In Support of a Renewable Energy and Materials Economy (REME):

A Global Green New Deal (GGND) that Includes Arctic Sea-Ice Climate *Triage* and Carbon Cycle Climate *Restoration*

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I. Introduction

A Global Green New Deal (GGND) is a critical transformative goal that could be funded by the US alone by creating dollars at roughly the 2008-2011 rate (that though historic is considerably less than the 2020 rate) for almost thirty-years (Baiman, 2020: Sections 2 and 6).[1] In fact, a case could be made that as the current custodian of the world's global fiat currency, the US government has a responsibility to employ its unique monetary power to help all of humanity by issuing dollars to restore a stable global climate (Baiman, 2020). Similarly, stopping climate change, certainly Arctic Sea-Ice climate triage, could cost less than fighting Covid-19 (King and Parnell, 2020).[2]

But a GGND needs to include practical climate, *triage* and *restoration.* If we do not *prevent the Arctic Sea-ice from melting* through urgent climate triage measures; and do not commence to rapidly implement carbon cycle carbon restoration with *Carbon Direct Removal* (CDR) and *Carbon Capture*, *Sequestration*, *and Use* (CCSU); our efforts to prevent accelerating climate catastrophe through mitigation and adaptation alone will fail, see Figure 1 below.[3]

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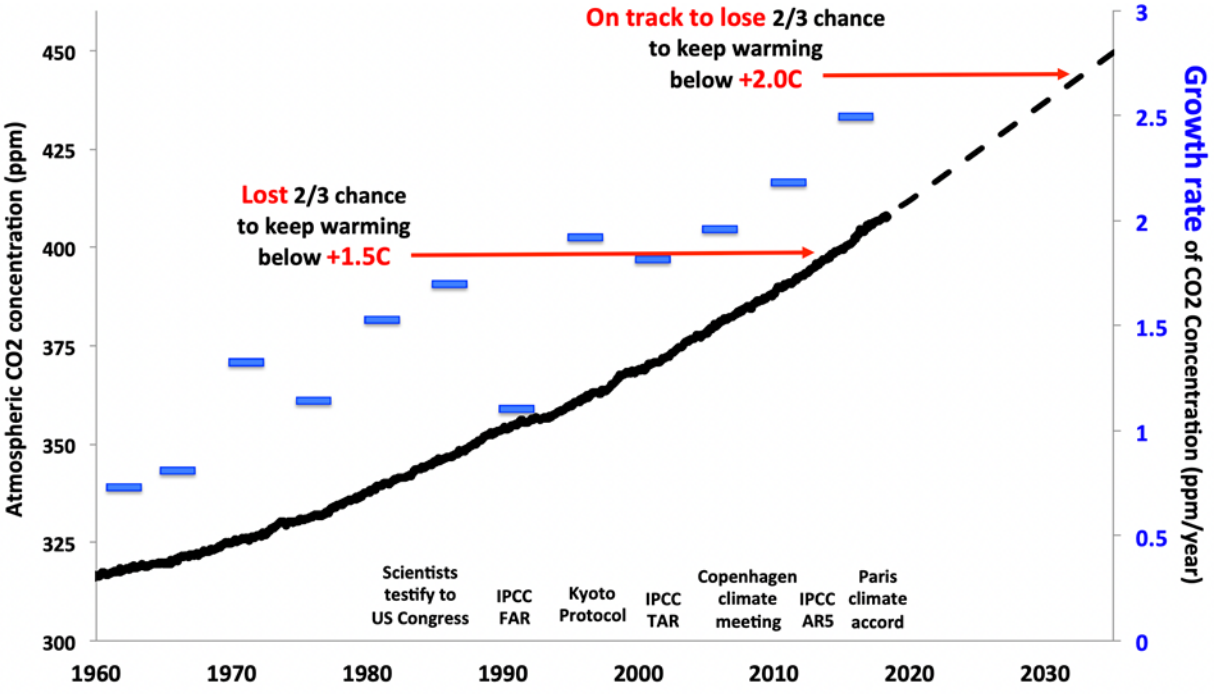
[1] Over ten years from 6/2009 to 6/2019 the Fed stock of T-Bills increased by $1.7 T (Baiman, 2020: 3). Over eight months from 2/12/2020 to 10/28/2020 the Fed stock of T-Bills increased by $2.1 T, see: https://fred.stlouisfed.org/series/TREAST (downloaded 11/23/2020). As the Fed is legally required to turn its profit (minus negligible operations costs) to the Treasury, this represents money created by the Fed for Treasury.

