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The science of climate change

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Climate change represents the greatest challenge to human existence we have ever experienced.

This is not a universal view. On 29 April 2019, Dr C.J. Hamilton wrote:

> *'Climate Change' alarmists base their case for man-made Global Warming on two key claims. Their first claim is that carbon dioxide is 'dirty'and a pollutant — it is not. Their second claim is that the increase in global temperature since the onset of the industrial age around 1850 is primarily due to the increase in atmospheric carbon dioxide caused by the combustion of fossil fuels — it is not. There is no evidence in all the historical scientific records to support this claim. The real cause of 'Global Warming' is the repeat of the Warm Period cycle which made Greenland green a thousand years ago during the Medieval Warm Period and caused the Little Ice Age from 1350 to 1850.*

It is not a view I share. If Dr Hamilton would consider me a 'Climate Change alarmist', so be it. But although I am persuaded that carbon dioxide in the atmosphere is the principal cause of climate change, I do not regard it as 'dirty', or a 'pollutant'. And, despite Dr Hamilton's sharp views, I regard climate change as very important and a major threat to our species.

A lot of people think that our knowledge of climate change dates from Rachel Carson's *The Silent Spring* (1962) or Al Gore's later expressions of concern about it. In fact, we have known the mechanism of climate change for much longer: roughly 160 years.

It is worth considering the earlier history of climate change. In the 1820s, Joseph Fourier calculated that a planetary object the size of Earth should not be as warm as it is, given its distance from the Sun and the relatively small amount of sunlight falling on its surface. We now know that Venus and Mars both have atmospheres, as does the Earth. The atmosphere of Venus is about 100 times as dense as the atmosphere on Earth. Venus is closer to the sun than Earth is; Mars is further away. To make sense of the table below, it is worth bearing in mind (in relation to Fourier's observation) that Venus and Earth are roughly the same size; Mars is much smaller than both. The atmosphere of Mars is about 1% as dense as the Earth's atmosphere.

Table 1

Planet	Distance from Sun	Average temperature
Venus	108 million km	461° C
Earth	150 million km	61° C
Mars	228 million km	-60° C

The temperature on Mars ranges from 20° C in daylight to –73° C at night. As most commentaries on Mars note, its atmosphere is so thin that it does not have a thermal blanket to trap heat. The contrast between Mars, Venus and Earth is obvious.

In about 1859, Tyndall discovered that water vapour was an important heat-trapping agent, and that it tended to trap

carbon dioxide, which was also very good at trapping heat, by preventing the escape of infra-red radiation. The trapped heat enables the atmosphere to hold more water vapour, more CO_2 and so on. He demonstrated this on 10 June 1859 in a Royal Society lecture, pointing out that coal gas and ether strongly absorbed infrared heat

The central insight was in fact given earlier in a paper by Eunice Newton Foote, in about 1856, but Tyndall gets the credit. Some things just don't change. Eunice Foote was an American scientist, inventor, and women's rights campaigner from New York. At a conference in 1856, she presented a paper titled 'Circumstances Affecting the Heat of the Sun's Rays', which suggested that changing the proportion of carbon dioxide in the atmosphere would change the Earth's temperature.

In the 1890s, Svante Arrhenius demonstrated that CO_2 trapped infra-red rays, and that the consequent warming would enable more water vapour to be held in the atmosphere, and that water vapour would in turn trap more heat in the atmosphere. He worked out that if you halved the amount of atmospheric carbon dioxide, the temperature of Europe could drop by as much as 4–5° C. Conversely, increasing the level of CO_2 in the atmosphere would increase the average temperature of the Earth. His calculations were remarkably accurate. (The concern of 19th century scientists with water vapour is probably a reflection of the fact that the Industrial Revolution was, in large part, powered by steam).

Between the four of them, Fourier, Foote, Tyndall and Arrhenius showed us what we needed to know about the mechanism of climate change. We ignored the science, but now

it is getting critical. Let's hope we don't allow politics to distract us too much: our future depends on understanding the implications of what we have known for more than a century. Al Gore simply reminded us of this 'inconvenient truth'. And Dr Hamilton shows plainly that it is a very divisive issue. The sad fact is that it has become highly political.

In 2011, the Israeli writer Yuval Noah Harari wrote a book called *Sapiens*. It is a history of our species, *homo sapiens*. He makes the point that we have been around for about 200,000–300,000 years. Until we discovered agriculture we lived in extended family groups, hiding from our predators. But when we discovered agriculture, about 12,000 years ago, we started living in villages, towns, cities.

Harari raises a fascinating question, which he does not answer: Are we genetically disposed to be concerned about the immediate group rather than the entirety of our species? It's a good question, and all the more important because climate change is the first phenomenon in history that threatens our entire species. And that threat is now at its most visible and critical phase: In November 2018, the Intergovernmental Panel on Climate Change (IPCC) reported that we have until 2030 to take serious steps to defeat climate change, or it will be too late. Despite the urgency of that warning, the government in the United States seems to deny the reality and seriousness of climate change; and Australia's major political parties seem incapable of formulating policies that accept the sorry facts, the mechanism for which has been known since 1856. Both of Australia's major political parties seem content to ignore the science (as well as the evidence of our warming climate), and to

keep exploiting our fossil fuel resources, either for use or sale. Is it too cynical to think that their attitude to climate change might be different if they did not receive large donations from the fossil fuel industry?

