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Abstract

Understanding climate change is becoming an urgent requirement for those in education. The normative values of education have long been closely aligned with the global, modernised world. The industrial model has underpinned the hidden and overt curriculum. Increasingly though, a new eco-centric orientation to economics, technology, and social organisation is beginning to shape up the post-carbon world. Unless education is up to date with the issues of climate change, the estate of education will be unable to meet its task of knowledge transfer. This paper covers the basic science and ethical policy debates, and begins to outline the questions that will necessarily entangle education as we orientate ourselves to the new world that is upon us.

What is Climate? The atmosphere is the ubiquitous medium that we inhabit, as intrinsic to us as breath, and as unseen by normal consciousness. Climate, as Heidegger would put it, has been 'hidden' as it smoothly enabled our existence without conscious consideration. Heidegger argued in *Being and Time* (1962, orig. 1927) that it is only when a tool breaks down that what was effective about its readiness shows up. His example is a hammer, and climate is far more fundamental than the use of tools. The principle of failing as a motivation for something revealing itself to thought still holds. After thousands of years of almost complete obscurity, the climate is rapidly heating up, and subsequently it is becoming obvious that climate is now the greatest question. It is not a generational question, it is not even a question for our species. Climate havoc is triggering the 6th great extinction event in the history of the planet. The changes in climate that have been triggered by fossil fuel consumption are an existential threat to mammals, insects, plants and reptiles. This failure in climate generates a score of questions about the origin of the problem; in chemical compounds, in market forces, and in societal norms. The origin in chemical terms is rather simple to identify; fossil fuel burning, coal, oil, diesel, gas and a handful of other greenhouse gases such as methane. Yet the way these chemical emissions are an outcome of modern industrial processes are more difficult to acknowledge. Fossil fuel technology now underpins nearly every aspect of globalised modernity. It is so ubiquitous it is difficult to perceive society in any other way, and this makes fossil fuel technologies difficult to limit and regulate.

Heidegger (1977) later discussed the "Question Concerning Technology" (original 1954) where he argued that modern technology was essentially different from earlier forms, as it orders our lives, our ways of thinking, and everything we know about the world we live in, through a lens of 'standing reserve' for potential consumerism. Heidegger called this the 'technological *Gestell*' or 'technological horizon of thought'. This form of epistemology brings some aspects of the earth to visibility and obscures or hides other ways of understanding the earth we live in.

How do we tease out the question of climate change? How does the question of climate impact on the overt and hidden curriculum of educational institutions, at different levels? For a start, climate is a ubiquitous, existential question, of the deepest order. Fossil fuels are an essential element of the shift from earlier 'craft' forms of technology to the standing reserve of technological consumerism. The climate is 'broken' because of fossil fuels. Fossil fuels and modernity are inextricably entwined,

and thus far neither politicians, scientists, or policy makers have managed to ask the question of the epistemological framing of fossil fuel based modernity (Carrington, 2015).

For education, the hidden curriculum is firmly enmeshed in the values and practices, the 'habitus' as Bourdieu put it, of fossil fuel based modernity. At present, the climate crisis has hardly been noticed by the educational establishment, even if school students are now leading the challenge by going on climate change strikes. The overt curriculum in most areas is unchanged by climate awareness. But perhaps more importantly, many teachers have either no idea, or don't know how to tackle the question of climate change. This is hardly surprising, because it's a question that challenges our known way of doing things. Climate change challenges the technological horizon of thought. It is bringing to the surface the deeply problematic metaphysical assumptions of modernity, and thus, most of us are ill equipped to properly think it through or instigate constructive changes.

This paper does not seek to answer practical questions about how lecturers, teachers, pre-school teachers might approach climate change. It sets out instead, to look at the eco-political context of climate change – the emerging new horizon of thought – that is showing us what is problematic in the structure and normative assumptions of fossil based infrastructure and consumerism. Once this context is established, it becomes more visible how the unwritten rules, values, and normative patterns of behaviour that we have taught students to conform are helpful, and what is merely condoning the outdated carbon based economy. It is *after* we have established our own unconscious bias about reproducing the status quo, that we can begin to ask practical educational questions about what and how to implement a climate friendly curriculum that is age appropriate at different levels of the education system.

Turning point

Francis Fukuyama wrote that we have entered a period defined as the 'end of history' (1992). He argued that the dialectic that drives modernity between communism and capitalism had been 'won' by capitalism, at the fall of the Berlin Wall. The only role for the continuous unfolding of capitalism is to invent ever more innovative consumer products, to produce and reproduce fashion in wider ranges of material culture, and to encroach on every nook and cranny of the known world. Yet, as a result of climate change, history is changing before our eyes. Refugees from drought and war ridden countries are flooding stable and abundant areas such as Europe. Climate change impacts are affecting mountains, rivers, ocean, and every local economy that is based on them. Forest fires, massive species die-offs, and changes to soils, and other ecosystems are seriously impacting many countries. Environmental issues are in the process of radically shifting our normative lifestyle, alongside our ethics, ethos, and understanding of the world. But even now, the older generation tends to think these problems won't affect them during their lifetime.

— If it is a certainty, then it is not a turning point. The fact of being part of the moment in which an epochal change (if there is one) comes about also takes hold of the certain knowledge that would wish to determine this change, making certainty as inappropriate as uncertainty. We are never less able to circumvent ourselves than at such a moment: the discreet force of the turning point is first and foremost that.

Blanchot, 1993: 264

Precisely when the pivot point in a society occurs is arguable, but many philosophers, and many, many scientists have been making a claim for action on fossil fuel pollution over many decades (Irwin, 2010). This article outlines the basic facts and arguments in climate change science so that

we, as educationalists, can get to grips with the changes in global organisation and environment that are upon us.

If industrial technology shaped the modern world, climate change and environmental stress is shaping the Anthropocene (Irwin, 2010). Global debate is engaging with the science and is beginning to start the thinking necessary for adapting modern culture, and our educational systems, towards a more eco-centric orientation with the environment and each other. Pollution and environmental externalities have traditionally been marginal issues, barely attended. But now, they form deep seated challenges to the role of education. There are immediate considerations about the ethics of industrial pollution, and excessive consumerism, but climate change also has implications for migration, the nation state, the status of global polity, and the history - somewhat parallel to the international relationships of colonialism - of historical pollution and its impacts on vulnerable areas.

