Human Made Global Warming Must Stop

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Man-made global warming likely will worsen already existing human tragedies of war, starvation, glaring inequalities, poverty, flooding, prolonged droughts, erosion, extreme weather and disease (IPCC,2014). The problems with the fossil fuel age are grave. There are four main problem areas:

Environmental Pollution

Coal and oil contain chemicals and particles detrimental to health and environment. We emit carbon, nitrogen oxides, aromatics, benzene and sulfur in large quantities. Oil spills and air emissions have serious and long-term toxic effects. Fossil energy has many hidden costs. When costs of damaged eco system services, environmental damage and climate change are included in the overall accounts; fossil fuels are no longer profitable. According to the International Monetary Fund (IMF) energy subsidies paired with the negative impacts of fossil fuel consumption total $2 trillion annually. These subsidies are not only hurting the environment, they're also stunting economic growth and spurring inequality (Clements et al, 2013)

Non-Renewable, Finite Resources and Vulnerable Communities

Fossil fuels are non-renewable resources. We use the most readily available sources first, and become dependent. To meet global demands; less accessible, marginal sources are needed. The cost of extracting one barrel of oil from the old, big sources in the North Sea, Saudi Arabia, Texas and Baku is less than 10 dollars. The production price of the same *barrel from a marginal source such as a well in the Barents Sea might be ten times higher or more. Profit margins on unconventional, marginal sources drop rapidly. When the old sources go dry, oil revenues will decrease while costs rise. The oil industry is therefore a "sunset industry". International oil trading requires the marginal, unconventional oil sources such as tar sands oil and expensive sources in difficult areas to keep the wheels turning.*

Vulnerable Logistics, Volatile Prices and Uneven Geographical Distribution

The largest reserves of cheap oil are concentrated in the Middle East, some old "Soviet countries" and Africa. These reserves are controlled by "Big Oil" – directors in close connection with corrupt and fanatical regimes or individuals with their own agendas. More than half of the global oil proceeds go to such regimes. The Carbon Society is dependent on a regular supply, and is vulnerable to uncontrolled price fluctuations. Huge accumulations of capital by corrupt individuals and undemocratic regimes create violent conflicts that threaten democratic governance and continuously cause new financial crises.

CO_2 Emissions, Global Warming and Climate Change

The world's most esteemed climate scientists have proven global warming of air, land and sea (IPCC, 2013).. Rising temperatures, rising sea levels, reduction in glacier ice and snow, warmer seas and acidification are among the symptoms. Our climate systems are already changing, resulting in more unpredictable weather, extreme weather events such as storms, droughts, heavier snow in winter seasons, fifty-year-floods every five years, forest fires and various difficulties for agriculture. Society's vulnerability increases rapidly without massive development of alternative energy sources. Continued long-term use of fossil fuels is deeply unethical, threatens life on earth and in the long run will be financially devastating (Bjørke, 2013).

Transformation Urgently Needed

The generation currently in power has profited hugely from the era of oil, while the generation taking over shall have to pay the price of the accumulated ecological debts, inequalities and conflicts. It is only right that the generation in power cleans up its act.

Priority must be given to rapid transformation of our economic systems to a responsible, sustainable one, like e.g. the UN suggests in the proposal on a sustainable "green economy" (UNEP, 2011). We must wean ourselves off our addiction to fossil fuels. New energy forms must be developed and implemented as quickly as possible. A more equal and responsible distribution of wealth and education to all is a prerequisite for a successful transition to a sustainable society.

Indeed, it could be asserted that achieving a paradigm shift in education is required to enable us to abandon the short term exploitation goals and gain proper optics which would enable our civilization to abandon the addictions described above and switch to a long term sustainable development model. The change would have to be achieved, among others, by abandoning the pre-Victorian and industrial revolution models of development, distribution and education our societies still cling to. We need to develop ability to perceive and resolve social and environmental problems in a more integral way. It is therefore an equal priority for our societies as is the sheer survival issue of stopping the greenhouse gases proliferation. If we turn this equation upside down it could be said that, have we had been successful in reforming our educational systems timely, we might have not had to face the issues of unsustainable development in the first place.

