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Why Technical Fixes Won't Mitigate Climate Change

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Abstract

We may have already surpassed prudent limits for atmospheric greenhouse gas concentrations, and have exceeded (or are near) safe limits for a number of other Earth system processes. If fossil fuels maintain their present share, bringing the expected year 2050 world population up to US primary energy levels would involve a 6-fold rise in energy consumption, with a similar rise in CO_2 emissions. We argue that even a combination of the various conventional approaches for climate mitigation will prove to be 'too little too late'. If use of geoengineering to delay some of the consequences of climate change is judged too risky, we conclude the only remaining approach for meeting the needs of all humans while staying within the Earth's bio-capacity is to abandon our current growth-oriented economies. Even this strategy could face difficulties if population does not peak soon.

Key Words: alternative energy, climate mitigation, human needs, geoengineering, technical fixes

1. Introduction

Since the Industrial Revolution, the planet has warmed about 0.76 ºC, and because of thermal inertia of the oceans, a further 0.6 ºC is unavoidable. Yet avoiding dangerous anthropogenic climate change could require us to limit the total temperature rise to 2 ºC above pre-industrial, as adopted by the European Union (Meinshausen et al. 2009). Clearly, if this value is accepted, drastic action is needed either to reduce our emissions of greenhouse gases (GHGs) to the atmosphere, or to somehow counterbalance the positive 'forcing function' from GHG increases.

Rockstrom et al. (2009) have argued that we have already surpassed prudent limits for atmospheric GHG concentrations, and exceeded (or are near safe limits for) a number of other Earth system processes. Yet the high material consumption levels enjoyed by the West are restricted to a small fraction of the world population. Bringing the expected year 2050 world population up to US primary energy levels would involve a 6-fold rise in energy consumption, with a similar rise in CO_2 emissions, if fossil fuels maintain their present share (Moriarty and Honnery 2010a). Adaptation to the already changing climate is also needed, but there are clear limits to its efficacy. In brief, we need to mitigate climate change.

2. The Failure of Conventional Mitigation Methods

Conventional mitigation methods aim at reducing or slowing GHG emissions to the atmosphere (NAS 2010a,b,c). They are thus inherently conservative, in that their intent is to either slow down the rate of movement along an existing emissions path, or even return to earlier emission levels. Possible conventional approaches include:

- replacing fossil fuel energy use by renewable energy (RE) sources
- replacing fossil fuel energy use by nuclear energy
- reducing energy use through energy efficiency improvements and conservation
- reducing CO_2 emissions through biological carbon sequestration in soils and forests, carbon capture and sequestration (CCS), and air capture.

2.1 Renewable Energy

Modern forms of renewable energy presently provide about 17 EJ (EJ=exajoule=10^{18} joule) of primary energy, mostly hydro and liquid fuels from biomass. Much more is provided from traditional fuel wood, probably about 45 EJ. For comparison, present global primary energy use is around 500 EJ (Moriarty and Honnery 2009).

The renewable energy sources can be divided into two groups: those that can supply energy on a continuous basis (such as hydro, biomass and geothermal energy), and those that are only intermittently available (such as wind and the various forms of solar energy). Unfortunately, only the intermittent sources have sufficient technical potential to supply anything like our present global use (Moriarty and Honnery 2007). Using intermittent sources to supply continuous (baseload) power requires conversion of the energy to carriers such as hydrogen, which can reduce energy availability by a factor of roughly two and more if energy storage costs and reconversion back to electricity are included (Honnery and

Moriarty 2010). For solar energy, low winter output would require much redundant capacity (Trainer 2010). Hydro presently supplies about 11 EJ of electricity, but the world total that can be economically developed may be at most 30 EJ. Although technical potentials as high as 1000 EJ have been claimed for biomass, others consider that only around 30 EJ can be sustainably produced without reducing global food production.

The share of renewable energy (RE) in electricity production has been falling for decades, and in recent years, also its share of global primary energy use. What are its future prospects? Official organisations like the International Energy Agency (IEA) and the US Energy Information Administration (EIA) have projected RE use out to 2030 under various scenarios. For the IEA (2009), RE improves its present share of 12.7 % of world energy in 2007 to 14.2 % in their reference scenario. Only in an optimistic 450 ppm CO_2-equivalent (CO_2-e) stabilisation scenario does RE share rise to 23.4 % in 2030. The EIA (2009) foresaw RE achieving about a 3 % growth rate in all scenarios.

On present trends, all we can hope to do is modestly reverse RE's declining share of the global energy market. Fossil fuel power plants have lives of up to 50 years or more, and most new electricity plant will use fossil fuels. Even in the European Union, a region that has gone furthest in pledges to reduce GHG emissions, a 2009 survey of member countries found that only 8 % of new electricity capacity under construction would use renewable energy sources (Anon. 2009).