[2] King and Parnell also call for immediate climate *restoration* including Direct Air Capture, in addition to *mitigation* and *adaptation*.

[3] In 2010, 76% of GHG emissions are carbon, 16% methane, 6% nitrous oxide, and 2% F-gases: https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data. As approximately 25% of carbon released into the atmosphere that is not dissolved into the ocean stays in the atmosphere for thousands of years, and methane and nitrous oxide are removed more quickly (25 and 300 years, respectively). The focus of GHG climate change analysis (in this paper and others) is on carbon: http://blogs.edf.org/climate411/2008/02/26/ghg_lifetimes/

Figure 1: The Failure of Global Climate Mitigation and Adaptation Policy



The **thick black line** is the atmospheric concentration of carbon dioxide measured from Mauna Loa Observatory, after removing the cyclical seasonal effect. **Blue bars** indicate independently sampled points of a 5-year running average of the yearly global CO_2 growth rates estimated by NOAA. Red arrows point to critical points with respect to the Paris targets of 1.5°C and 2.0°C.

Source: https://www.policyforum.net/dont-feed-the-fossil-fuel-elephant/

We also need to once and for all stop thinking of climate change and Green House Gas (GHG) emissions as a *flow-reduction* problem, and to correctly frame the problem in *stock-capacity* waste-management, carbon-cycle closure terms (Lackner, 2020) (Eisenberger, 2020). The necessity of CDR and CCSU was officially acknowledged in a 2018 IPCC report that stated that carbon removal was necessary to keep below (an obviously too high given the melting Arctic, see Figure 2 below) 2 degrees Celsius guardrail (Hausfather, 2018).

The Climate Crisis will not wait for fundamental social transformation. There is no question that over the long-term we must work to: address our existing unconscionable environmental justice issues including efforts to:

- Stop the despoiling and destroying natural habitats,
- Work on medium term soil and water-cycle climate regeneration (Baiman, 2020),
- Reduce human population encroachment into hitherto distant viral and bacterial pools increasing the incidence of global pandemics.

But the Long and medium-term social transformations that we on the left envision as a solution to the climate crises require a fundamental reorientation of our political economy, including both *forces* (technologies) and *relations* (social organization) of production that will likely take decades, if not centuries, to accomplish on a global scale.

This should not be viewed as a political or moral failure of our species. Fossil fuels account for 84% of the world's energy and a large share of raw material inputs for much of modern industrial civilization (Rapier, 2020). This is slowly changing. Solar is catching up and, in many cases, is less expensive than fossil fuel in terms of unit energy cost (even without accounting for the externality costs of carbon dumping that most fossil fuel producers do not currently bear), but not in-terms of dispatchability and portability.[4] Carbon-negative cement and concrete, and carbon-based substitutes for steel and aluminum, as well as organic-carbon based substitutes for feed, fertilizer, and many other materials, currently exist or are being developed. But especially

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[4] Lackner has estimated that there are only three currently known energy sources with the potential to power modern human civilization into the 22nd Century: fossil fuels, solar, and nuclear fusion. Other sources of sustainable energy like hydropower, wind, geothermal, and ocean wave, can and should be used but do not have the capacity or scalability to be primary sources of energy into the next century. For now, as practical (if ever) nuclear fusion appears to be decades away, the most realistic options are to continue carbon-neutral or carbon-negative fossil fuel use (through CCS and DAC), and a combination of solar and synthetic carbon-based fuel for optimal storage and portability, (Lackner,2020).

for developing countries, and particularly those that are dependent on fossil fuel or natural resource exports - often by public companies, there are no other current viable options. [5] As discussed below, a REME economy will develop these alternatives, but not overnight (Eisenberger, 2020).

