An Economist’s Look at Climate Change

By Tom Rohling[1]

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Humans have long transformed the Earth’s natural systems. Forests have been cleared to make farmlands; river flows have been changed through dams and reservoirs; and plants have been artificially bred to create new, stronger varieties. Most of these changes have been deliberate. But changing the global climate stands apart in being unintended with potentially very large costs to Australia and the planet.

The debate on how or whether humans are responsible for changes in the composition of the atmosphere and what impacts, if any, climate change will have on living standards has been particularly polarising. This paper, which forms the background to the climate change lectures, first looks at the claims made by scientists and climate change sceptics of climate change using available statistical evidence. The second part looks at the economic importance of climate change and what policies, if any, should be used to overcome it. While the statistical evidence points strongly to rising global temperatures driven by carbon emissions, the economic costs are difficult to quantify, making sensible economic policies based on cost/benefit analysis difficult to formulate. This paper takes an ‘insurance’ view of the problem: there is, on average, a risk that temperatures rise will rise by 1.5°C above pre-industrial temperatures by the end of the century, but there is also a risk of about 10 per cent that temperatures will exceed a catastrophic 6°C. Homeowners take out insurance policies against house fires that have risks that are much less likely than 10 per cent. The risk that high future temperatures can cause catastrophic economic costs leads to the key policy implication: countries should move quickly to reduce carbon emissions. Despite Australia’s small share of global emissions, Australia can contribute to a global solution by joining with other countries and adopt common carbon abatement strategies and impose import taxes on goods and services from countries that do not adopt similar strategies.

Climate change theory: CO2 levels cause the planet to be warm

In 1824 the famous French mathematician Joseph Fourier proposed a link between the atmosphere’s gases and the Earth’s temperature. Fourier asked what determines the average temperature of a planet like the Earth? When the Sun’s rays strike the Earth's surface and warms it up, why doesn't the planet keep heating up until it is as hot as the Sun itself? His answer begins with the fact that sunlight consists of long and short-wave radiation (see Graph 1).

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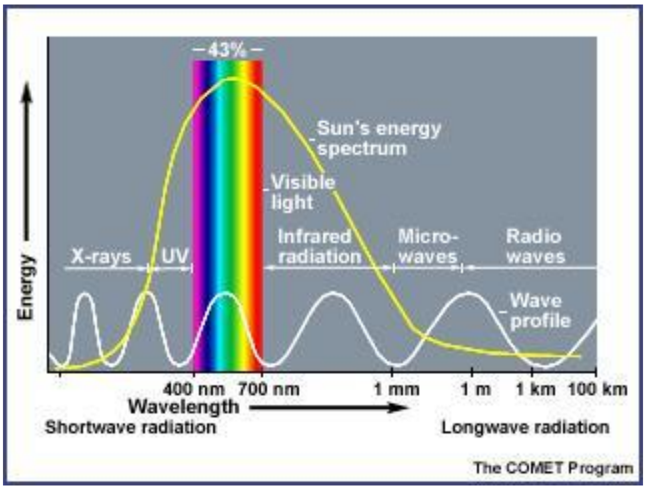
Graph 1: Sunlight Spectrum



Source: https://beyondpenguins.ehe.osu.edu/issue/energy-and-the-polar-environment/solar-energy-albedo-and-the-polar-regions