2.2 Nuclear Energy

Nuclear energy in 2008 had a 6 % share of world primary energy use, and provided 13.6 % of global electricity, down from 16 % in 2004 (BP 2009). The IEA (2009), in their Reference Scenario, forecast nuclear's share of primary energy falling to 5.3 %, and in their more optimistic scenario, rising to 9.5 % by 2030. The EIA, even in the scenario most favourable for nuclear power, only saw a 6.3 % share of global energy in 2030. Even the International Atomic Energy Agency (IAEA) (2008) projected that nuclear's share of global electricity will at best only rise to 14.4 % by 2030. Like the EIA and IEA, their less optimistic scenario saw nuclear energy losing share.

In their recent survey of the global status for nuclear energy, Schneider et al. (2009) argued that nuclear power will not be able to maintain its present share of global energy, mainly because most nuclear power plant construction will merely replace ageing reactors. The high costs and financial risks of new nuclear plants (Romm 2008) will further limit net growth in nuclear power.

2.3 Energy Efficiency

At first glance, there is enormous potential for energy efficiency to cut energy use, and thus CO_2 emissions. Only a small fraction of the energy in the petrol tank propels the vehicle forward, and a far smaller fraction moves the occupants and their luggage. Similarly, the energy efficiency of incandescent light globes is very low. Furthermore, many measures for improving energy efficiency are available at low or even negative cost. The obvious question arises: why aren't these energy savings taken up by households and businesses?

One possible answer is that energy efficiency is not the only criterion used to select which mode we travel by, or how we run our factories and buildings. Other types of efficiency may be considered more important, such as 'time use efficiency' (i.e. speed) in travel and land use efficiency (i.e. output per hectare) in agriculture and other activities where land has a real or imputed rent. These different types of efficiency can be in conflict with each other: the more energy efficient travel modes (public transport, walking) are also slower; traditional subsistence agriculture may be more energy efficient, but often has much lower output per hectare than modern industrialised farming.

Another important reason why energy efficiency is not likely to cut our energy use and consequent GHG emissions much is that various feedback mechanisms operate. The energy rebound effect occurs because an improvement in the energy efficiency of some device now makes its operation cheaper, which in turn increases its use. Population growth also increases energy consumption, as do rising incomes which allow larger houses needing more heating or cooling. And in a growth economy, new energy-using devices are constantly entering the market, pushing energy use up. The overall result is that our devices and practices are becoming more energy efficient, but at the same time (except for 2009) global energy use has continued to rise (BP 2009).

2.4 Carbon Sequestration

The world's soils and forests have lost an estimated 200 billion tones of carbon (GtC) over the past two centuries (Lal 2004). Reforestation and increasing soil carbon would thus merely help restore the *status quo ante*. However, the world is still losing biomass carbon to the atmosphere, because of net deforestation. Given ongoing climate and land-use change and global population growth, we will be fortunate if we can prevent further net carbon loss.

Other methods of carbon sequestration are mechanical. CCS would capture CO_2 from large fossil fuel plants, such as coal-burning power stations, compress it, then transport it to chosen sites for underground burial. According to the 2007 IPCC report (Solomon et al. 2007), CO_2 accounts for about 77 % of all net climate forcing, and 74 % of CO_2comes from fossil fuel combustion and other industrial processes. If only 40 % of CO_2 from fossil fuel use were technically suitable for capture, then at best we could sequester 23 % of all CO_2-e emissions. For a longlived gas such as CO_2, it is *cumulative* emissions that are important for climate change. Since CCS can only capture current emissions, at best we will fall far short of 23 % capture. Clearly, CCS cannot be more than part of a mitigation strategy. At present, only about five Mt of CO_2 are sequestered each year, compared with total CO_2-e emissions of about 30 Gt. Even capturing 23 % would need some three orders of magnitude scale-up. Air capture could potentially capture all past and present CO_2 emissions but its heavy energy costs would rule it out (Moriarty and Honnery 2010a,b).

3. Geoengineering and its Risks

As discussed here, geoengineering is action intended to manipulate climate on a global, or at least regional, scale. Corner and Pidgeon (2010) have pointed out that our emissions of CO_2 (which have raised atmospheric CO_2 levels from the pre-industrial 280 ppm to the present 387 ppm) could also be considered geoengineering. If so, we are merely arguing about different forms of the practice.