The "carbon-free economy" framing may have become an obstacle to practical progress. This framing needs to be replaced with a practical and realistic Arctic sea-ice *triage* and waste management and carbon cycle *restoration* framework. We need to be pointing out that climate change is fundamentally a closing the carbon cycle REME *reuse* problem, and as it is likely to be impossible to reuse as much carbon as we need to sequester in the coming decades, also a carbon *sequestering* waste management problem. A stable climate can and must, due to the time urgency, be restored *within existing capitalist social and economic systems*, and with current and evolving *infrastructure* and technologies. We need a GGND that includes Arctic Sea Ice climate *triage* and Carbon Cycle *restoration*, and that that works toward a REME technological and economic transformation that will reduce or eliminate energy and materials scarcity and *allows for* a democratic socialist political and economic transformation over the long term.

II. Saving Arctic Sea-Ice Climate Triage

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[5] This was driven home to me by two incidents: a) the President of Ecuador offering to not exploit newly discovered oil reserves in the Amazon rain-forests if the international community would reimburse Ecuador for forgone oil earnings, and after getting no response, moving ahead with oil extraction (Goldman, 2017), b) Norway, one of the most social democratic, environmentally responsible, and wealthiest (per-capita) countries in the world, going ahead with exploitation of newly-discovered north sea-oil reserves using "green" technologies (Kottasovana, 2020). If Norway cannot resist cannot fossil fuel exploitation, I doubt that any other major country in the world will be able to.

Arctic Sea-Ice melting is the first major climate *tipping point* (Lenton et al, 2008) (Wang and Hausfather, 2020). Melting Arctic ice, unlike the Greenland and Antarctic ice-sheets, is not voluminous enough to cause massive sea level rise, so this is not the major effect that makes this a climate tipping point. Rather, this would be an abrupt and catastrophic global climate tipping point for at least the following reasons:

- Arctic sea-ice melting would have a global warming impact roughly equal to that of 17.3 years of global green-house gas (GHG) emissions relative to the 2016 base level of CO2 in the atmosphere (Pistone et al, 2019)[6], that would blow through the global carbon budget (Hausfather, 2018).

- Increased solar polar heating from the loss of reflectivity will rapidly warm Arctic oceans as the heat will no longer be absorbed by melting ice. A “warm water time bomb” has already been discovered accumulating under the Arctic that is accelerating ice melt (Coghlan, 2018).

- “Arctic amplification”, or disproportionate Arctic warming relative to mid-latitudes weakens the Polar Jet and Gulf Streams (Alfred Wegener Institute, 2019) (Rahmstorf, 2020), and may cause the cold center of the Jet stream to move toward northern

