The Case for REME Mobilization to Address the Economic Damage of the Pandemic and Prevent the Catastrophic Climate Change

Overview

The case is made for transforming from our current natural resource based economy to a Renewable Energy and Materials Economy (REME) based on renewable energy, CO2 from the air and hydrogen from water. The transformation will provide the economic stimulus to simultaneously address the current economic damage created by the Covid19 Pandemic and prevent the future catastrophic damage of climate change. Allowing the CO_2 concentration in the atmosphere to rise above "tipping points" identified by the IPCC will cause a runaway climate change, the climate change version of the pandemic. The economic devastation, infrastructure destruction, ecosystem destabilization, and the associated loss of human and other species that will result is much worse than that caused by the current Pandemic. The painful lesson from the current Pandemic that one needs to prepare before the damage begins when translated to the climate change threat means we need to mobilize now to address the threat of climate, with that mobilization providing the stimulus for economic recovery from the Pandemic. The basic features of the mobilization required are presented but more specific plans will be provided in other documents.

The Pandemic and Catastrophic Climate Change (CCC)

The recent Pandemic has made four things very clear:

1. A global threat that grows exponentially will eventually overwhelm any response that grows linearly, causing greatly increased damages.
2. To prevent being overwhelmed one needs to be prepared and start responding as quickly as possible, while in the linear growth region (Flu like)

before it becomes exponential (Pandemic). There is a delay between cause (exposure) and impact (hospitals overwhelmed).

3. The response to a global threat requires global cooperation to develop the science and technology needed to both slow down the spread of the virus and to develop a solution (vaccine).
4. While one is waiting for a solution to prevent a threat (a vaccine), one needs to reduce its growth rate (social distancing) so that it does not overwhelm the linear response (our medical system) causing greatly increased damages.

The threat of Climate Change has many of the same features as the Pandemic, but the threat is much greater:

1. The human contribution to the CO_2 concentration in the atmosphere has been growing very fast because of the positive feedback connected with economic development and meeting the needs of a growing population. Those efforts depend upon our use of energy, which has until recently largely been driven by energy that emits CO_2. But while CO_2 emissions have been growing fast, with shortening doubling times, the emissions rate is determined by human behavior and thus is inherently a linear phenomenon. Our progress in science and technology has itself been growing exponentially leading to the so-called singularity.[1] Thus providing a powerful response to an exponentially growing threat if given enough time. The planet's carbon cycle is also inherently evolving in a linear manner as CO_2 is exchanged between atmosphere and sea. In this sense one can call global warming flu like. But if the CO_2 level reaches a "tipping point"[2], [3] which is characterized by exponential evolving releases of CO_2 with time, both our human infrastructure and those of the planet's ecosystems will be overwhelmed. Not only will lives and jobs be lost, but also our infrastructure will be destroyed by sea level rise and extreme weather events. Additionally, many ecosystems will be lost and or transformed making recovery extremely more difficult than from the Pandemic. This can be thought of as the Pandemic stage of climate change which is much worse and one to be avoided at all costs.

2. We are already experiencing the impact of climate change and there are valid concerns that we may be approaching "tipping points". Because the climate system has long delays, its own version of the delay between infection and

being sick, between drivers of change like increased temperature and the effects they cause, we can take no comfort from the fact that we have not been devastated yet. We are clearly experiencing the damage of climate change in terms of extreme weather events droughts, and changing ecosystems. We need to respond to the climate change threat now! We cannot let the absence of devastation prevent us from mobilizing a response as if our future is at stake, because it is.

3. Our response cannot be using our existing capability the way we have in the past. Because we are already experiencing climate change, a linear response is inadequate. We need to cooperate at the global scale and ensure that the required effort gets the support it needs. We need efforts like conversion to renewable energy and emissions reductions to slow the rate of CO_2 release, while we develop a permanent solution, which is asserted below is to be a transition from a natural resource economy to REME.