It is increasingly clear we need to change both development and educational models at the same time if we are to keep our ambitions to change our civilization so to enable its long-term sustainable development. This planet never properly came to terms with the consequences of more than doubling its population within the lifespan of a single living generation and accordingly, never came up with a strategy of reorganization of its obsolete social models. Such a change in size of our population never happened on this scale in human history, and most likely never will be repeated. This singular challenge has not been neither adequately nor timely addressed and we would submit that it has to be tackled on a massive scale by adopting the different consumption and development models in order to avoid aggravating the problems we are facing now in respect of the environmental pollution.

Climates Already Changing

Unfortunately, the man-made global warming has gone too far. According to the latest IPCC report, it would be wise to leave most of the remaining fossil fuels underground (Le Page, 2013). Global warming and climate change happens now. The impacts are already severe. The target of a 2-degree limit in the Copenhagen accord is based on what was politically possible to achieve at that time, not on science. The two degree limit is estimated to be exceeded when the accumulation of CO_2 in the atmosphere passes 400 ppm. This limit is probably not safe, and should rather have been set at 350 ppm (UScan, 2010). The 400 ppm threshold was briefly passed in 2013, and will likely be permanently passed by 2016 (NOAA, 2013). If the other greenhouse gases are included as CO_2-equivalents, we have passed 473 ppm, according to UNEP. If we add the 5% increase in atmospheric water vapor that global warming so far has caused, we are approaching 500 ppm

Since the start of the industrial era in 1750, about 375 billion tonnes of carbon have been released into the atmosphere as CO_2, primarily from fossil fuel combustion, according to WMO's 2011 Greenhouse Gas Bulletin, which had a special focus on the carbon cycle. About half of this carbon dioxide remains in the atmosphere, with the rest being absorbed by the oceans and terrestrial biosphere. "These billions of tons of additional carbon dioxide in our atmosphere will remain there for centuries, causing our planet to warm further and impacting on all aspects of life on earth...Future emissions will only compound the situation. Until now, carbon sinks have absorbed nearly half of the extra carbon dioxide humans have emitted in the atmosphere, but this will not necessarily continue in the future. We have already seen that the oceans are becoming more acidic as a result of the carbon dioxide uptake, with potential repercussions for the underwater food chains and coral reefs. There are many additional interactions (feedback loops, synergistic reactions) between greenhouse gases, Earth's biosphere and oceans, and we need to boost our monitoring capability and scientific knowledge in order to better understand these.

The National Oceanic and Atmospheric Administration's Annual Greenhouse Gas Index, quoted in the bulletin, shows that from 1990 to 2011, radiative forcing by long-lived greenhouse gases increased by 30%, with CO_2 accounting for about 80% of this increase. Total radiative forcing of all long-lived greenhouse gases was the CO_2 equivalent of 473 ppm in 2011 (UNEP, 2012).

We now see an accelerated melting of the glaciers in the Arctic (NASA, 2013), in turn triggering the big feedback mechanism of reduced albedo contributing to further warming and increased heterotrophic respiration on land. The global warming the last three decades has been dramatic and seems to have an accelerating trend (WMO, 2013, Cowtan and Way, 2014). The Pacific Ocean now warms 15 times faster than it used to (Rosenthal, Braddock and Delia, 2013), and according to another report global warming accelerates (Skeptical Science 2013). A devastating global warming will be very difficult to avoid in this century if the ecosystems reach a tipping point and the large feedback systems like reduced albedo, increased atmospheric water vapor and the release of methane (and carbon dioxide) from melting permafrost (Solovyov, 2007) and clathrates – frozen methane hydrates on the sea floor (Ruppel, 2011). Many indicators point to that it is probably too late to stop a global warming of 2 degrees centigrade. Most likely, we shall reach a 4-degree warming this century. Such a rise in temperature will most likely mean the end of civilization (Nature, 2013).