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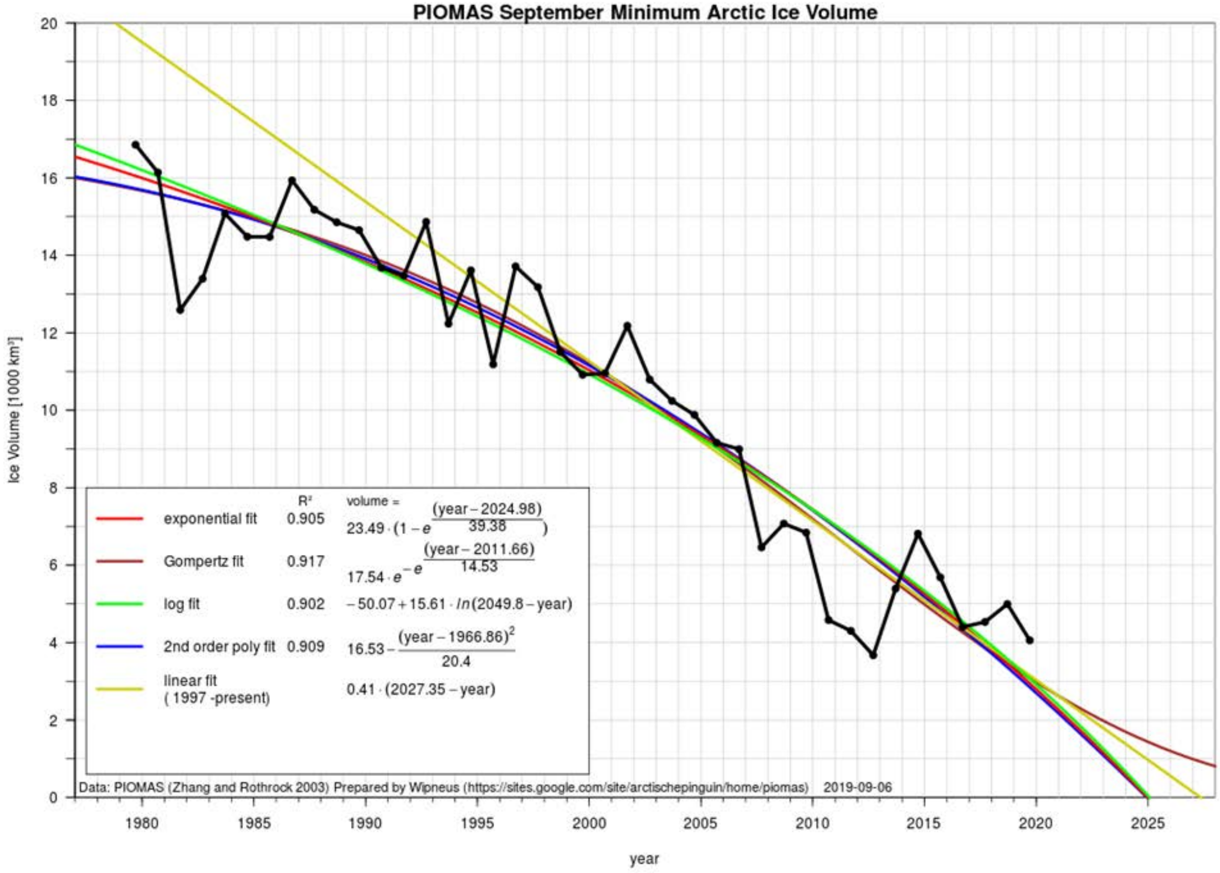
[6] The authors use the approximate formula f = (5.35 W/m^2) ln(x/R) were f is radiative forcing relative to R, and x atmospheric concentration (Pistone et al, 2019, p. 7479). For a given R and f this implies that: $x = Re^{\left(\frac{f}{5.35}\right)}$. The authors used f=0.71 W/m^2, which they estimate is increased radiative forcing from 1979 to an ice-free Arctic, but used 2016 400 CO2 ppm as the relative base value for R to get 456.8 as the CO2 ppm after Arctic sea-ice melting for an increase of 56.8 CO2 ppm. They then multiply this by 7.77 and divide by 0.44 to get 1002.5 increased GT CO2 equivalent. By dividing this by average current emissions of 40 GT they derive an estimate of 25.1 years of GHG emissions at current levels. However, they estimate 0.5 not 0.71 as radiative forcing from 2016 (Pistone et al, 2019, p. 7476). Correctly starting with f=0.5 W/m^2 and using the same procedure as above produces an estimate of 17.3 years of 40 GT emissions from 2016.

Greenland, 17 degrees latitude south of the north pole, exacerbating extreme planetary climate crisis (Beckwith, 2018).

- Warming Arctic atmospheric and ocean water, and increased Arctic humidity, will accelerate the risk of crossing other dangerous climate tipping points like large-scale Siberian permafrost methane release, and the melting of the Greenland ice-sheet (Harvey, 2016) (Francis, 2018).

As can be seen in Figure 2 below: the exponential, log, and 2nd order polynomial, fits for September Arctic Sea-Ice go to zero in 2025; the linear fit in 2027; and the Gompertz fit (with the highest displayed R2) appears to asymptote with the horizontal axis outside of the plot sometime between 2030 and 2040. In other words, direct measurement is telling us that if current trends continue there will be a zero “blue ocean” September Arctic sea-Ice event by 2025-2040. Similar trends for other months suggest that complete Arctic sea-ice melt will occur in following years.