Many issues in education will be revisited as we enter this new era. The planetary nature of climate change and pollution brings the limits of the nation state into stark relief. In the context of a democratic polity that is increasingly global rather than national, questions arise about whether critical education that used to drive civic education is still fit for purpose? The old question was whether the purpose of education is cultural reproduction, but now we could ask whether education be thrust into the driving seat of cultural transformation? At a tertiary level, the question is whether universities need first to educate teacher educators, teachers, and students, about the dramatic consequences of climate change in order to raise these issues of civic polity in the globalised context.

My aim though, is not necessarily to raise issues of curriculum content; we also need to consider how graphic the information is for children in schools. Frightening children with Armageddon type consequences was terrifying for my generation, as we were raised with the spectre of the Atomic bomb. It did little for our psychological well-being. Climate change is not the responsibility of small children. It is enough that they learn to value highly their ecological environment, and to understand how interconnected all things are. The real shift needed is the overall *habitus* embedded in education *vis a vis* the wider society, biodiversity, and society futures.

More importantly, in regards to tertiary students (as opposed to very young children), and the existing teaching profession, is to ask the question of climate change as it raises serious concerns about the current consensus in society. Climate change brings the environment into the foreground, and pushes back against the constant messaging that economics is the only driver of all things.

Fossil fuel driven industrialisation has enabled the biggest boom of humanity in all of history. But it is also causing long term and extremely severe pollution that is disrupting the planet's ecosystems. Greenhouse gas emissions take between twelve and over fifty thousand years to reabsorbed from the atmosphere¹ and so the pollution is cumulative from the beginning of the industrial era, 200 years ago. Oil is itself a finite resource but long before we have used all known reserves, we need to severely limit fossil fuel consumption. The evidence of polar ice melt, glacial melt, ocean temperature, severe cyclones, heat waves, drought, and flooding is proving far worse than the most pessimistic climate modelling predictions. The latest science suggests that we need to quarter our total remaining emissions to 570 gigatonnes this century. Given that we have already burnt more

¹ IPCC, 1998, methane has a half life of 12 years, CO₂ is between 5 and 200 years, and CF₄ is over 50,000 years.

than 1 trillion barrels, this is a serious reduction. The role of the Humanities, Social Sciences and Education in this debate has up until now been negligible. Yet traditionally these discipline areas are the corner stone to cultural, civic, and political self reflection, understanding and critique. The question of climate change, reveals the sort of responsibility we need to take as philosophical, normative, systemic, and global (Irwin, 2008). Resetting the norms amounts to a profound shift in the cultural reproduction that is the special responsibility of education.

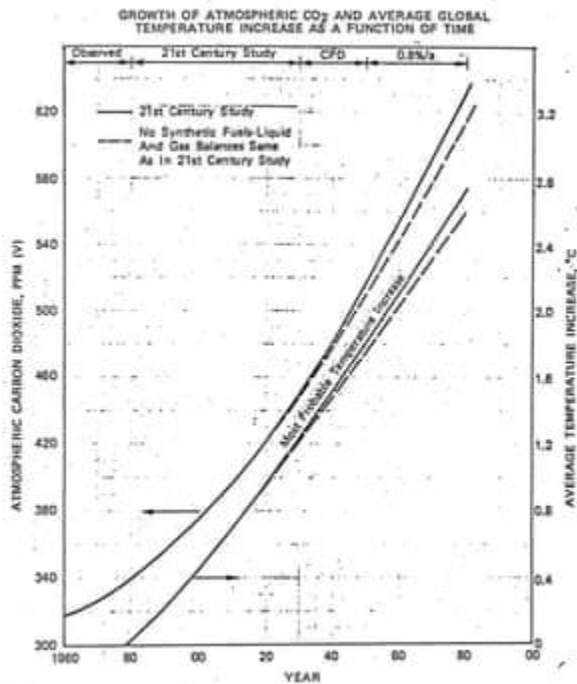
History of Economics and Normative Modernity

Since Adam Smith wrote *The Wealth of Nations* in 1776, and especially since Ricardo wrote the efficiency principle of comparative advantage in 1817, the orientation of our worldly endeavours has shifted from 'home' economics to international or global economics. The guiding rationale has been 'efficiency' on the grounds that some resources are abundant in some places and not others, and mass production is a more cost effective way to produce goods than small holdings scattered thinly across every village and town. It could be argued that this has been remarkably successful, allowing the human population to blossom from less than a billion people worldwide, to 7.7 billion now, with an estimated peak of 10 or 11 billion by the end of this century (Irwin, 2015). Technological capacity has created the conditions for modernity, and modern thought has created the conditions for a certain kind of industrial production.

There has been a fatal flaw in the mathematical formula that justifies the economic cost = benefit analysis. Pollution was relegated to an 'externality' which meant it was not counted (Meade, 1973). The environment and in many cases, local communities bore the brunt of those costs, and the firms producing goods and services avoided them. This hidden burden has continued for generations, and the protest of locals has been met by law courts with relatively small fines against offending industry when and if the problems ever arose. It is not until the problems have become existential that the economic system has even begun to consider addressing this oversight.

During this period, over the last 250 odd years, education has been at the service of the spread of western ideas (Jones and Jenkins, 2008), and the entrenchment of the skillset necessary to thrive in a global, modern, industrial world. That consists of the 'three R's': reading, writing and 'rithmetic, along with more fundamental skills of the hidden curriculum including social skills, turning up on time, and regular attendance, sitting quietly and resisting the urge to jump and leap about, and so forth. This industrial skillset has helped people prepare for the industrial modern world. In addition, (and usually it is additional) the rationale for schooling is to encourage students to think for themselves, and understand themselves as individuals, so as to vote in our democratic institutions, and to mature into fully rational, individual adults (Rousseau, 1762)

Fossil fuels have been the backbone of the industrial revolution, ever since 1784 when James Wood invented the coal powered steam engine. There were opportunities to come up with alternatives at many points during the last 250 years. Indeed, electric cars were first invented at about the same time as petrol ones. Evidence is coming to light that the fossil fuel companies have known about the impact of climate change since the 1980s. Exxon and Shell hushed it up (Franta, 2018).