4. As described elsewhere in detail and below in general terms, responding by building the Renewable Energy and Materials Economy (REME),[4] we cannot only slow down the rate of climate change (e.g., bend the CO_2 curve), but we can also make the threat go away at a global scale (a vaccine) by enabling us to return to CO_2 levels lower than they are today. While we should also slow the growth rate by emissions reductions and switching to renewables, energy efficiency, conservation, and natural drawdowns, REME has a positive feedback that will eventually dominate our response.

The Role of REME

REME mimics nature by using CO_2, captured from the air by Direct Air Capture (DAC), hydrogen produced from water, and renewable energy to make the energy and materials we need.[5] Carbon-based materials as in carbon fiber, cement, plastics, and many more offer us the opportunity to sequester CO_2 from the air.

Here it is important to note that our science and technology has advanced, so we know how produce energy and materials from CO_2 and hydrogen. All we have to do is scale up and reduce the costs. Besides, REME will create many new jobs to recover from the Pandemic, it will also reduce the growth rate of CO_2 in the atmosphere. But most important of all is that REME is not a linear response because it links CO_2 removal from the atmosphere to the growth in the REME economy, which means it will grow exponentially.[6] The more jobs created ,the more demand there is for REME products. In simple terms, by mimicking nature the more renewable energy is used, the more CO_2 is taken out of the atmosphere, and the more hydrogen is separated from water the more energy and materials we will produce. This can create a future in which we and the rest of life on our planet will flourish. Many of the materials we make from atmospheric carbon and hydrogen from water can sequester the carbon, thus providing a profitable way to address the threat of climate change.

In summary: one needs an exponential growing response to address an exponentially growing threat like climate change. At this time no other viable alternative (vaccine) to REME exists for us. Here it is important to note that the reason our natural resource economy is linear and REME is not is exactly because the natural resource economy produces negative externalities like pollution and climate change and depends upon materials in limited supply that ultimately slows down its rate of growth.

At this point some are calling for a solution analogous to shutting down the global economy as was done for the Pandemic by proposing draconian restrictions on fossil fuel energy use. This would hurt the global economy and prevent lifting billions of people from climbing out of poverty and cause other similar negative impacts to those created by our response to the Pandemic. REME includes a plan on how to use the existing energy infrastructure, and our abundant natural gas energy resources, to increase our ability to respond to the threat of climate change in a more timely manner than would otherwise be possible by creating the so-called “carbon negative power plants”[7] Furthermore, the IPCC has concluded that even if the most aggressive increases in renewable energy deployments and emissions reductions are implemented, the atmospheric concentration of CO_2 will rise to levels that are above potential “tipping points”. The IPCC has affirmed that Carbon Dioxide Removal (CDR) technologies are needed to remove CO_2 already in the atmosphere to achieve the levels needed to avoid potentially catastrophic climate change.

The power of REME is that while removing atmospheric CO_2 to address climate change, we can also address the economic damage created by the Pandemic and create economic prosperity. It may sound too good to be true, but by mimicking nature, REME creates a positive feedback in our economic growth, deleting the negative feedback of our natural resource-based economy. However, as promising as the development of REME combined with other emissions reductions efforts are, they cannot be implemented fast enough through current economic development and carbon management policies to avoid exceeding tipping point concentrations in the atmosphere.

The concentration at which that will occur is uncertain (1,2). Keeping the atmospheric CO_2 concentration below 450 ppm (2C degrees warming) has been taken as the best estimate to avoid catastrophic tipping points, but there is far from a consensus. Recently there is growing belief that an even more aggressive target is needed (1.5C degrees). In the end, the uncertainty would lead one to conclude that the faster we reduce emissions and actually start to reduce the concentration in the atmosphere by Carbon Dioxide Removal using renewable energy-powered DAC, the better. We will use 450ppm in our analysis, but the calculations below can be used to explore the implications of varying that target.