The potential use of geoengineering for climate mitigation received a boost with a paper by Nobel laureate Paul Crutzen (2006). Like the present authors, he argued that conventional methods of mitigation were not working—the CO_2 atmospheric concentration continues to climb at about 2 ppm each year. His inspiration was the significant drop in global temperatures recorded in the year following the Mount Pinatubo volcanic eruption in the Philippines in June 1991. The cooling resulted from the emission of some 10 Mt of sulphate aerosols into the lower stratosphere in the tropics. Continuous deliberate placement of fine sulphate aerosols in the lower stratosphere would reflect some of the incoming short-wave solar radiation, increasing the Earth’s albedo, and counteracting the positive forcing from increased levels of GHGs.

The options available for geoengineering can be either local in extent (such as altering the albedo of deserts, crops or urban areas) or global (such as the use of giant space-based mirrors). Only aerosol placement in the tropical stratosphere, albedo enhancement of marine stratiform clouds and reflective mirrors in space would have the potential to counteract a doubling or more of atmospheric CO_2 ppm (Lenton and Vaughan 2009). Of these global approaches, the cheapest is likely to be aerosol placement. Except for space-based mirrors, the approaches appear both far cheaper and far faster to implement than more conventional mitigation methods.

Because of the lack of progress in slowing emissions and the low cost and rapid cooling resulting from global measures, geoengineering is gaining acceptance. The U.K. Royal Society (2009) has endorsed it as a technique to be used alongside other mitigation methods. But implementing measures to reduce the planetary albedo run enormous risks. Global precipitation would on average be reduced—it is not possible to bring both global temperatures and precipitation to their previous levels (Bala 2009). Acidification of the oceans would continue, potentially destabilising ocean ecosystems (Doney et al. 2009).

Also, because elevated levels of CO_2 will persist for centuries, so too must geoengineering—the continuous placement of aerosols, for example. Any abrupt cessation because of dangerous side effects discovered would rapidly raise the forcing to levels corresponding to the GHG concentrations at that time, resulting in very rapid warming, with possibly catastrophic effects on ecosystems (Matthews and Caldeira 2007). Thus although the costs of aerosol*placement* may well be modest, the overall cost of countering the unwanted consequences could be very high.

Recently, perhaps because of these serious drawbacks, some researchers have modelled the effects of more modest aerosol placement schemes. Rather than global year-round aerosol coverage, they have looked at techniques that might prevent melting of the Greenhouse ice cap or Arctic summer sea ice, or summer warming of the north Atlantic during the hurricane season (Caldeira and Wood 2008, MacCracken 2009). The aerosols might be locally applied, for part of the year, to address a very specific problem resulting from climate change. But to be effective, their effects would necessarily be felt globally (Caldeira and Wood 2008), and if several of these projects were to be implemented simultaneously, the combined gobal effects might be extremely uncertain.

4. Discussion

We have argued so far that none of the various conventional approaches for climate mitigation will be effective, and that even in combination will prove to be 'too little too late' (Moriarty and Honnery 2010a). This conclusion is also reached by the rising numbers of researchers supporting—perhaps reluctantly—geoengineering, who usually view it as the sole remaining option.

But it is not; technical fixes such as those discussed do not exhaust the possibilities. In previous work, we've argued that the policy of continued economic growth should be abandoned for two reasons. First, as argued by Kitzes et al. (2009), the demand for ecosystem services may have already exceeded the sustainable biocapacity of Earth—we are in unsustainable overshoot, as Randers (2008) has stressed. Second, as a number of researchers, including Jackson (2009), van den Bergh (2009) and the editors of Nature (Anon. 2010) have argued, GDP per capita is no longer a reliable indicator of welfare, at least in the high-income countries. Globally, the rise in GDP in recent decades has been tightly linked to rise in global primary energy use (Moriarty and Honnery 2010a). As it presently measured, we probably can't increase global GDP for very much longer, and we shouldn't even try, given its decreasing relevance to global welfare. If we remove the artificial constraint of ever-rising GDP, we can focus on the global satisfaction of human needs.

All humans have a need for adequate provision of food, potable water, shelter, health and education services, as well as for sociality and so on. The UN has incorporated these human needs into its Millennnium Development Goals (Moriarty and Honnery 2010a). We propose that economies focus on these needs, attempting to satisfy them for all, with a minimum use of depletable resources and environmental damage. In a world with many resources yet to be exploited, the wealth of a minority would not be at the expense of the poor. But if resource use is already at or nearing unsustainable levels, our argument is that the only way the needs of an expanding population can be met is by abandoning global economic growth, and with it the high-energy lifestyles of the West. Rees (2008) argues that the West will need to cut 'energy and material consumption by up to 80%', with equity being an essential component of this challenge (Moriarty and Honnery 2010b). Social innovation, just as much as technical innovation in energy efficiency or renewable energy, is urgently needed for a just and sustainable future.

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