaching its emissions targets.

Recently, Agriculture Secretary Tom Vilsack announced the recipients of a grant program that aims to revitalize urban areas through community forestry grants.[61] While this is a relatively modest program in terms of its funding ($900,000) and scope, [62] programs like this should be expanded to urban areas around the country. As a consequence of the current economic downturn, there are many former business and industrial centers in urban areas ("brownfields")[63] that could be re-purposed as green spaces or as constructed wetlands. The benefits of urban green spaces are widely known and constructed wetlands have been shown to provide valuable ecosystem services at a lower cost than traditional methods.[64] Ultimately, these improvements could act as an urban carbon sink, provide local and global ecosystem services, and enhance the aesthetic appeal of previously abandoned areas.

Conclusion

While these initiatives may appear overly ambitious or unlikely, they present a more pragmatic approach to addressing one of the most profound and complex challenges of our time. Other proposals for geoengineering are more expensive, less reliable, non-deployable, and likely to stir political controversy. In contrast, reforestation and albedo management are relatively apolitical policies that are readily deployable. Furthermore, with the climate bill currently pending in the U.S. Senate,[65] the nation has a unique opportunity to enact new domestic initiatives that could have both national and global benefits. While it is undoubtedly important to conduct further research and continue to debate the effectiveness and risks associated with geoengineering, we do posses effective methods for sequestering carbon and managing planetary albedo. But every day of inaction and lack of leadership brings the world closer to the harsh consequences and realities of a planet in great peril.

Endnotes: Readily Deployable Approaches to Geoengineering: Cool Materials and Aggressive Reforestation

1 *See* William F. Ruddiman, *How Did Humans First Alter Global Climate?*, Sci. Am., Mar. 2005.
2 *Id.*
3 *Id.*
4 K.L. Denman, et al., *Couplings Between Changes in the Climate System and Biogeochemistry*, *in* Climate Change 2007: The Physical Science Basis 542 (S. Solomon, et al. (eds.), Cambridge Univ. Press 2007), *available at* http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_Ch07.pdf.
5 *Id.*
6 Ruddiman, *supra* note 1, at 51.
7 *Id.*
8 *Id.*
9 *Id.*
10 National Geographic, Facts, Deforestation Information, Effects of Deforestation, http://environment.nationalgeographic.com/environment/global-warming/deforestation-overview.html (last visited Feb. 10, 2010).

Endnotes: Readily Deployable Approaches to Geoengineering: Cool Materials *continued on page 63*

[11] *Id*.

[12] Josep Canadell et al., *Managing Forests for Climate Change Mitigation,* 320 Science 1456 (2008).

[13] The second Industrial Revolution is the later period of industrialization generally characterized by larger-scale organization of industrial production rather than new technological developments. It generally dates from 1870 to the 1914, although some of the characteristics can trace back to 1850. *See generally* Joel Mokyr, The Second Industrial Revolution, 1870-1914 (Aug. 2008) (unpublished manuscript) (outlining the increases in technological developments between 1870- 1914), *available at* http://faculty.wcas.northwestern.edu/~jmokyr/castronovo.pdf.

[14] Carbon Dioxide Information Analysis Center, Global Fossil-Fuel Carbon Emissions – Graphics, http://cdiac.ornl.gov/trends/emis/glo.html (last visited Feb. 10, 2010).

[15] *Id*.

[16] Ruddiman *supra* note 1, at 46.

[17] *See* Environmental Treaties and Resource Indicators, Climate Change: Treaties, Indicators, and National Responses, http://sedac.ciesin.columbia.edu/entri/guides/sec3-climate.html (last visited Feb. 10, 2010) (noting the political responses to climate change issues).

[18] Intergovernmental Panel on Climate Change, Climate Change 2007: Synthesis Report 53-54 (2007) [hereinafter IPCC], *available at* http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf.

[19] *See Geoengineering*, *supra* note 1.

[20] *See* IPCC, *supra* note 18.

[21] *Geoengineering Projects That Could Offset Global Warming*, ScienceDaily, Jan. 28, 2009, http://www.sciencedaily.com/releases/2009/01/090127190338.htm (last visited Feb. 10, 2010) [hereinafter *Geoengineering Projects*].

[22] *See* Sanna Jaronen & Markku Oksanen, *Uncivil Engineering the Serious Problem with Further Climate Tinkering,* Science Progress, Oct. 5, 2009, http:// www.scienceprogress.org/2009/10/uncivil-engineering/ (last visited Feb. 10, 2010) (explaining how geoengineering can be implemented to increase the Earth's reflectivity).