Exxon's private prediction of the future growth of carbon dioxide levels (left axis) and global temperature relative to 1982 (right axis). Elsewhere in its report, Exxon noted that the most widely accepted science at the time indicated that doubling carbon dioxide levels would cause a global warming of 3°C. Illustration: 1982 Exxon internal briefing document (Franta, 2018)

Climate change, along with other pollutants, are compromising life on earth, as we know it. We are presently in the midst of the largest extinction event since the dinosaurs (Carrington, 2014). David Attenborough's documentary *Planet Earth II* (2016) shows the impact of plastics on birds, fish and mammals everywhere. Memes are proliferating, supermarkets are responding, alternatives are finally getting traction. The ozone hole was the first atmospheric disaster to be noticed, regulated and solved. The global Montreal Protocol on Ozone was formulated in 1987 prohibiting these chemical emissions, and in 2018 rogue industry allowing ozone depleting chemicals were identified by satellite, and rebuked (Buckley, 2018). Climate change is acknowledged by everyone.² Even Koko the gorilla knows about it (Noe, 2015).

There are strong calls from scientists that old modes of economic distribution that ignores pollution as externalities, during the early era of industrialisation need to come to an end. Post fossil fuel modernity is beginning to emerge. The shift requires a reorientation of ethos, of philosophy, of world-scape, and of economic distribution that prioritises ecological health and biodiversity as the core of social health (Irwin, 2008, Raworth, 2018). In philosophical terms, eco-centrism signals a collapse of the harsh distinction between individual subjects and natural objects, or between culture and nature (Plumwood 2002), and a reinvigoration of indigenous philosophy which understands human communities *as* the land, not *in contrast with* the land (Smith, 2000, Irwin and White, 2019). These ideas have been a long time brewing, but the urgency and widespread discussion that is now taking place is unprecedented. Education has two options, both of which are active, politicised positions; education can come to terms with this change and promote it, or remain committed to

² Climate change denial is a form of recognition, unlike 20 years ago when most people had never heard of climate change.

neoliberal economics, which saturates the organisation and *raison d'état* of schooling as producing individual human capital. As the wider community accepts and moves towards eco-economics, ecological health, and biodiversity could become central in all sectors of the curriculum, both overt and hidden. In preparation, educators need to understand climate change in particular, to see why a new world order is upon us. It may be true that many politicians are still in denial about the severity and consequences of climate change – Trump being the most eloquent on these matters at present. However, whether we like it or not, the environmental consequences of the ‘externalities’ of the last 250 years are now catching up with us (IPCC, 2014). The new world of ever deepening crisis is already upon us.

How to respond to these new characteristics is still in our hands. A little bit like diabetes, it is possible to take a number of courses in remedial action: ‘ignore’ it, lose first toes, then limbs and gradually go blind; or ‘manage it’ by taking insulin and adjust diet to some degree; or ‘solve’ it, by recognising the commercial diet is incompatible with health, and learning all you can about the body so you can feed it the nutritious food the body really needs. Ignore, manage or solve are the three options available. Oil companies and governments ignored it for as long as possible, keeping the population in ignorance as well (Franta, 2018). We are now in a phase of ‘management’ where governments at national and global levels are placing far too much emphasis on technological fixes, carbon capture is a good example, even though this remedial action is completely non-existent. ‘Solving’ it by halting all fossil fuel combustion is conceptually simple, but has infrastructure and financial implications of monumental complexity. But a transition is possible. All government oil subsidies, pension funds, and finance could be redirected towards genuinely sustainable energy solutions (wind, water, solar). All new infrastructure could be aimed at developing networks that enable people to live genuinely sustainable lives. Regulations for all sorts of aspects from shipping and flights, pesticides, to house insulation and roading could all be re-orientated to make eliminating ecological damage the first priority. Education contributes to this reprioritisation.

The need for action is increasingly clear (IPCC, 2018). There is now little doubt that the frequency and severity of many weather events over the last couple decades are linked to climate change. The massive heatwave in Europe that killed thousands in 2003, Hurricane Katrina that wiped out New Orleans in 2005, the floods caused by Hurricane Sandy in New York, 2012. Record breaking floods in the UK in 2015, massive heatwaves in Russia that annihilated grain production in 2016, new records in the northern hemisphere for heat in 2018, monsoon failures, rapid unprecedented ice melt at both the Arctic and Antarctic from 2012, record breaking hot oceans causing toxic algae and coral bleaching, the massive Typhoon Haiyan in the Phillipines in 2013, mega storms like Cyclone Pam in Vanuatu in 2015, and Cyclone Winston in Fiji in 2016 which reached 320 km/hr winds, and Hurricanes Harvey, Irma, Jose and Maria in 2017, all of which were Category 5 (or greater) storms. Add to these, the one in a thousand year drought in Southern California, and unstoppable wildfires in Siberia, Canada, Alaska, Australia, California, Indonesia, Borneo, and elsewhere. What follows is a short synopsis of the most salient facts about climate change. It is an introduction to the issues and debates that are still playing out.