It will also be shown that once one develops the capacity to stabilize the CO_2 concentration at 450ppm, reducing it further is relatively easy because we will already have a large installed capacity and basis for further growth. In fact, once one achieves the capacity to reduce the CO_2 levels in the atmosphere, one can continue to achieve an optimal concentration. This means we will have the capacity to control the temperature of the planet, providing climate protection against future climate changes caused by the Milankovitch cycles.[8] Cycles that have created great destruction of life on our planet in the past and will do so in the future if we do not intervene. Thus, an additional benefit of REME is that it is actually the vaccine to make climate change for our planet a problem of the past. It is worth noting that before we emerged, climate change repeatedly ravaged life on our planet. So our evolutionary emergence with our distinctive brain and ability to grow and use knowledge is what will enable us to protect ourselves and the planet from these destructive cycles in the future.

Because the REME approach generates a positive feedback it is unlike other approaches like CO_2 sequestration underground or economically extremely abrupt emissions policies that are a cost to the economy in terms of jobs and resources. But REME itself will need to realize doubling times of growth not achievable by relying on normal economic incentives, and thus it needs to be implemented using a combination of the approaches used in the Manhattan Project and Marshall Plan. It needs a Manhattan Project cooperative approach to develop the REME technologies at the scale needed and to drive their costs down through learning by doing. We need to use a Marshall Plan type approach to ensure that the developing world can grow at the high rates needed to avoid the threat of climate change.

The scale and rate of REME development, including the important carbon to value technologies that transform the atmospheric CO_2 and the hydrogen from water into the energy and materials we need, is described in the attached REME paper. The rate of REME development needed is of course dependent upon the effectiveness of our renewable energy growth and emission reduction efforts and the target concentration needed to avoid crossing tipping point thresholds. The time scale needed will in all cases require mobilizing a global effort to cooperatively develop the technologies needed and a financial program to provide the capital needed for both the developed and developing countries to implement it.[9] It will also require a cap on CO_2 emissions with a carbon policy that provides the cost for removing carbon that is sequestered and a credit for CO_2 that reduces the amount in the atmosphere. The size of the penalty and credit would be determined by what is needed to drive the transformation to the REME economy at the pace needed to avoid catastrophic climate change.

In this paper, we will use a simple analysis to support the above assertions.
The details of the Manhattan Project approach to develop the required technologies at the rate needed, the Marshall Plan approaches to enable the economic growth rates needed, and the way to implement the carbon policies needed will require additional effort. This paper is simply intended to provide the case that mobilization is urgently needed, and we that we have to start mobilizing now.

Analysis Framework

As discussed above, there is a crucial distinction between the growth of our economy and its increasing CO_2 emissions and the increased CO_2 released by passing a tipping point threshold of atmospheric CO_2 concentration.

The difference is that in the fossil fuel case, the growth is driven by the increased use of energy that produces positive benefits, in particular benefits that enable us to accumulate knowledge, which has provided us the capability to use fossil fuels with no emissions and/or choose another energy source, like solar, that does not emit CO_2 and, of course, ultimately REME. There is a positive feedback in the knowledge generation rate, represented by the singularity, which will continue to help us in our attempts to deal with the climate change threat and can be explicitly increased by support for research and development and the establishment of courses and training programs for the skills needed for REME.

The first signs of our progress is the growing evidence of the decoupling of energy growth and GDP.[10] The fraction of our energy provided by renewable energy is also increasing.[11] As noted above, decoupling and renewable energy conversion and emissions reductions will not be enough to address the threat of climate change. This is the state of the human carbon cycle today. However, the fact that the technologies needed to implement REME exist, is a result of the growth in knowledge, so one can assert that in addressing the climate change threat by REME, we will be developing a vaccine that will mark the transition where our exponential growth in knowledge will provide our species the ability to design our own future rather than react to changes the future might bring. This is an exciting future to look forward to, but we need to mobilize our capability to ensure that we do not lose this battle with climate change.

In the case of the melting of the permafrost or other tipping point threats[12],[13] the atmospheric CO_2 itself is the feedback mechanism for increased CO_2 release. There is no decoupling possible. This is the part of the planet's carbon cycle that has caused the devastation in the past, and that now we are threatening to create ourselves. The two cycles together determine the CO_2 concentration in the atmosphere, and thus impact climate change in similar ways, even if the causes are different.