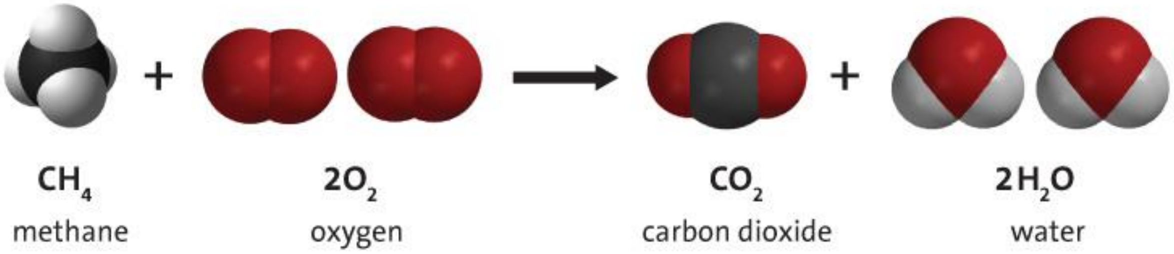
Almost half of the sunlight is short wave visible light. Short wave radiation leaves the Sun like an arrow, and most (around 70 per cent) of it gets past the particles in the Earth's atmosphere and hits the surface. When sunlight hits the surface of the Earth, the atoms in the Earth start to vibrate and the Earth becomes warm to the touch. The absorbed energy is transformed into heat energy. Fourier's insight was that rather than gradually heating up the Earth to the Sun's temperature, the heat energy, which is infrared or long wave radiation, is radiated back towards space. His calculations indicated that, given the Earth's distance from the Sun, the flow of energy leaving the Earth would leave it with a temperature of -18°C. At this temperature, the Earth would be covered in snow and ice - way too cold compared to actual temperatures. He suspected something in the atmosphere was blocking some of the heat from escaping. The atmosphere was acting like a greenhouse.

- Fourier did not know which elements of the atmosphere was absorbing the energy coming back from the Earth's surface. In 1862 Irish Physicist John Tyndall had discovered in his laboratory that certain gases, including water vapour and carbon dioxide, are opaque to heat rays. Long wave infrared radiation rebounding from the Earth has a much bigger chance of hitting these molecules in the atmosphere. The water vapour and CO2 gases in the atmosphere absorb the infrared radiation and eventually emit it back into the atmosphere, but it goes in all directions: some of this infrared radiation goes back into space, but some of it hits the Earth's surface and the cycles of absorption and emission are repeated. Essentially, this process of radiation emitting and re-emitting slows the loss of heat to space, keeping the Earth's surface warmer than it would be without the greenhouse gases. When more CO2 is added into the atmosphere, more of this longwave infrared radiation is re-emitted back to the Earth, thereby increasing its temperature. If the CO2 gasses stop rising, the Earth will reach a new, higher, temperature equilibrium. If CO2 gasses keep rising, the Earth will continue to warm. Tyndall, however, was not the first to make this connection. That honour goes to Eunice Newton Foote who showed with remarkably simple but compelling experiments that it was CO2 that made the earth inhabitable. She wrote, in 1856, that "An atmosphere of that gas would give to our earth a high temperature; and if as some suppose, at one period of its history the air had mixed with it a larger proportion than at present, an increased temperature... must have necessarily resulted" (Foote, 1856).

Where does the CO2 come from?

Carbon dioxide emissions occur naturally from the decay and combustion of plant material and the emissions from volcanic eruptions. For most of the Earth's history, the amount of emissions from animals and volcanoes has been, more or less, in balance with the amount of extraction largely by plant photosynthesis. Plant photosynthesis takes CO2 from the atmosphere and coverts it into plant material. Over millions of years, under exactly the right conditions, some of this plant material gets compressed and turns into hydrocarbons, which is commonly called fossil fuels. The combustion of fossil fuels releases the CO2 to the atmosphere. In terms of chemistry, hydrocarbons are basically long chains of carbon atoms with hydrogen atoms attached. The main difference between different fuels, like oil and natural gas, is the length of the carbon chain in their molecules. The shortest chain hydrocarbons are gases (up to four carbon atoms), petroleum is made of medium length chains (seven to twelve carbons long) and oil has a long length (up to 20 carbons). Coal is mostly made of rings of carbon, not chains, and has fewer hydrogen atoms.

Regardless of the type of hydrocarbon, combustion with oxygen produces three products: carbon dioxide, water and heat. An example, using a simple hydrocarbon – methane - is shown in the reaction below.