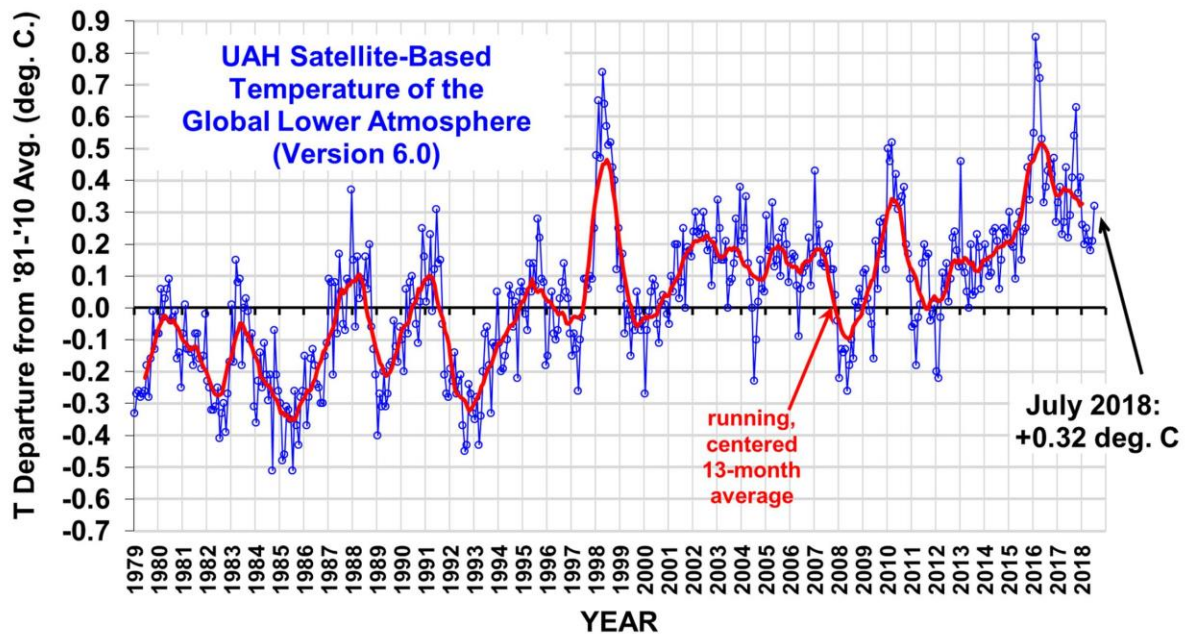


Koro Island, Fiji, in Perry, *The Star*, 2016. See also <http://www.abc.net.au/news/2016-03-07/fiji-before-after-photos-cyclone-winston/7220784>

Greenhouse Gas Effect

Industrial production has been almost exclusively based on energy from fossil fuels over the last 200 years. In that period the amount of carbon dioxide and other greenhouse gases has escalated exponentially. Greenhouse gases include carbon dioxide, sulphur dioxide, nitrous oxide, methane, and one or two other trace gases. The greenhouse effect is a result of these specific gases being released into the upper atmosphere. The particles absorb sunlight as it comes into the atmosphere of our planet and 'captures' it as it heats up the molecules rather than harmlessly reflecting back out of the biosphere into space. These heated molecules then pass back higher temperature to the planet rather like a glasshouse. Only a very limited range of gases in the infrared spectrum affect the upper atmosphere with a greenhouse gas effect, although they each have a different impact and a different half life. In the literature all these gases are often clumped together as carbon dioxide equivalents, or CO_{2e}. In science, the greenhouse effect is usually called radiative forcing.

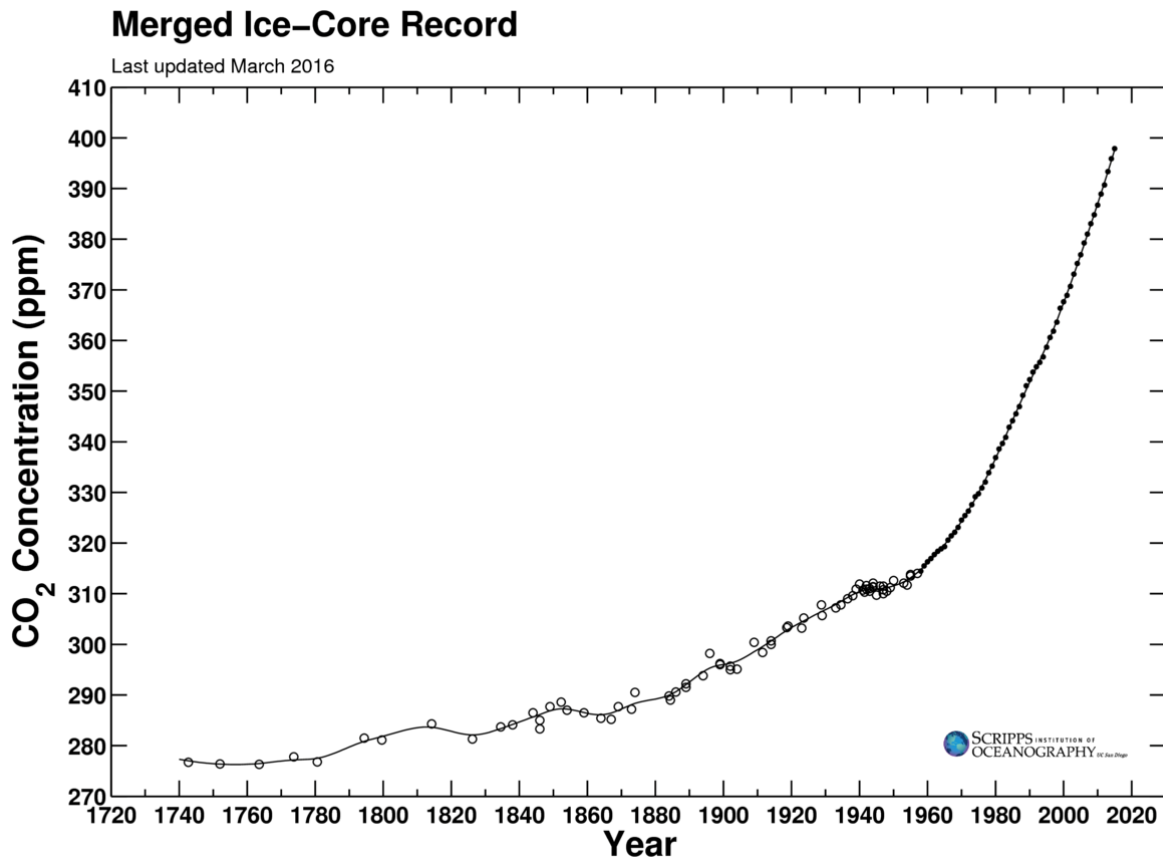
Below is a graph showing the planetary mean average temperature which is impacted by CO_{2e}, caused by industrial emissions, and el niño, sunspots, and ocean absorption amongst multiple other things.