Mathematically, the difference between global warming and catastrophic climate change can be demonstrated by the following simple argument:

In global warming, H(t) = C(t)X(t)

H is the human rate of CO_2 emissions per year, C is the CO_2 intensity per GDP and X is the GDP per year.

The time derivative of H(t) is **H(t)**

H(t) = C(t) **X(t**) + **C(t)** X(t)

Where **X(t)** and **C(t)** are time derivatives of the GDP growth/year and carbon intensity per GDP respectively.

In the global warming state, the rate of CO_2 emissions changes with time and will increase, as it has, if the GDP growth rate is much faster than the reduction in CO_2 intensity. Global warming could be prevented if the CO_2 intensity per GDP was zero, where all our energy sources are renewable. The CO_2 growth rate will be determined by the difference in the two rates. This is the basis for the switch to renewables and emissions reduction efforts that have until now been the basis for our approach to global warming. It is important to note that as long as we are emitting more than the natural system can sequester, the CO_2 concentration in the atmosphere will continue to increase. This is clearly the case today.

There are many potential tipping points, and even discussion of a cascade of tipping points with the sudden release from one of greenhouse gases raising the temperature to the extent that another tipping point is exceeded, releasing another burst of greenhouse gas (see 12+13). All the tipping points share the characteristic that the release is sudden because it has a feedback created by the release of the greenhouse gas causing an increased temperature, which than increases the rate of release. This results in an exponentially growing rate of release of CO_2, a so-called runaway release, which will not stop until the particular stock of greenhouse gases affected by it have been fully mobilized (see references above). Therefore, one can think of the human carbon cycle impact as the flu, with solar and emissions reductions as social distancing, and if one triggers tipping point releases in the planet's carbon cycle that are large compared to normal releases, one has the equivalent of a pandemic whose severity is determined by the size of the release. In this context, a cascade of tipping point releases would be the equivalent of a global scale pandemic. In that case, one would have catastrophic climate change, which would create great damage for both humans and their infrastructure and other life and their ecosystems. This is clearly an outcome we need to avoid and should therefore act now to prevent it's occurrence by limiting the levels of CO_2 in the air.

Now the distinction between REME and either sequestration or other emissions reduction approaches is that they are linear in their growth rate while REME because of the positive feedback with economic growth is exponential.[14] If the incremental demand created for REME energy and materials/products is caused by the jobs REME itself creates, one has the equivalent of runaway economic growth. In this case the critical issue is, as it was for the tipping point releases, that the fraction of the economy driven by REME is large enough to determine the first order economic growth rates. This can clearly be the case for REME because it produces both the energy and materials that are used in the economy. It is an industrial revolution that transforms the inputs and outputs which drive economic growth. It is important to note that the REME economy needs lots of highly skilled jobs, like solar has had [15] and, of course, solar is part of REME. The highly-paid workers create the jobs that generate wealth, which in turn will create demand for new infrastructure and a greatly increased service economy. High economic growth rates leading to global prosperity is the solution to the Pandemic damage and to address the climate change threat. Stimulating the growth of REME will be the most effective stimulus package ever with even greater benefits than the Marshall Plan, which is credited with taking us out of the carnage of WWII.

Rates of REME Growth Needed

Here again we can provide a simple analysis to determine the rates of mobilization needed. More detailed analysis is needed to determine the specific actions required to stimulate the development of REME.

The key issue is the determination of the rate of CDR, or R in tonnes per year, needed to stay below the atmospheric CO_2, C, identified as a tipping point threshold. For this analysis, we will use C= 450 ppm. The rate of CO_2 increase in 2020 is 2.4 ppm per year.[16] The concentration today is 415 ppm. Thus, we have 35/2.4 years to have a CDR rate R of minus 2.4ppm. That is 14.6 years to have R be -2.4 ppm. One ppm is equal to 7 gigatonnes of carbon dioxide, so we need to be able to remove 17 gigatones of CO_2 per year by 2035. In this simple analysis, we will make the assumption that emissions reductions via switching to renewables and other approaches just hold the current growth rate of increase of 2.4 ppm constant, but to make the math easier a target is for REME to provide 15 gigatones of removal capacity with the caveat that if it falls short we can also do sequestration underground, still recognizing that it lacks the positive feedback that REME provides.