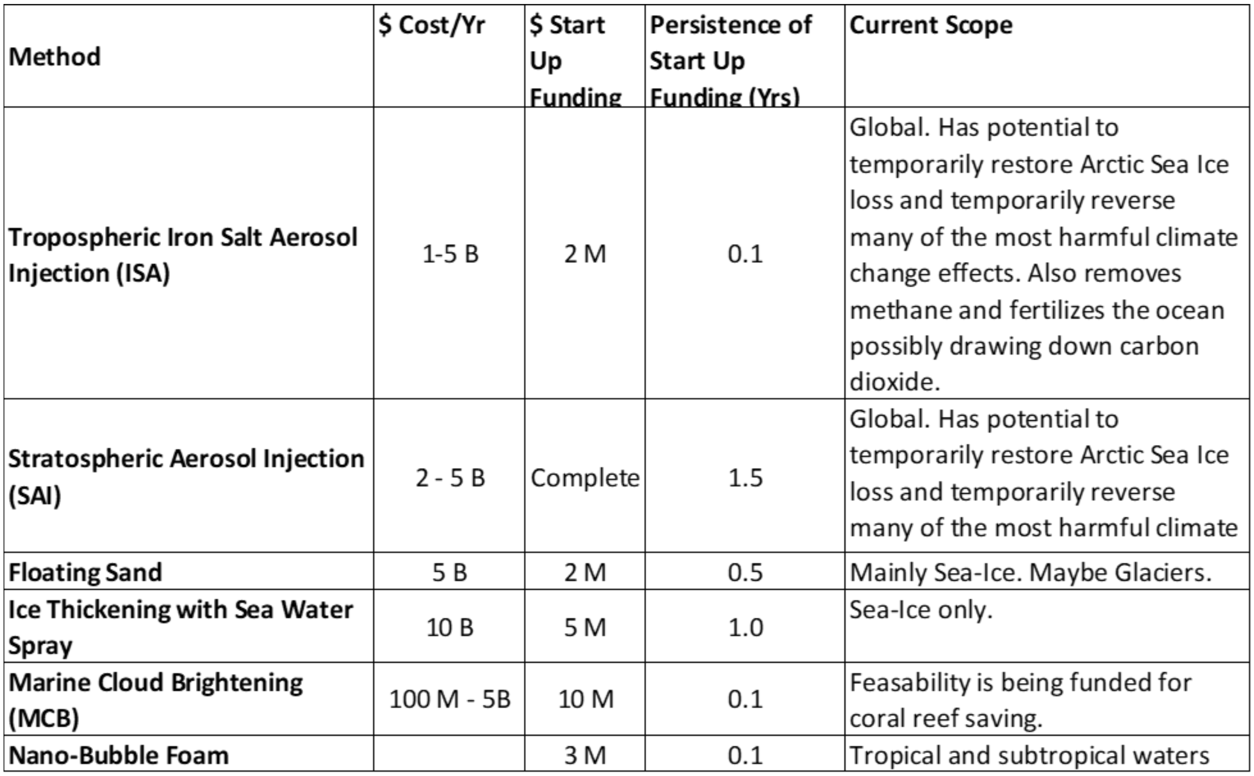
Figure 2: September Minimum Arctic Sea-Ice Volume 1979-2020



Source: https://sites.google.com/site/arctischepinguin/home/piomas

Proposed triage methods for saving the Arctic sea-ice include the following, see Table 1 below.

Table 1: Methods for Saving Arctic Sea-Ice with Cost Estimates



Method	$ Cost/Yr	$ Start Up Funding	Persistence of Start Up Funding (Yrs)	Current Scope
Tropospheric Iron Salt Aerosol Injection (ISA)	1-5 B	2 M	0.1	Global. Has potential to temporarily restore Arctic Sea Ice loss and temporarily reverse many of the most harmful climate change effects. Also removes methane and fertilizes the ocean possibly drawing down carbon dioxide.
Stratospheric Aerosol Injection (SAI)	2 - 5 B	Complete	1.5	Global. Has potential to temporarily restore Arctic Sea Ice loss and temporarily reverse many of the most harmful climate
Floating Sand	5 B	2 M	0.5	Mainly Sea-Ice. Maybe Glaciers.
Ice Thickening with Sea Water Spray	10 B	5 M	1.0	Sea-Ice only.
Marine Cloud Brightening (MCB)	100 M - 5B	10 M	0.1	Feasability is being funded for coral reef saving.
Nano-Bubble Foam		3 M	0.1	Tropical and subtropical waters

Sources: (Fiekowsky et al, 2019: Table 3, p. 25) (Oeste et al, 2017) (Smith and Wagner, 2018) (Field et al, 2018) (Desch et al, 2016) (Mims, 2009) (Kostigen, 2020, p. 108-117) (Clarke, 2018) (Seitz, 2010)