(Spencer, 2018)

In the last 150 years, the huge amount of fossil fuels that have been burnt has increased the atmospheric parts per million volume (ppmv) to over 410. Climate science is a very multidisciplinary field. Palaeolithic climatologists have looked at ice cores that go back 800,000 years to investigate the 'normal' range of atmospheric CO_{2e}. Ice core evidence from East Antarctica shows that concentrations of carbon dioxide in the atmosphere ranged from 180-210 ppmv during ice ages, up to 280-300 ppmv during warmer interglacial periods (Vostok Ice Core Data).

We are now in the midst of a huge extinction event, not unlike the event that killed off dinosaurs. Current estimates are that insects have reduced by 75%, and thus, bird populations are also dropping radically. Fish stocks are dramatically reduced, some species of dolphins, whales, sharks, and dugongs are all endangered. Many large animals in Africa are endangered, including, most recently, the giraffe. The last male white Rhino died in 2018. The current instability has been dubbed the Anthropocene epoch by the Royal Society because of human induced climate change and the impact of modernity (plastic and other isotopes) in the rock strata all over the planet.



(Scripps Institute of Oceanography 2016)

The graph above shows levels of CO₂ in the atmosphere from the beginning of the industrial revolution. It takes between 12 and two hundred years for most CO₂ gases to be scrubbed out of the atmosphere. By and large, emissions are *cumulative* year on year. The cumulative nature of emissions still fails to make the public debate, but it means that to begin reducing the pollution in the atmosphere back to a stable 280 ppmv, we need to reduce current emissions to zero as quickly as possible.

Historical emissions per person are dominated by the UK, the USA, Germany, Canada, Russia, and Australia, in that order. Historical emissions are an indicator of responsibility but also 'development' and wealth. Most of these large emitters have been extracting resources and cheap labour from poorer countries while they were generating large scale pollution, leaving the low emission countries much more financially and physically vulnerable to rapid shifts in climate. The global climate change negotiations (COPs) have tried to address historical responsibility without much traction. By 2014, the biggest emitters per capita had changed somewhat, and in order are the USA, Australia, Canada, the Middle East, Russia, Japan, Germany, UK, and China. These countries are over the global mean of approximately 1.4 tons of carbon per year, per person (Hansen et al, 2016).

The first stages of climate change are global warming. The overall mean temperature of the planet is gradually increasing. In 2016 the mean planetary temperature is 0.9°C higher than at the outset of the Industrial revolution (UK Met Office). There is a direct correlation between the levels of CO_{2e} in the atmosphere, and the mean temperature of the planet. Stefan Rahmstorf (2009) has warned that if the planet reaches 2°C higher than preindustrial norms then we can expect to lose at least 50% of

species to extinction. Conditions are increasingly tenuous for humanity as well. 2°C has become one of the thresholds that policy makers use as a limit point we should strive urgently not to cross. A lot of climate modelling is based on the 2°C threshold. Many scientists, including Hansen et al. (2016) and Rogelj et al. (2016) argue that the models are over-optimistic about how much CO_{2e} the earth's cryosphere and oceans can absorb. They argue that 2°C is far too high and that we should aim for 1.5 at the most to reduce the rate of extinctions and not throw billions of people into havoc (IPCC, 2018). The Paris Agreement (2017) tries to put 1.5°C in place as an international goal.

Oceans

The ocean plays a crucial role in climate change. Thus far, the ocean has absorbed over 93% of the total warming of the planet. To put it in some human perspective, Brian Kahn claims "the average annual energy absorbed by the upper ocean alone equals 43 times the amount of energy U.S. consumed in 2012" (in Yulsman, 2016).

There have been a few significant milestones, where ecosystems go over a tipping point, and the impacts of global warming shows up in new and unprecedented ways. Up until 2005 the ocean absorbed carbon dioxide, but now, in the northern hemisphere summer, the ocean has become a net CO_{2e} emitter. As the ocean continues to absorb heat, it is expanding, and also accommodating land ice melt. The potential for significant changes in sea level rise is increasing. To give you an idea of how important the ocean is to climate change, here is a quote from Hansen et.al (2016: 2).

If the ocean continues to accumulate heat and increase melting of marine-terminating ice shelves of Antarctica and Greenland, a point will be reached at which it is impossible to avoid large scale ice sheet disintegration with sea level rise of at least several meters. The economic and social cost of losing functionality of all coastal cities is practically incalculable.

Both the Arctic and the Antarctic, along with glaciers and mountain ice are all melting at an extremely alarming rate that outpaces even the most radical climate modelling (IPCC, 2007, 2014). Hansen et. al, (2016) put more emphasis on land based ice melt because it increases the sea level whereas sea ice is already accommodated by water displacement. Scientists in Antarctica have published on the instability of the East Antarctic ice sheet.

This vast mass holds enough water to raise sea levels by 53 meters (approximately 174 feet) worldwide. And researchers have confirmed that one stretch of the southern polar coastline has melted many times in the past: by enough to raise sea levels by three to five meters (approximately 10 to 16 feet) (2016: 6).

Hansen et al. argue that the sea level rise in the Eemian period gives an indicator of the speed of change that CO_{2e} radiative forcing can generate. At that time sea levels responded to CO_{2e} of 400 ppmv by increasing 5 – 9 metres (depending on where on the planet). At the same time, the extremities of storm, tsunami, and ocean turbulence increased to almost unbelievable forces. In the Bahamas the relics of these huge tsunami wave action can still be seen, with giant rocks as big as houses perched on hilltops, 40 metres above current sea level, (2016: 6).

Currently, land based polar ice is melting faster than any of the climate models have predicted. Partly the melting is amplified because of unaccounted feedback loops. For example, the permafrost in the Arctic circle has begun to melt, and large quantities of natural methane is being released in suddenly appearing craters, called pingoes (Serov et al. 2015). Methane is one of the most damaging

greenhouse gas emissions, so the volume of methane issuing from the Arctic circle is extremely alarming (Serov et al. 2015). Methane does, fortunately, have a relatively short half life.