As an example, I will use Global Thermostat (GT) technology, the analysis can be applied to other technology solutions and scenarios also. For GT, we will have in 2020 a plant capturing CO_2 at 2000 tonnes per year in a machine roughly the size of a shipping container. As the REME analysis shows, the demand is so large that one will reach the learning curve limiting cost well before one produces the 7.5 million machines needed. Based on the National Academy study, the capital cost per tonne for $250 or $500,000 per machine is reasonable. To build 7.5 million machines at $500,000 per machine is $4 trillion. Now, not all the machines will sequester carbon because many will be used to make renewable liquid fuels. So 20 million machines and $10 trillion is a reasonable estimate and is certainly affordable because in REME the economy is growing at a very fast rate so that $10 trillion will be a low single digit percentage of the economy. Of course, the carbon-to-value technologies that use and sequester the CO_2 will be more capital intensive. The whole idea is that REME will create economic growth and prosperity, so it is not a cost to the economy, it is the economy.

Now, to produce 7.5 million machines requires 32 doublings or roughly a doubling every six months. This is faster than can be expected from the economy on its own, and is why a mobilization effort is needed, especially because the carbon-to-value efforts need to grow at a comparable pace. However, viewed from the point of view of having a capacity to produce 7.5 million units the size of a shipping container or even 20 million is smaller than the number of cars produced each year, which is about 100 million vehicles.[17]

In the paper describing REME credit was taken for roughly 10 million tonnes per year capacity of installed flue gas technology reducing the doublings needed or DAC from 35 to 17. In the REME paper it was also assumed that there was limits based upon past attempts of how fast one would scale up. The response to the Pandemic has made clear that it is better to take unusual steps before a crisis hits and thus changing the doubling time for DAC to one year and combining them with accelerated conversion to renewables and emission reductions could also avoid going above 450 ppm. In any case much more detailed analysis will be needed to specify the exact rate of deployment needed and it too will need to be continually modified as we get new information about the technology and the state of our planet. But in all cases considered we will be challenged to develop the needed capacity in time to avoid catastrophic climate change.

Once one has reached zero emissions, one will then need to decide whether reducing the CO_2 levels below 450 is needed or desirable. To go back down to say 400 ppm in 10 years would require an increase in capacity from 2.4 ppm/year to 5 ppm/year, which is just another doubling. This is clearly not difficult and is part of an important conclusion: we will have the capacity to control the total carbon cycle of the planet, both human and natural contributions, and maintain the temperature of the planet of our choosing. As shown in[18] stabilizing the planets temperature requires less energy than we use to maintain the temperature in our buildings because of the positive feedback created by the long lifetime of CO_2 in the atmosphere. It means that we will no longer have ice ages. More generally, we can conclude that the threat of climate change arose because of our success in science and technology and that in addressing the threat of climate change, the same capability if redeployed wisely, can prevent any future climate change.

Carbon Management Policy for REME

To provide incentives for converting to a REME economy, one needs a simple system that provides a financial penalty for using currently sequestered carbon, a benefit for sequestering carbon from the air in products and in the ground, with the former being preferred because of its positive feedback. Processes that take carbon from the air and have it returned to the atmosphere are unaffected. The specific amounts and how to implement them is beyond the scope of this document but is a crucial part of the mobilization effort. However, to develop the carbon-to-value technologies required, various incentives will be needed and cooperation rather than competition within the new industries will be required to develop them and DAC at the scale and rate needed. But in REME, the demand is so great that each new industry will be challenged to develop the needed capacity. This is not much different than what we see happening at a smaller scale among drug companies and the health industry in trying to find and develop a vaccine in an unprecedented short period of time. Such fast rates happened in the past during ship building in World War II and more recently in China with solar, though their rates were slower – a doubling time of a year.[19]

Financial Mechanisms and Policies to ensure Equity

The past work of Graciela Chichilnisky in the development of the Carbon Market[20] within a United Nations Framework together with her recent work and those of others on "green economics" and more generally the need to have policies that reflect the social value of our efforts become part of a future economy, REME. REME has the additional benefit that it makes those policies easier to implement because of the more equitable distribution of the sun, air, and water than was the case for the inputs in our natural resource-based economy. Again, the specifics of this need to be developed and are beyond the scope of this document that is making the case for mobilizing via REME.