Too Little Too Late

There are signs indicating that the increase in the rate of anthropogenic carbon emissions might be going somewhat down. However, this is far from enough. The G20 countries need to reduce its carbon intensity at 6% per year. But the 5-year trend shows we have only averaged 0.7% decarbonization annually. Even doubling the current 0.7% rate of decarbonization puts us on a path consistent with the most extreme scenario presented by the IPCC, and thus a potential warming of around 4^{o}C by 2100 (PWC, 2013).

It seems that even with a long and severe financial crisis, we have so far been unable to significantly reduce our GHG emissions. If the economic situation should improve, it is likely that emissions will increase. Some people point to that solar radiation has been low the last decades, and that we might even experience a "Maunder's minimum", which gave us "the little ice age" some centuries ago (Pearce, 2013). However, the Maunder's minimum meant an average reduction of 0.4°C, which is only half of the manmade global warming so far. The last three decades are the warmest ever measured (WMO, 2013) and the 9 warmest years have occurred after 1998 (Satterfield, 2013). This indicates a quite significant jump upwards in temperatures when the solar activity and radiation revert to "normal".

The Earth's ecosystems are already strained. It is therefore not sufficient to just reduce the rate of GHG emissions. We should prepare for sequestering CO_2 at a large scale to be on the safe side.

Man-made climate change is happening and its impacts and costs will be large, serious and unevenly spread. The impacts may be reduced by adaptation and moderated by mitigation, especially by reducing emissions of greenhouse gases. However, global efforts to reduce emissions have not yet been sufficiently successful to provide confidence that the reductions needed to avoid dangerous climate change will be achieved. This has led to growing interest in geo-engineering, defined here as the deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change (Royal society, 2009).

Blinded by Events

One of the most serious impediments to properly perceiving the real impact of climate change is that climate change can be better described as a process then as an event. Our media do not favor reporting or analyzing processes, most likely because, to put it simply, they don't sell the content. In order to be able to sell as many advertisements as possible the media prefers to promote events over the processes as they enable thicker rhythm of programs that tie the consumers to their streams. Hence the proliferation of daily news on the events that have suffocated clear vision throughout the entire twentieth century, when the large scale pollution started overwhelming the natural balance of the Earth. Most individuals were just not prepared to see the bigger picture at the critical time. It could be speculated that only the onset of the Internet enabled the emergence of the group vision that compensated for the short span views that characterized the industrial and individual logic until after the turn of the century. We need to boost this capacity on a large scale and speed up emergence of public opinion on relevant and complex issues.

Another important weakness, easily perceived in the context of fighting global environmental challenges, is the absence of institutional mechanisms for submitting, evaluating and deploying the promising technologies in an efficient manner. Barriers, such as national sovereign barriers and the established business models with their vested interests have proved to be proverbially hard to crack. There could be little doubt that the future global community needs to develop consensus and find a solution to uproot this type of barriers. Many promising technologies were repeatedly faced with the resistance of the existing industrial models that blocked introduction of differing models. The tendency to resist change so long as the existing model is profitable has repeatedly proved to be a major factor of slowing down implementation of necessary solutions. In the case of climate change, slowing down is the last thing we can allow ourselves at this juncture. This problem is compounded by the fact that the successfully established business models do gain market dominance that allows them to use their vast resources in order to, both overcome the national borders, clog the social institutions with vested interest and thus hamper the efficiencies our societies need to properly react in defense of the environment.

Geo-Engineering

On this background it seems that some kind of geo-engineering is inevitable to give us sufficient time for transforming economies and societies in an adequate direction. Whether we want to admit it or not, we humans have been involved in large scale geo-engineering since 1750 by continuously adding greenhouse gases into the atmosphere. Unfortunately the only solution to a problem of such magnitude is another form of deliberate geo-engineering. We must catch this excess fossil carbon dioxide and sequester it back into the geological reservoirs where it originally came from.