Up until 2014 temperature differences were too gradual for most people to be fully cognizant. But gradually the ability of the ocean and the ice caps to absorb more heat has become saturated and less able to absorb CO_{2e}. 2015 showed temperature changes of 20% of the total warming from the last 150 years. We are entering a new phase, where climate change is having increasingly obvious, violent environmental impact. At the same time, consumerism and economic growth continues to increase exponentially. Yet finite and supposedly sustainable resources are well past peak and limits are being exacerbated by climate change.

A good example of the complex interaction of mass industrial consumerism and climate change is fishing. For quite some time fishing catch has been massively depleted. Most people have put the problem down to the industrialisation of the fishing industry, which uses huge factory ships, working in pairs with sophisticated satellite equipment to identify large shoals of target fish. The levels of catch are unsustainable and the by-catch also has a terrible impact on other species such as dolphin, non-target fish, and turtles. However, there is a new crisis for fish stocks. On several occasions, fish, squid, whales, penguins, and seals, are washing up dead on the coast in large numbers. Nobody has been very sure why this is happening. Research on sea birds is likewise showing huge drops in the population of seagulls and other species because of the lack of food far out at sea.

In the incredibly hot el niño years of 1998, 2002 and 2016, the Pacific ocean had days on end of temperatures over 30°C. This is outside the narrow range of temperature viability for coral, and those years show huge coral bleaching and coral die off. At the same time, large amounts of tropical fish washed up dead, ashore. Anoxia is where high temperatures make the water very oxygen poor and the fish asphyxiate (Hoegh-Guldberg and Bruno, 2010). Anoxia is also having a massive impact on plankton, which is at the base of the marine food chain.

The threat to coral reefs is having direct consequences for the millions of people who live in the Pacific (and most coastal communities around the planet). The reefs are the centre of biodiversity in the region, and villages rely heavily on fishing for food. Many of the islands are low lying coral atolls, and these atolls are 'alive' in the literal sense, that they grow about an inch a year, and at the same time, sink under their own weight by about an inch a year. With coral bleaching, where the coral dies, the atolls are sinking lower. An increase in tropical cyclones because of the warmer water in the hot season, is combining with the lower atolls, allowing salt water to breach the fresh water lens at the centre of the islands. Without fresh water, even hardy trees like the coconut cannot survive, and the atolls are becoming swamped in sea water, and uninhabitable.

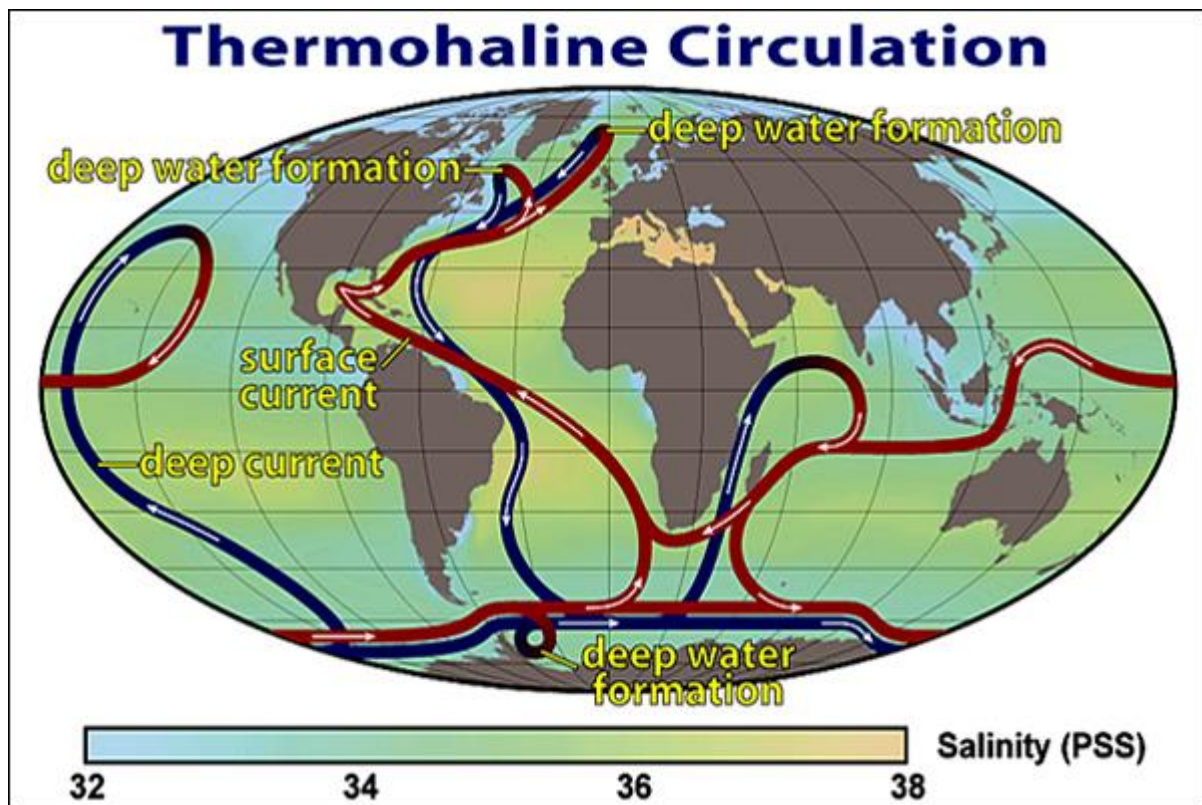
Even at a 1 metre sea level rise, countries like Bangladesh are likewise extremely vulnerable, as it is a large river delta, and huge displacement of 160 million population is likely to take place. Climate refugees are already a reality, and their numbers will grow into multimillions over the next few years.

Once land based ice has fully melted, especially massive ice fields like Greenland, the expectation is that sea levels will rise significantly. Hansen et al (2016) suggest that there is a high correlation with previous Eemian events of similar radiative forcing of 400 ppmv. Evidence suggests that during the Eemian, the sea level rose very rapidly - over only several decades - between 5 and 9 metres

(depending on location). The present conditions are very similar to the Eemian, although greenhouse gas forcing this time is much more rapid (Hansen et al. 2016). If that is what happens again, it will make large swathes of land underwater. At present, anxiety around sea level rise revolves over loss of habitat, especially for coastal dwelling humans.