Conclusion

Mobilizing behind REME can turn the devastation of the Pandemic and the threat of climate change into the creation of an equitable, sustainable future for us and life that shares this planet with us. The encouraging fact is that our past science and technology has provided us the capability to implement REME and its fast pace of innovation promises even better solutions during the decades during which the climate change challenge will be addressed. The bottom line conclusion is very clear: we have the responsibility to cooperate globally and use our capability and mobilize to transform from a natural resource to a REME for the sake of those suffering economic devastation today and to provide the future that we would want for ourselves. In coming together will in fact make the most important change of all – in ourselves.

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[1] From Wikipedia, https://en.wikipedia.org/wiki/Technological_singularity

[2] Tipping points Explainer: Nine 'tipping points' that could be triggered by climate change, 10.02.2020

https://www.carbonbrief.org/explainer-nine-tipping-points-that-could-be-triggered-by-climate-change

[3] As Climate Change Worsens, A Cascade of Tipping Points Looms, 5.12.2019, https://e360.yale.edu/features/as-climate-changes-worsens-a-cascade-of-tipping-points-looms

[4] Renewable Energy and Materials economy, 17.05.2020, https://elkinstitute.files.wordpress.com/2020/05/remepdf.zip

[5] Renewable Energy and Materials economy, 17.05.2020, https://elkinstitute.files.wordpress.com/2020/05/remepdf.zip

[6] International Journal of Green economics 21.1.2009, 3(3/4) : 414-46

[7] Carbon Negative Power Plants, May 2011, https://chichilnisky.com/pdfs/Carbon Negative Power Plants.pdf

[8] Eisenberger PM. Chaos Control: Climate Stabilization by Closing the Global Carbon Cycle (Energy & Environment. 2014 Jul 1; 25(5):971-90),

[9] Saving Kyoto, Graciela Chichilnisky 2009

[10] The decoupling of GDP and energy growth: A CEO guide, 24.4.2019, https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/the-decoupling-of-gdp-and-energy-growth-a-ceo-guide

[11] How much of world energy consumption and production is from renewable energy?, 27.9.2019, https://www.eia.gov/tools/faqs/faq.php?id=527&t=1

[12] Tipping points Explainer: Nine 'tipping points' that could be triggered by climate change, 10.2.2020,

https://www.carbonbrief.org/explainer-nine-tipping-points-that-could-be-triggered-by-climate-change

[13] As Climate Change Worsens, A Cascade of Tipping Points Looms, 5.12.2019,

https://e360.yale.edu/features/as-climate-changes-worsens-a-cascade-of-tipping-points-looms

[14] International Journal of Green economics 21.1.2009, 3(3/4) : 414-46

[15] The U.S. solar industry now employs nearly 250,000 workers, according to the 10th annual National Solar Jobs Census. These jobs are providing clean, affordable, renewable energy in all 50 states, 2019, https://www.thesolarfoundation.org/national/

[16] CO_2 earth – are we stabilizing yet? 8.1.2020, https://www.co2.earth/co2-acceleration

[17] Estimated worldwide automobile production from 2000 to 2019, 2020, https://www.statista.com/statistics/262747/worldwid

[18] Eisenberger PM. Chaos Control: Climate Stabilization by Closing the Global Carbon Cycle (Energy & Environment. 2014 Jul 1; 25(5):971-90),

[19] China's solar power capacity more than doubles in 2016, 4.2.2017, https://www.reuters.com/article/us-china-solar/chinas-solar-power-capacity-more-than-doubles-in-2016-idUSKBN15J0G7

[20] Saving Kyoto, Graciela Chichilnisky 2009, for purchase online at https://www.amazon.com/Saving-Kyoto-Graciela-Chichilnisky/dp/1847734316