Dr Hamilton's disdain for climate change is reflected in the fact that (in Australia) the only political party to take climate change seriously is the Greens, and that party is treated as a refuge for people whose ideas do not deserve to be taken seriously.

Harari's question has immediate importance for all of us, unless we are willing to be so selfish that we will accept the best the planet has to offer us, despite the fact that future generations will probably be unable to survive on this planet.

It troubles me that, as a species, we seem unwilling to accommodate the idea that it will be difficult for us to keep going like this; that we need to recognise that climate change is a serious threat — a serious threat to us, and to the whole of our species.

In Australia, we seem able to accept all that is good, while ignoring the dangers we have created. If the bushfires over the summer of 2019–2020 were a kind of warning, we seem able to ignore the warning.

Perhaps it is because we have a government that has denied the existence of climate change for a long time and a prime minister (Scott Morrison) who took a lump of coal into the parliament, apparently to show us how safe it is! Perhaps it is because we have a dispirited Opposition that does not have a clear policy on climate change.

Perhaps politicians in both major parties see that they will be long gone before the harshest consequences of climate change are apparent, and for that reason they are willing to accept huge donations from the fossil-fuel industry. I have a different view.

For my part, I expect to live out my life before the worst effects of climate change make human life on Earth impossible, but I think we all have an obligation to make sure that we leave the planet as liveable for the future as possible, or at least foreseeable.

It would be a fine thing if the science of climate change turned out to be wholly wrong, but that seems highly unlikely. So far, all the evidence seems to support the science. It is interesting that politicians who are willing to dismiss the science of climate change would probably not be willing to board a plane if science told them it had a 20% chance of crashing before it arrived at their destination. And most politicians who are willing to dismiss or ignore the science of climate change nevertheless use mobile phones, the functioning of which is plainly a product of science.

The rich, advanced countries in the world have benefitted greatly from the phenomena that are responsible for climate change: the use of fossil fuel to power the remarkable enterprises of the post-industrial revolution world. But climate change has consequences for every country, rich and poor; for the entire planet. The phenomena responsible for it are, essentially, fossil fuels used to create light, heat and energy.

While the mechanism of climate change has been known for about 160 years, the precursors go much further back, to

Newton's time. Newton's law of the conservation of energy teaches us that energy can neither be created nor destroyed; rather, it can only be transformed or transferred from one form to another. So, an explosion of petrol in an engine is transformed into motion, heat, noise, and so forth.

Fossil fuels (coal, natural gas and oil) were produced tens of millions (or hundreds of millions) of years ago as a product of the sun's energy (i.e. sunlight provides the energy for plant growth; plants eventually die and become coal). Fossil fuels store energy in the bonds between the atoms that make up their molecules. Burning the fuels breaks apart those bonds. This releases the energy that originally came from the sun. That is why timber can be burned to produce (release) heat. Allowed enough time, the timber becomes a fossil fuel. Simply stated, the sun is the original source of energy on this planet (and all others in our solar system).

It is worth remembering that the fossil fuels we use today store energy from the sun from millions of years before our species existed. And since the start of the industrial revolution, at least, we have been releasing that energy with increasing enthusiasm, to the great profit of some, but at a terrible risk, eventually, to us all.

The difficulty (and the confusion) about the conservation of energy arises when the transformation of stored energy to noticeable energy results in wasted energy. So, the heat and noise produced by fuel in a car engine are forms of energy that are difficult or impossible to capture and reuse. When a stick of dynamite explodes, the chemical energy is transformed into heat, noise (sound energy) and movement of objects (motion energy).

Energy which dissipates that way is difficult to harness for useful purposes. Because of this, Newton's law of the conservation of energy is not self-evident. The simple fact is that all the energy we use ends up going somewhere. Using fossil fuels releases energy that arrived on the Earth many millions of years ago. If we use fossil fuels now, the stored energy has to go somewhere. Using fossil fuel means that energy that arrived on the Earth millions of years ago will be released. The science of cimate change shows that the stored energy ends up warming the vast amount of water in the oceans and causing catastrophic weather effects — increasing average temperatures, storms and so on.

And where a byproduct of the transformation of one form of energy to another is CO_2 (or water vapour, nitrous oxide, methane or ozone), the tendency of those chemicals to trap infra-red radiation in the atmosphere means that our planet gets warmer.

The fact that the sun is the original source of energy on this planet raises interesting possibilities for Australia. I have heard that if just 3% of the centre of Australia was covered with solar panels, we would produce enough electricity for the entire globe. There are many obvious practical difficulties with implementing that approach, but it makes a very important point about Australia's natural advantages.