Climate change is not limited to global *warming*, although for our immediate future, this is the larger concern. The later stage of the staggering radiative forcing and subsequent sea level rise, is the inverse of the greenhouse effect. Water is very reflective, and when larger areas of the planet are reflecting sunlight back out of the atmosphere, the net heat absorption is dramatically negative, setting the long term cycle on a rapid cooling swing (Hansen et al. 2016: 2, 4).

Coupled with the inverse greenhouse dynamic, Rahmstorf (2006) has speculated that the Greenland ice melt could 'switch off' the thermohaline ocean escalator. This ocean current circumnavigates the globe in a complex figure of eight type pattern. The current circles the Antarctic, going deeper as it gets colder, and picking up nutrients from the sea floor as it goes. The current then comes up, through the Pacific ocean, rising closer to the surface as it passes the hot equator region, and dropping its heavy nutrients as it heats up. These deep sea nutrients are essential for plankton and other life forms in the hot, light waters of the equator. The thermohaline current then carries hot water further north, passing Europe and Great Britain, as the Gulf stream, and circling the Arctic with warmer surface waters that cool, deepen, and pick up a nutrient rich mineral load once more. The current circles back south, taking cool waters back to the equator region, and rejoins itself circling the Antarctic pole.



The thermohaline current is vitally important for moderating the temperature of the planet. It cools the equator region and warms the polar regions. Without it, the equator could be degrees hotter, and the ice at the poles would come down several latitudes lower. The comfortable zone for humanity would be radically reduced. These kinds of swift and radical shifts in climate are what caused the extinction of the Neanderthals, and further back, the dinosaurs. Many species have survived previous extinction events; bacteria, ferns, slaters and other insects, lizards are all species that have successfully negotiated large variations in habitat. But by far the majority, perhaps some 90% of extant species on earth will not cope with the rapid oscillation from the stable Holocene period to rapid global warming, and potential subsequent ice age.

Not all feedbacks are exclusively bad news. The increase in evaporation and perspiration (rain) from warmer temperatures results in increased cloud cover – and that reflects sunlight back out of the atmosphere. Volcanic eruptions produce a type of aerosol which is also a short term atmospheric coolant. Higher levels of CO_{2e} offer increased nutrients to plants and in some ecosystems (where extremes of drought or flooding are not impacting) trees and plants are growing faster than ever before. Climate *change* is increased volatility. It increases and exacerbates existing conditions. Tropical cyclones get more frequent and severe, drought prone areas suffer longer and drier periods, for every one degree warmer, cloud carries 7% more water, and flooding is faster and deeper than it has been before. The Anthropocene is an era of extremes.

Energy

The development of the steam engine, and subsequent use of solid, liquid and gas fossil fuels completely changed the nature of work in modern times. The pace of energy had been regulated by the pace of sunlight: rivers, seasonal growth, and the physical labour of animals and humans were harnessed with cogs and levers to increase the effect of their strength. But oil has such incredible energy density, that one barrel is the equivalent of 12 years of one person's labour.

Oil, is effectively trapped sunlight. It is the result of large swathes of algae and organic matter that has sunk deep under the ground and been subject to immense geological pressure over millions of years. The oil we burn in one year took 5 million years to be formed. Cheap and high quality energy has forged the basis of industrial agriculture, industrial transport and storage, industrial cities, and consumer lives.

Fossil fuel energy has released us from the dangers and vulnerability of local problems with food crops or water supply, and enabled human beings to thrive to a volume never seen before. With industrial agriculture, we have increased the 'output' of farms, cut down swathes of forest, increased the capacity, frequency, and speed of international transport for consumables, and completely changed the nature of trade. The pre-industrial population was probably much less than a quarter of a billion people, across the planet. At present we are at 7.7 billion and according to UN data, will peak at about 9.5 – 10 billion people in 2100.

Modern lives have been constructed with extremely dense energy resources. Most obviously is transport, which uses oil directly for motive force. But embedded in all manufacturing is an immense amount of energy. Tyres are made with oil; plastic, furniture, cosmetics, steel, concrete, and ashfelt

are all made either with oil as a base ingredient, or needing high density energy for production. Furthermore, the make up of modern cities, and modern trade is highly dependent on oil. Industrial agriculture is based on oil. Life is no longer set up around small villages with local arable fields, but rather large urban centres with billions of people who live well beyond walking distance from their places of work, shops and amenities (Heinberg, 2015).

When fossil fuel was first discovered, it was available in vast quantities and with very easy extraction costs. In many cases, as oil is under pressure, it literally bursts from the ground. Over time, the pressure is gone, and extraction costs rise much higher. In the early days, according to the Post Carbon Institute, one barrel of oil produced 100 barrels. Following the law of diminishing returns, one barrel of oil now produces between 1.5 and 5 barrels depending on the field. Peak oil was reached in approximately 2005. This is when the known and estimated oil reserves, of some 2 *trillion* barrels, were about half used up. It was estimated that new global oil reserves take about 40 years to peak, but as consumption has been speeding up over the decades these time periods are likely to become much shorter. More importantly, as we explored earlier, climate scientists are telling us that the finite carbon budget is only 570 – 1240 Gigatonnes CO_{2e} from 2015 onwards (Hansen et al. 2016 and Rogelj et al. 2016).

In industrial communities, when oil is no longer produced, government will struggle to create alternative infrastructure because the easy flows of transport and energy for construction and infrastructure will no longer be available. This lag time is extremely important and suggests that we should be putting in infrastructure for walkable distance amenities, shops, housing density in New World urban centres now, so we cope better without oil in the future.

Social Responses

Thus far, despite many UN meetings for nearly 30 years, despite the Intergovernmental Panel on Climate Change (IPCC) advice since the 1990s, despite widespread understanding of the issue amongst the population, and amongst politicians, climate emissions keep rising year after year (see Keeling data above). Initiatives like climate emissions trading have been a colossal failure, partly because people rort the system, but mostly because the neoliberal market is incapable of comprehending or limiting the role of consumerism in oil consumption (see Irwin, 2014a & 2014b). Environmentalists have realised that most of the reduction in emissions, or 'efficiencies' gained from alternative fuels, increased public transport, improved building insulation, and so on, are offset by ever increasing amounts of consumer goods that are produced with cheap, subsidised, fossil fuels (Carrington, 2015). Nobody can blame the rise in the middle class in China, India, and other erstwhile 'third world' countries for wanting the consumer luxuries that have flooded 'developed' countries for so many decades. But the abandonment of subsistence living, and the spread of consumerism is one of the prime causal factors of emissions growth. At a macro level, the commensurate modern obsession with undiscerning economic growth makes exponential increase in productivity and its associated exponential increase in CO_{2e} emissions unavoidable.