According to the Royal Society there are two basic categories of geo-engineering methods:

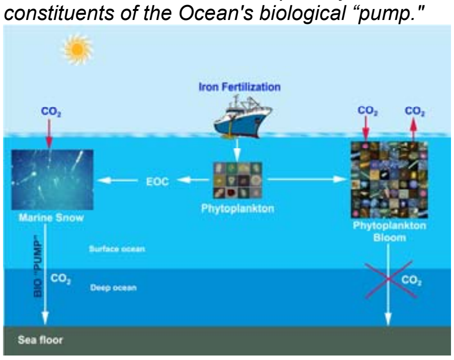
Carbon Dioxide Removal (CDR) techniques, which remove CO_2 from the atmosphere. As they address the root cause of climate change, rising CO_2 concentrations, they have relatively low uncertainties and risks.

Solar Radiation Management (SRM) techniques, which reflect a small percentage of the sun's light and heat back into space. These methods act quickly, and so may represent the only way to lower global temperatures quickly in the event of a climate crisis. However, they only reduce some, but not all, effects of fossil fuel combustion and climate change, while possibly creating other problems. They also do not affect CO_2 levels and therefore fail to address the wider effects of rising CO_2, including ocean acidification.

The solar radiation techniques as a rule will add chemicals like sulfuric acid aerosols to the stratosphere, thereby increasing the albedo. However, it is probably not very wise to combat one type of pollution with another type of pollution. Millions of tons of sulfuric acid "solar mirrors" would have to be sprayed throughout the stratosphere to produce a cooling effect. At some point in time these chemicals would deposit out of the atmosphere in wet or dry form, both on the continents and oceans.
We therefore strongly advocate the CDR technique. As far as we can see, the only natural system on the planet powerful enough to reverse the current trends of global warming, is the formation of marine snow. Other attempts, such as carbon capture and storage and fertilization on high nitrate low chlorophyll

(HNLC) regions of the oceans by initiating large-scale phytoplankton blooms have failed.
Marine snow aggregates are ubiquitous components of all oceanic systems, appearing in different sizes and forms depending on the local oceanographic conditions. They appear to be self-contained and self-sustaining environments and can significantly contribute to sequestration, sedimentation and burial of newly produced organic matter from the water column. In specific conditions aggregates are not degraded, remineralized or colonized by zooplankton. When sinking below the pycnocline (the layer separating upper and lower waters in a water column) they efficiently bypass mid-water biota thus becoming perhaps the most important sequestration component of the marine biological pump (see Figure 1) and the path of particulate organic carbon to the sea floor.

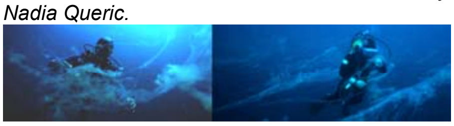
Figure 1 *Communities of heterotrophic bacteria and autotrophic cyanobacteria within the "marine snow" matrix, are the primary constituents of the Ocean's biological "pump."*



In some regions of the world, the surface waters of the oceans, notably the Southern Ocean, are deficient in iron, which limits the growth of phytoplankton (Martin and Fitzwater, 1988). By fertilizing the oceans with the proper amount of iron, these microscopic plants would be encouraged to grow and absorb excess carbon dioxide from the atmosphere (Martin et al., 1994).