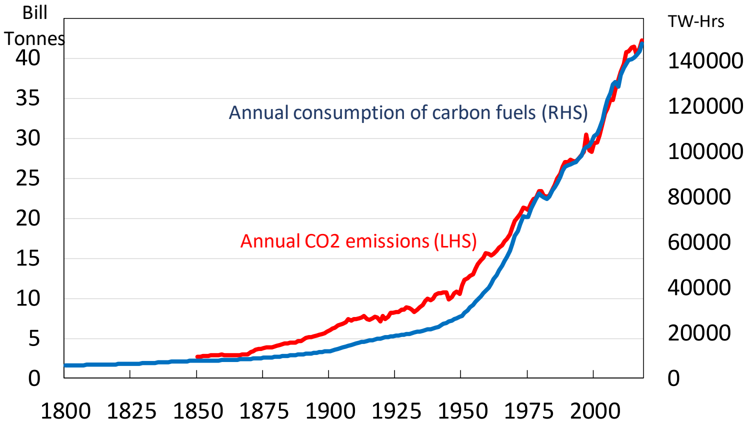


The energy required to break the bonds in the hydrocarbon molecules is substantially less than the energy released in the formation of the bonds in the CO2 and H2O molecules. For this reason, the process releases significant amounts of thermal energy (heat). Humans have used carbon fuels for fires to cook and to keep warm for centuries. Much later, humans began burning forests for grazing and crop land, releasing larger amounts of carbon into the atmosphere. Since the industrial revolution, beginning in the late 18th century with the invention of the steam engine, energy to power the new engines was provided from burning coal, producing even more carbon emissions. The invention of the internal combustion engine in the late 19th century spurred the combustion of oil in the form of petroleum, adding to the accumulation of carbon dioxide in the atmosphere. Today, in Australia, fossil fuels still provide 94 per cent of all energy consumed. Oil is the largest contributor at close to 40 per cent. Coal is second at 30 per cent and gas is third at 25 per cent, leaving renewables with around 5 per cent (see Australian Energy Statistics).

The evidence that increase in carbon in the atmosphere is human-induced is pretty solid, with the relationship between global consumption of wood and fossil fuels and CO2 concentrations in the atmosphere very close (Graph 2).

Graph 2

Annual Emissions of CO2 and Annual Combustion of Carbon Fuels



Source: Our World In Data; CDIAC/Global Carbon Project

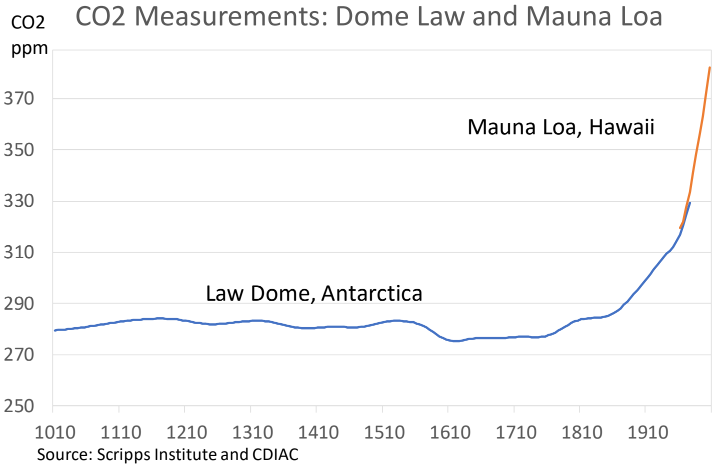
The natural decay of CO2 in the atmosphere is very slow. It is estimated that if atmospheric CO2 concentrations peak at 800 ppm, followed forever after by zero emissions, then atmospheric concentrations would be around 650 ppm after one hundred years and around 500 ppm after one thousand years. In other words, “most of the excess carbon dioxide in the atmosphere that wasn’t there when humans started burning coal and fossil fuels will still be there in 1,000 years” (Weitzman).

How do we know CO2 is increasing?