Stratospheric Aerosol Injection (SAI) mimics the way in which large scale volcanic eruptions temporarily cool the planet by dispersing sulfate aerosols that reflect sunlight into the stratosphere (Watson, 1997). Mount Pinatubo, for example was estimated to have released about 15 million tons of sulfur into the stratosphere and cooled the planet by about 0.6 degrees Celsius for 15 months (NASA, 2011). SAI is estimated to achieve an about 1.5 Celsius average cooling across the planet relative to scenarios with 2xCO2 (that would increase average temperature by about 2.5 degrees Celsius in these models) with no average change in precipitation, and reduced variation, and maximum, for global temperatures and precipitation. A leading current SAI proposal is estimated to have an approximate cost of only $5 billion over 1.5 years to build 100 customized aircraft that would make about 120,000 flights per year (there are about 40 million commercial flights per year) (MacMartin et al, 2017) (Keith, 2019) (Smith and Wagner, 2018). Concerns about possible adverse effects of SAI on the Ozone layer could be addressed by using calcite instead of sulfate aerosol (Keith et al, 2016).

Similarly, Iron Salt Aerosol (ISA) injection by 100 large coal burning power stations is estimated to have a global cooling effect equivalent to eliminating current global CO2 equivalent GHG emissions of approximately 40 GT per year. The iron salt aerosol only needs to be elevated to heights of 1000 meters above ground and would stay in the troposphere for only weeks which would allow for quick cessation and reversibility of its impact in the event of unintentional adverse side effects. The iron aerosol is also likely to interact with and reduce methane and CO2 in the troposphere and stimulate ocean fertilization and carbon sequestration when it falls into the ocean (Oeste et al, 2017, p. 34).

III. Carbon Cycle Climate Restoration through CDR and CCSU

CDR projects, are based on either biology or chemistry, remove carbon from the atmosphere or the ocean, and sometimes also produce economically useful outputs. Atmospheric and oceanic carbon are in rough balance with an approximately 10-year lag, so that carbon must be removed from both places to reduce its concentration in either (Broecker and Kunzig, 2008, p. 70). The objective of CDR is thus to capture carbon from the atmosphere or ocean, and the objective of CCSU is to sequester carbon over the long-term (more than 100 years) in the land or deep ocean , or to use it in carbon-based replacements for materials like: cement, concrete, steel, aluminum, synthetic fuel, rugs, fertilizer, feed, and food (Eisenberger, 2020, 2020a). Tables with references for many of these methods are provided in (Baiman, 2021, Tables 2-5). Below are short discussions of three of them.

Numerous companies like Blue Planet[7] and CarbonCure[8] are currently producing carbon negative, or reduced carbon, concrete, aggregate, and other building materials. Carbon negative concrete been used in construction for the San Francisco airport. Estimated costs of synthetic stone at $50/ton at capacity are competitive with quarried stone at $30-$200 a ton (Fiekowsky, 2020, p. 20). Concrete is the most widely used building material in the world as twice as much concrete is used as any other building material (Gagg, 2014), and construction materials (at 35 GT in 2009) make up over a third of all materials used globally by humans (other major categories are: biomass, fossil energy, and ores and industrial materials) (Eisenberger, 2020, p. 21).

Multiple point-source, or point-source related, carbon capturing plants are currently operational and capturing carbon at scales of thousands of tons a year. Global-Thermostat, a company founded and run by two academics Graciela Chichilinsky and Peter Eisenberger who believe that rapid scaling up of Direct Air Capture (DAC) and CCSU is critical to solving the climate crisis, has in collaboration with ExxonMobile built two plants that capture 3,000 – 4,000 tons of CO2 a year and is scaling up to a 50,000 ton CO2 a year plant (Soltoff, 2019) (Chichilinsky and Bal, 2019). The plants are designed to be added to existing and new natural gas fired electric power generators to draw down carbon from the air when the gas plant is operating using excess heat generated by the power plants, and from the air using concentrated solar energy when the gas plant is not operating - *in both cases with a net carbon negative outcome*. The idea behind these

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[7] https://www.blueplanet-ltd.com/

[8] https://www.carboncure.com/

plants is *to use continued natural gas fossil fuel use to rapidly scale up CCSU to advance toward a REME* (Eisenberger, 2020)