The major problem facing ocean fertilization is the amount and form of iron needed to initiate growth response of phytoplankton. Applying a "traditional" fertilization approach (Boyd et al., 2000; Boyd et al., 2004; Coale et al., 2004), a fleet of ships would have to be commissioned to spread the millions tons of iron (Fe) needed each year to initiate massive phytoplankton blooms that have a tendency of dramatically changing community composition of autochthonous, native microbial communities. This would be necessary each year in order to mitigate anthropogenic emissions of CO_2. Also the precise area of the ocean where such fertilization must be done is uncertain.
The second problem is that the phytoplankton absorbing the excess carbon would not easily sink into the deep oceans. They are too small, and ocean currents work against their sedimentation (Buesseler et al., 2005). Moreover, other organisms within the ocean surface food webs eat phytoplankton cells and through respiration convert their carbon back to atmospheric carbon dioxide in short periods of time. In essence, the biology of the ocean works against the burial scheme (Chisholm, Falkowski and Cullen, 2001). The system that efficiently transports the newly produced organic matter, sometimes called "biological pump", refers to marine snow (See Figure 2). By stimulating the formation of marine snow by triggering elevated extracellular release of specific organic compounds by existing phytoplankton populations (instead of initiating massive phytoplankton blooms that have a tendency of dramatically changing community composition of autochthonous, native microbial communities) we could remove tremendous amounts of organic matter to the ocean depths without significantly changing the conditions occurring naturally in the surface oceanic environment. Environmental impacts that must be scrupulously considered prior to large-scale application are benthic carbon load, water column nutrification and implications to natural communities. Numerous studies throughout the world have documented the benthic impact associated with fish farming (Table 1; from Costa-Pierce and Bridger, 2002). Owing to greater residual current, potentially deeper water, and greater assimilative capacity in open ocean conditions, benthic impacts from exposed aquaculture operations are anticipated to be less than comparable sized near shore operations. According to the Riedel and Bridger (2004) impact model, cages operated at 40 m depth resulted in 20% less TOC (total organic carbon) accumulation than those operated at 20 m. Operations at 60 m resulted in an accumulation of TOC of over 60% less of that from 40 m. Hence marine snow particles have slower sinking rates than feed and feces from aquaculture operations. It can be postulated that marine snow sinking out of the epipelagic zone (0-200m depth) over a water column of >3000 m depth will not have measurable environmental impact on the sea floor below. Additional research is necessary to validate the impact of increased production of marine snow on the nutrification impact of the "twilight zone".

Figure 2 *Massive aggregation of marine snow in the Northern Adriatic in 1997. Photos taken by Nadia Queric.*



Action

If we accept that ethical hacking might be one of the acceptable methods of bringing our civilization's system up to date, and that a participatory social model require of the individuals to indeed try to upgrade the inadequate models, we might bring about an important emergence of understanding of our powerful influence on our planet. This might bring about an emergence of increased responsibility of our civilization towards the environment.

In a further analogy with the computing world, it might be said that the proposed model of using marine snow on a geo-engineered scale is a kind of "white hat" (ethical) intervention that we must responsibly engage in, once we are certain that the benefits outweigh the potential pitfalls. Obviously, for this to work we need to achieve a consensus within the global community and secure that the "black hat" (unethical) hacking does not interfere with the deployment of the proposed marine snow based method of carbon sequestration.

In other words, a multi-stakeholder partnership encompassing public and private, sovereign, group and individual interests, such as countries, regions, multilateral and bilateral international organizations, NGOs and citizens need to become aligned in their understanding of the need to change and the particular change they wish to achieve. The above is a proposal for such action.

Representing the Future Generation

Because the economy and modern society is built on consumption it is very difficult to rehabilitate and quit abusing oil and overconsumption. These patterns of life and values have been deeply embedded in the lives of the coming generation. This generation has become accustomed to a leisurely and easy lifestyle, and many children have lost connection with nature. Some even think milk comes from the shop, not a cow. The transformation towards a sustainable society and economy will take time. Previous research has shown that significant part (81 %) of the population between 18 and 40 years old are open-minded towards sane geoengineering approaches (Edvardsen and Puškarić, 2012). It must be clearly understood that geoengineering the climate is not a quick fix to all the environmental problems we face, but it can buy us some time to transform our society towards a sustainable future. Furthermore more than 50 % of the respondents in the study think they can change towards a more sustainable lifestyle if the environmentally friendly products and greener options are available. Luckily, technologies such as waste to energy, recycling, and clean energies are already available. Organic production, products made from natural material instead of oil based synthetic materials, healthy living instead of toxic non degradable medicines and long lasting products instead of planned obsolescence must be available and promoted. This demands a large transformation in behavior and value patterns in our society. Luckily the generation taking over is used to a society defined by constant change (Tulgan, 2009, p. 7). Such a change is therefore possible. However, it takes time. Since time is not the luxury we have any more, we opt geoengineering as one element in the rehab and transformation process of our society.

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