Until relatively recently, there were no direct instrument measurements of CO2 in the atmosphere. The best measure of historical CO2 atmosphere concentrations comes from ice core samples taken from places with thick ice. An ideal place is Antarctica, where some places have accumulated layers of ice over many thousands of years. One such place is the Law Dome site, named after the Australian scientist Phillip Law, Director of the Australian Antarctic Division from 1949-1965. Special drilling rigs take an ice core hundreds of metres, even kilometres, long. The ice cores are taken to a laboratory where bubbles trapped in the ice are released and the CO2 concentration is measured using lasers. The ice core samples indicate that over the past 800,000 years CO2 levels have shown a regular cycle, but never exceeded 300 parts per million. The cycles also correspond with conditions of glacial and interglacial periods.

More recent data of C02 are collected directly from atmospheric collections from a number of recording stations around the globe. The earliest direct measurement of CO2 in the atmosphere is from the UCSD Scripps Institute of Oceanography, where Charles Keeling set up a station atop of Mauna Loa in Hawaii. The station has been in continuous operation since the 1950s and show that the concentration of CO2 in the atmosphere has risen from around 300 parts per million in the early 1960s to over 400 today, an increase of over 30 per cent (Graph 3). For the years where the data overlap, the Mauna Loa observations line up with the ice core samples taken in Antarctica very closely. This means the historical record of CO2 levels recorded in ice core samples can be used with some confidence.

Graph 3



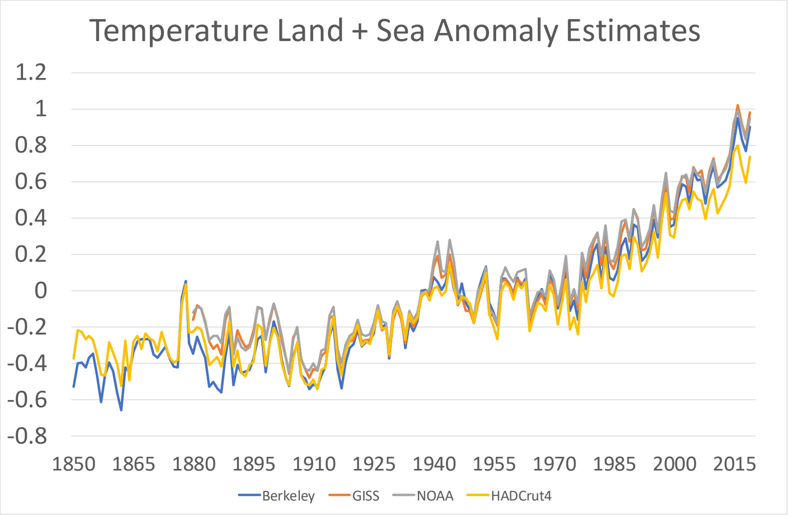
Source: Scripps Institute and CDIAC

How do we know temperatures are increasing?

Evidence of the Earth's actual historical temperature change was not possible until Gabriel Fahrenheit invented the mercury thermometer in 1714. The accurate measurement of global atmospheric temperature in the 18th century is therefore fraught with uncertainty because a truly global measure was not available- there were only a few stations, primarily in Europe and North American, and none in the southern hemisphere. It has only been from the early 19th century that a wide enough distribution of weather stations can give a reliable estimate of global temperatures.

Collections of sea surface temperatures have been even more difficult to collect, especially in the early years. Data were collected from ships' logbooks, such as the English East India Company fleet, but were often non-instrumental observations. In 1853 the world's great nautical nations formed the Brussels Maritime Conference for the purpose of "establishing a uniform system of meteorological observation at sea… with a view to the improvement of navigation". The participants agreed the ship's captain would record the ship's position, air and sea temperatures and wind currents. These historical observations are combined with modern records from ships, floating and fixed buoys, coastal and other fixed stations such as tide gauges to form a record of global temperatures from the mid-1800s. The various independent measures of global land and sea temperature are in very close agreement (Graph 4). The measures are from NASA Goddard Institute for Space Studies (GISS), the UK Met Office Hadley Centre and the Climatic Research Unit at the University of East Anglia (HadCRUT), the National Oceanic and Atmospheric Administration (NOAA) and finally Berkley Earth. Are these measures accurate? Berkeley Earth was formed because a group of scientists found some merit in some climate change sceptics' claims regarding temperature readings. They got funding from Koch brothers, among others, and set to discover for themselves if Earth was warming. They found that there was no bias in the temperature record, and that a simple model shows CO2 explains temperature rise.