[23] *Geoengineering Projects, supra* note 21.

[24] *Id*.

[25] Video: U.S. Energy Secretary Dr. Steven Chu on the benefits of using white roofs, http://www.youtube.com/watch?v=5wDIkKroOUQ (last visited Feb. 10, 2010).

[26] *Id*.

[27] Arthur Rosenfeld, Presentation to the annual California Air Resources Board's Hagen-Smit Symposium: Cool Roofs: From Cool Cities to a Cooler World (June 3, 2009)*, available at* http://www.energy.ca.gov/commissioners/rosenfeld_docs/index.html.

[28] *Id*.

[29] U.S. Environmental Protection Agency, Heat Island Effect, http://www.epa.gov/hiri/index.htm, (last visited Feb. 10, 2010)

[30] *Id*.

[31] *Id*.

[32] U.S. Environmental Protection Agency, Cool Pavements, http://www.epa.gov/hiri/mitigation/pavements.htm (last visited Feb. 12, 2010).

[33] Rosenfeld, *supra* note 27, at 23.

[34] *Id.*

[35] *Id*.

[36] Cambridge Systematics, Cool Pavement Report (2005), *available at* http://www.epa.gov/hiri/resources/pdf/CoolPavementReport_Former%20Guide_complete.pdf (prepared for the U.S. Environmental Protection Agency).

[37] *Id.*
[38] *See* George Musser, *Cool Roofs are Finally Cool*, SCI. AM., July 30, 2009, *available at* http://www.scientificamerican.com/blog/post.cfm?id=cool-roofs-are-finally-cool-2009-07-30 (outlining one household's experience with sustainable roofing).
[39] *See* Cool Roof Rating Council, General Questions about Cool Roofing, http://www.coolroofs.org/coolroofing.html#radiative (last visited Feb. 12, 2010) (explaining that "cool roofs" are offered in various colors).
[40] *Id.*
[41] *See* Rosenfeld, *supra* note 27, at 29 (opining that the same reflectivity of roofs may be implemented in automobiles).
[42] Canadell, *supra* note 12, at 1456.
[43] Gordon B. Bonan, *Forests and Climate Change: Forcings, Feedbacks, and the Climate Benefits of Forests,* 320 SCIENCE 1444, 1444-1449 (2008).
[44] *See* National Geographic, *supra* note 10 (citing deforestation as a contributing factor to climate change).
[45] IPCC, *supra* note 18, at 33.
[46] *Id.* at 36.
[47] Oak Ridge National Laboratory – Carbon Dioxide Information Analysis Center, Recent Greenhouse Gas Concentrations, http://cdiac.ornl.gov/pns/current_ghg.html (last visited March 5, 2010).
[48] Canadell, *supra* note 13, at 1456.
[49] *Id*.
[50] *Id*.
[51] *Id*.
[52] *Id.* at 1457.
[53] *Id*.
[54] *Id*.
[55] *Id*.
[56] *Id.*
[57] *Id*.
[58] Press Release, National Institute of Standards and Technology, Technology Innovation Program, 2009 Technology R&D Competition to Address Civil Infrastructure, Manufacturing (Mar. 26, 2009), *available at* http://www.nist.gov/public_affairs/releases/20090326_tip_2009_comp_announce.htm.
[59] *Id*.
[60] American Clean Energy and Securities Act of 2009, H.R. 2454, 111th Cong. (2009).
[61] Press Release, U.S. Department of Agriculture, Agriculture Secretary Vilsack Announces $900,000 for Urban and Community Forestry Grants: Cost-share grants provide funds which are matched by recipient organizations (Oct. 28, 2009), *available at* http://www.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_1OB?contentidonly=true&contentid=2009/10/0531.xml.
[62] *See id*. (listing the ten organizations receiving grant funds).
[63] U.S. Environmental Protection Agency, Brownfields and Land Revitalization, http://www.epa.gov/brownfields/about.htm (last visited Feb. 12, 2010).
[64] *See* U.S. Environmental Protection Agency, Constructed Treatment Wetlands, http://www.epa.gov/owow/wetlands/pdf/ConstructedW_pr.pdf (last visited Feb. 13, 2010) (outlining the fiscal benefits of constructed treatment wetlands).
[65] H.R. 2454.