Sunshine could easily create enough electricity for all of Australia, and there would be a lot of energy left over. That's important, given that the sun does not shine brightly every day, and does not shine at all at night.

But on days when the sun shines brightly, the use of surplus sunshine in a country like Australia raises many possibilities,

especially as the spare sunshine could easily be used to create energy that can be stored and used later. For example, Alan Finkel, Australia's chief scientist, has suggested using the energy from surplus sunshine to split water molecules into hydrogen and oxygen. Later, the hydrogen could be burned (as a source of energy) and the byproduct of this is, of course, water. Hydrogen is readily transportable.

Other suggestions include using sunshine to superheat various salts that can be stored underground as a medium- to long-term heat storage. Another suggestion is to use surplus sunshine energy to lift water in projects like Snowy 2.0.

Wind power is another obvious energy source. Europe, especially, has many wind-turbines in use. The number of wind farms in Australia is increasing, but depends largely on government encouragement which at present is sorely lacking.

And Elon Musk has shown how efficiently energy can be stored in lithium-ion batteries. Australia has vast deposits of lithium: one prediction says that Western Australia could supply half the world's lithium. Whether lithium-ion batteries remain a preferred way of storing energy is not clear, but it offers immediate possibilities.

Right now, the wealthiest countries in the world are run by the luckiest generation in history. The baby-boomers are a generation that has not seen a world war or a depression, although it remains to be seen if the COVID-19 pandemic changes that. It is a generation that has had the very best the world can offer. This has been managed (in part) by massively exploiting the fossil fuel resources of the Earth, the impact of which is being felt especially in poor countries that cannot afford to protect their people against it; and in low-lying

countries, which are becoming increasingly unliveable. And yet, the richest countries in the world are doing little or nothing to protect poorer countries from the impact of what we have done. The injustice of it is obvious.

Australia is in an interesting position. Our domestic CO_2 production is relatively small by world standards: China is the largest producer, United States number 2, Australia number 17. However, on a per capita basis Australia is at the top of the list: per head of population, Australia is responsible for more greenhouse gas emissions than any other country.

Unfortunately, it is easy for us who have benefitted from the use of fossil fuel to deny that there is a problem or to assert that it will resolve. After all, the consequences are comfortably remote. By contrast, the world's reaction to COVID-19 was much sharper because it showed immediate consequences. That said, America's response was tragically relaxed. As at the start of June 2020, about 105,000 people had died in America because of COVID-19. It took a delayed (and relaxed) approach to the pandemic, and had the biggest death toll in the world. In Australia we responded much more actively, and our per capita death rate was very low, as at the start of June 2020.

But even America's death toll was way less than 1% of its population. Yet its approach to the threat of climate change, which threatens 100% of its population (as well as the population of the rest of the world), is to deny it or ignore it. And the reason for that striking difference appears to be simply this: COVID-19 is an immediate threat with consequences that are visible right now; climate change is a threat that might not destroy us for 50 or 100 years. Our 'leaders' will be long dead

before the consequences of their short-sightedness are noticed; but ignoring climate change rewards Americans with a booming economy. As a result, political pressures mean that warning about climate change (let alone taking steps against it) looks politically difficult; politically disadvantageous.

To those of us who are old enough to remember early advertising about smoking, this is a familiar response. The fact that smoking tobacco was associated with adverse health outcomes was known from the 1890s.

When science first raised doubts about the health consequences of smoking, the tobacco industry responded with advertising lines like 'You've got nothing to lose but your smoker's cough'.

In the early 1950s, an English study showed a clear link between smoking and lung cancer, although it could not predict that a given individual who smoked would certainly get cancer: the likelihood increased, but it was not a certainty.

On 11 January 1964, the *U.S. Surgeon General's Report on Smoking and Health* was published; it led millions of American smokers to quit, and it resulted in certain advertising being banned.

Cigarette advertising was banned progressively over the following 40 years. Australia slowly followed, so that many types of tobacco advertising are no longer legal in Australia.

In short, the known ill-effects of smoking were resisted (or doubted, or denied) for a very long time, because there was good money in pretending the truth lay elsewhere; and the effect of smoking on any given individual was almost certainly a long way in the future and impossible to predict with any confidence. The parallel with climate change is obvious.

For most people, the idea that our planet will become impossible for human life is nearly impossible to accept. Denying the possibility is easy and comforting. Not one of us would like to think that the quality of our lifestyle will cost a future generation the possibility of continued existence. If the science was plainer, or more definite, or more precisely predictable, it is likely that our response (as a species) would lie somewhere between our recent response to COVID-19 and our current attitude to smoking.

The human rights implications of climate change are profound, and obvious. The rich, lucky countries have got richer and luckier, while the whole world pays the price. Those of us who live in New World countries enjoy the benefits of the consumption of fossil fuels: in the United States there are 838 motor cars for every thousand people in the population; in Australia, there are 790 motor cars for every thousand people in the population. But our avoidable production of greenhouse gases has an impact in every country, and on all the oceans.

It is tragic that concern about climate change and greenhouse gas emissions has become so mired in politics and commerce and blind optimism.