Klaus Lackner (reportedly the first person to prove that Direct Air Capture (DAC) is feasible (Lackner, 2012)) and his team, have developed "mechanical trees" that can remove carbon from the *ambient air* much faster than ordinary land or sea-based organisms. Just like real trees, Lackner's mechanical trees capture carbon from the air passively by letting the wind blow through them and rely on energy from sorbent moisture swings in dry air to capture CO2, reducing costs per ton of carbon capture to below $100 per ton. The mechanical trees are also not limited by access to, or proximity to, a point-source carbon emitter. One tree can draw down almost one metric ton of CO2 a day, and a cluster of 1,200, like the one that Silicon Kingdom Holdings, the company that Lackner and ASU are working with, is planning to build in California, 36,500 metric tons a year (ASUNow, 2019). For comparison, a normal tree removes approximately 48 pounds CO2 a day, or takes almost 46 years to remove 1 metric ton.[9] Large scale "farms" of 120,000 trees are estimated to be able to remove 4 million tons of C02 annually and occupy a land area of about one square mile (ASUNow, 2019a). 250 of these farms could thus remove a gigaton of CO2. This is critical as forests of trees, bamboo or Buffalo Grass can also potentially draw down vast amounts of carbon but over much larger areas and time periods.[10]

III. Climate Policy for a Renewable Energy and Materials Economy (REME)

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[9] http://www.tenmilliontrees.org/trees/

[10] Nature based CCSU in the ocean is limited less by space than by essential mineral nutrients.

The climate *crisis* needs to be turned into a climate *opportunity* for a fundamental transformation of the forces of production from being based on the work of "hunter-gatherers" of carbon-based fossil fuel energy and materials and one-way utilizers of the oxidization part of the carbon cycle, to "cultivators" of a "Human Designed Carbon Cycle Run by Renewable Energy" (HDCCRRE) (Eisengerger, 2020). Up until now humans have relied on nature to close the carbon cycle for reuse through photosynthesis, and sequestration through weathering mineralization and ocean sinks. But we have reached the limits of our hunter-gatherer unidirectional utilization of carbon-based energies and materials pillaging of nature, as our planet's atmosphere and oceans can no longer absorb the excess carbon imbalance that we have created.

Though we currently have dumped more carbon that we can possibly use in the atmosphere and ocean, in the future we may be able to adjust our use and sequestration, or carbon cycle management, in order to stabilize our climate and avoid geological "glacial" and "hot-house earth" periods driven by Milankovic and carbon cycle events (Eisenberger, 2020) (Broecker and Kunzig, 2008). At some point we may be interested in "storing" carbon in an accessible way that will make it easy to utilize, but right now, to avoid catastrophe we need to remove and sequester what we cannot use as quickly as possible.

On the *use* side, the climate crisis is forcing us to close the carbon cycle by taking over the production of carbon-based renewable fuel; or "photosynthesis", using renewable, currently mostly solar, energy for the production of human-designed materials; in a process of a HDCCRRE. These include building materials to replace cement, concrete and aggregate; other materials to replace steel and aluminum with carbon fibers and graphene; synthetic polymer composite materials to replace plastics and fiber; and the use of biological CDR processes to produce animal feed and fertilizer (Eisenberger, 2020) (AirMiners, 2020)[11]. Interestingly, one of many possible methods for addressing the other major link in this transition, biological or electro-chemical capturing of hydrogen using manageable levels of renewable energy, may be through closing the cycle for methane, the second largest GHG (Eisenberger, 2020a).

As we are unlikely to be able to *use* enough of the stock of accumulated carbon that we need to remove from the atmosphere and ocean at a rapid enough pace to stabilize planetary climate, we are going to have to assist nature in *sequestering* it for long periods of time. Carbon sequestration methods include mineralization, geological sequestration in basalt rock formations, sequestration in saline aquafers, or in enhanced oil recovery wells (Lackner, 2020). It is estimated, for example, that about 72% of CO2, captured from a powerplant emitter and injected into Basalt rock formations by CarbFix, mineralized within about 2 years (Pogge von Standmann et al, 2019). As Basalt rock, saline aquafers, and oil wells are widely available, there appears to be no near-term problem with sequestration options at levels necessary to restore a stable climate.[12]