A lot of good things have already begun in response to the climate crisis. 95% of new energy in 2015 was renewable which stabilised emissions from the energy Sector for the first time, in 2016-17, although emissions continued to rise in 2018.

There is a lot of creative and critical work that needs to emerge from the Humanities and Social Sciences that will bravely set out a pathway into a new and unknown future. The earlier we embark on a low carbon lifestyle the less we will exacerbate flooding, resettlement, and climate refugees. The orientation of economics until now has been focussed on 'efficiency' and individual consumer choice. Most social 'solutions' to climate change have been framed in terms of better consumer choices; eat vegan, turn off the power pilot light when you go out of the house. But even with the best will in the world, these individual decisions cannot be properly ecologically sustainable and promote biodiversity if the infrastructure system is not in place to make better choices.

The cost/benefit equation of efficiency has altogether ignored the costs to the wider environment of pollution (Irwin, 2014a). Describing pollution, and especially climate emissions as an 'externality' to the market place allowed highly toxic practices to be normalised for the last 250 years. Climate change alters that orientation fundamentally. No longer can companies, whether global or local, get away with this kind of pollutant mentality. Instead, 'efficiency' needs to give way to a new economics, one that is fully engaged with planetary limits, and places environmental health and biodiversity at the centre of productivity. Kate Raworth has just written a good book on this topic, called *Doughnut Economics* (2018), where she places environmental limits as the outside of the 'doughnut ring' and safeguarding equitable distribution at the inside of the 'ring' with economic activity occupying a safe place between the two. To help ecological limits, in my view, we need to recognise more fully the plethora of activity that is 'economic', much of which is local families, not global, nor multinational, in nature. It is a diversity of economic practices that make up contemporary modern life, not a universal monetised system, that entails economic growth through narrowly proscribed increases in efficiency and innovation (Irwin, 2017). Public health requires diversity in the biosphere, in democracy, and in knowledge.

The rate of change of planetary warming is extraordinary, and the ability of humanity and other species to adapt to this rate of change is not promising. Nevertheless, things are starting to improve in many arenas. The number of coal fired electricity stations in China and the USA has dropped dramatically. Germany has just announced it will retire all of its coal fired stations in the next 20 years. The huge oil interests in top level politics has made this a very difficult process for the USA, so a lot of this achievement is at the hands of Green activist groups like the Sierra Club, which funded lawyers to take coal stations to court for pollution. Obama stopped an Oil pipeline. US State governments have also been far more effective than Federal government in introducing sustainability measures and ensuring massive polluters are shut down. In China, centralised government has been better able to accept and respond to the deep set energy changes that the climate needs. Many old coal stations have been scrapped. Some new ones were being built with scrubbers on the chimney to reduce emissions, but in 2015 all new coal stations were halted. This is radically good news. Coal is cheap and abundant, but it produces vast amounts of CO_{2e}.

The other good news, ironically, comes from fracking. This new initiative for extracting gases from nearly any land mass became widespread in the 2000s. It is a very destructive and inefficient form of extracting fossil fuels but it released the USA and other nations from relying exclusively on OPEC countries for oil. OPEC has responded by pumping vast quantities of oil and flooding the market. On the face of it, this is disastrous for climate change as it enables fossil fuelled production processes to thrive and releases ever greater quantities of CO₂ into the atmosphere. But OPEC's market saturation was in close juxtaposition to the 2008 financial collapse, and capital flows have been hard

to find, especially for small businesses. So fewer people have been able to make use of the cheap oil than might have been expected. Economic slow down is very good news for climate gas emissions. Furthermore, the massive drop in oil price, from over \$100 a barrel in 2012 to less than \$40 a barrel in 2015 had the impact that OPEC was aiming for; it made fracking uneconomic. In the short term these are good results in the emissions war. But they are unintended side effects of oil profiteering and not a long term commitment to a post-carbon economy.

The fact is, there is still a trillion barrels of oil available underground, and we cannot burn it, unless we wish to fry the atmosphere to a crisp. Instead, what we need is alternative energy, regulation, and a post-carbon economy that respects the earth and its biodiversity instead of treating it as a mining resource. This is a simple shift in orientation; economics with ecology as its centre. Unfortunately, these changes are not so simple to implement. At present, halting extraction is next to impossible as multinational oil corporations have powerful global political influence. The banking industry is tightly committed to economic growth and interest payment. The best means people have to limiting fossil fuel extraction is to create dynamic alternative energy, to divert the economy away from oil reliance, to follow initiatives such as 350.org.s de-investment campaign where individuals and large institutions are encouraged not to invest in fossil fuel companies are important. Nation states need to stop subsidising the fossil fuel industry, and strictly regulate and enforce pollution measures (Carrington, 2015). There is significant positive movement though; in 2018 the Green candidate in the UK, Caroline Lukas, has persuaded the EU to increase the risk factor for petroleum futures trading, so that 20 year bonds are now ruled out. In 2019, Norway withdrew a trillion dollar fund from any type of fossil fuels investment. These types of shifts are profound and indicate the post-carbon economy will be here sooner than it was possible to imagine, even a year ago.

Education can play a key role in the shift to a postcarbon world. Educationalists need to have a clear idea of the problems, and the direction of travel for remedial action, in order to make necessary changes in the school curriculum. The school students that are striking about climate change put it succinctly:

Our education system is failing us. We're not being adequately taught about the climate crisis in our classrooms. Schools are not preparing us for the world we're about to enter, yet still prepare us for jobs and a society based on the system that caused the crisis. We must urgently reform the national curriculum and learn to address the ecological crisis as an educational priority. (UK Student Climate Network, 2019)

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