In order to practically address the climate crisis within a *climate dictated timeframe* we need to restrict and quickly eliminate further "carbon dumping" by setting up a mandatory "dumping fee" or "cap and trade" market for all carbon dumped into the atmosphere or ocean, with a cap that very rapidly goes to zero. A global cap and trade market with equitable *net-emissions caps, for all countries, based on responsibility and capacity*[13], and *policed by national governments,* would address the regulation and governance issues brought by critics (Hahnel, 2012, 2012a, 2013) (Bond, 2012). Though this debate was over the Kyoto "Clean Development Mechanism",

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[11] https://youtu.be/P0EDuXQgrJA?list=PLz5_mBpUiEFV608rHt-J7O6f7z9yXfhD3

[12] Author's calculations from recent data suggest that about 1,710 Gigatons of CO2 would need to be removed from the atmosphere to get back to 1989 level of 353 ppm (K von Schuckmann et al., 2020).

[13] As proposed for example by the Greenhouse Development Rights Framework: http://gdrights.org/about/

these points also apply to Article 6 of the current Paris Agreement. As national carbon emissions can be accurately measured, individual countries can be held responsible for their emissions regardless of whether traded “carbon offsets” are real or not – an issue that is less likely to be a problem for Carbon Direct Removal (CDR) than for “carbon mitigation”. A global cap and trade market would increase the efficiency and scope of drawing down GHGs and lead to a large transfer of funding and investment to developing countries. Similar, national and state, public compliance, and private voluntary carbon removal markets, are critical to developing protocols and creating markets for CCSU.[14]

Since even a “zero cap on carbon emissions” is not adequate, we need to also directly subsidize and expand support for large-scale CDR and CSSU markets. Sources of funding for this could be the unique power of the US federal government to directly pay for global GHG drawdown by issuing and lending dollars (as in the Marshall Plan); and additional carbon high-income and wealth, and rentier, taxes (Baiman, 2020). These funds could be used to stimulate GGND targeted “climate justice” economic development by supporting CDR and CCSU projects and creating carefully monitored public or private carbon sequestration certificates and “dump sites” or sequestering facilities where carbon could be sequestered, prioritizing underdeveloped and climate crisis affected locations. Most importantly, public and private markets for carbon negative products, and for carbon and carbon-based materials, need to be rapidly created.

A keyway to do this would be to pass laws and regulations mandating the use of carbon neutral or negative construction materials, fertilizer, fuel, feed stock, food and other goods and services. We need to turn carbon drawdown, including CDR and CSSU, into major private-profit

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[14] For example, the two compliance offset protocols for California’s cap and trade law that primarily address carbon (Urban forest, and US forest) address carbon *mitigation* or natural drawdown: https://ww2.arb.ca.gov/our-work/programs/compliance-offset-program/compliance-offset-protocols .

opportunities, and use public policy to directly fund GGND REME and CCSU that will address global economic equity and real (rather than rentier) production of goods and services (Baiman, 2020).

As Lackner has pointed out, the minimum price for ambient (atmospheric or oceanic) carbon drawdown would become the effective “carbon tax” in a publicly enforced “no carbon dumping” compliance regime, and the public subsidy price for large-scale additional carbon drawdown and climate restoration (Lackner, 2020). Thus, the more efficient DAC CDR becomes, the more pressure on point-source emitters like for-profit fossil fuel producers and users, who currently have an incentive to stall, delay and deny; to rapidly develop less costly (than DAC CDR) carbon-zero or carbon-negative facilities, like the Global-Thermostat retrofitted natural gas power plants.

We need to immediately fund, pilot, and deploy Arctic Sea-Ice saving climate triage to avoid crossing the first critical Arctic Sea-Ice loss global climate tipping point, and utilize large scale public infrastructure and jobs program roll-outs coupled with existing competitive for-profit markets embedded in government compliance regulations, and tax and subsidy regimes, to incentivize the development of CDR and CCSU for the REME economy of the future. Sustainable energy use and social and economic transformations that increase environmental justice and overall equity and opportunity are central to the GGND vision. REME transformation from one-way carbon combustion and materials that use “hunter gatherer” industrial civilization, to more complete HDCCRRE “cultivator” REME civilization, is possibly the opening to a world free of scarcity that would allow us to move toward democratic socialism or even democratic communism.

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