Graph 4



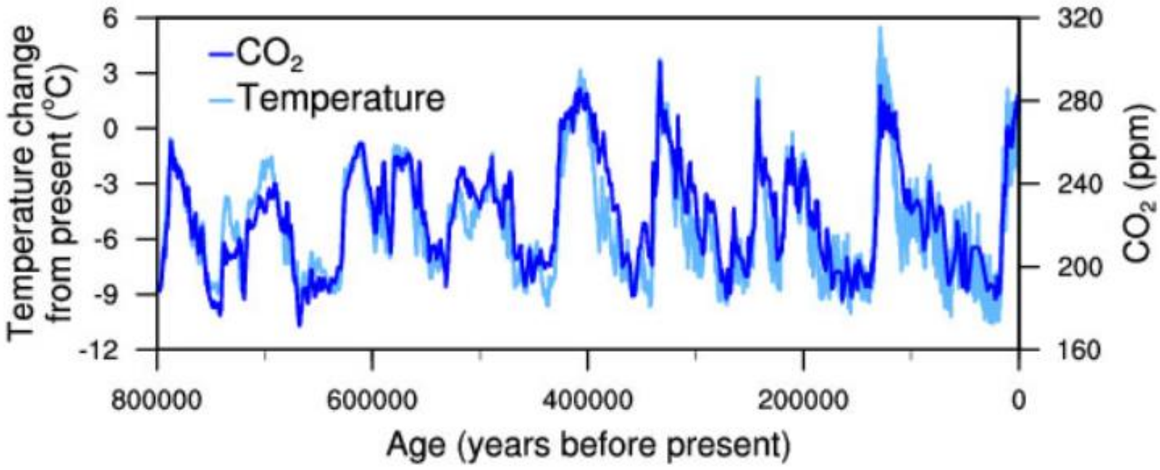
Before the 1800s, only indirect measurements of global temperature are available. There are numerous indirect methods available, including examining layers in lake beds and tree rings and examining the decay of chemicals in fossils. But the most accurate measure of ancient temperatures has been gathered by scientists looking at the layers of ice cores using molecule dating techniques to determine how old each layer is; much like counting rings of a tree. The measurement of layers of ice for temperatures is inexact. The uncertainty increases with the depth of the core, but scientists argue that “estimates indicate that it is usually less than 5% of the true age and is frequently much less than that” (CDIAC).

Is there evidence of a relationship between CO2 and global temperatures?

The link between CO2 and the Earth’s temperature is probably one of the most controversial links in the climate change debate, so it is important to examine the available evidence. John Tyndall’s laboratory work showed that certain gases, including water vapor and CO2, are interfering with escaping radiation. The role of CO2 in increasing temperatures can be demonstrated in classrooms today (for example, see the BBC for a good video).

But real-world evidence of a link between CO2 and temperature is hampered by a lack of direct data. Historical data, as mentioned, must come from indirect sources like ice core measurements. The ice core data suggest a link exists: CO2 and temperature seems to move very closely together during ice ages and warming phases over the past 800,000 years. But the ice core data also present a problem: C02 sometimes lags behind temperature changes (Graph 5). That is, if CO2 is supposed to cause temperature rise, how is that temperatures seem to go up before CO2? Climate sceptics have jumped on this. The answer is that there is a complex feedback relationship between temperature and CO2. Inexact measurement also plays a role. The air bubbles move in ice as more and more layers of snow compress the ice sheet. Taking this into account removes most of the lag (see Scientific American for an explanation).

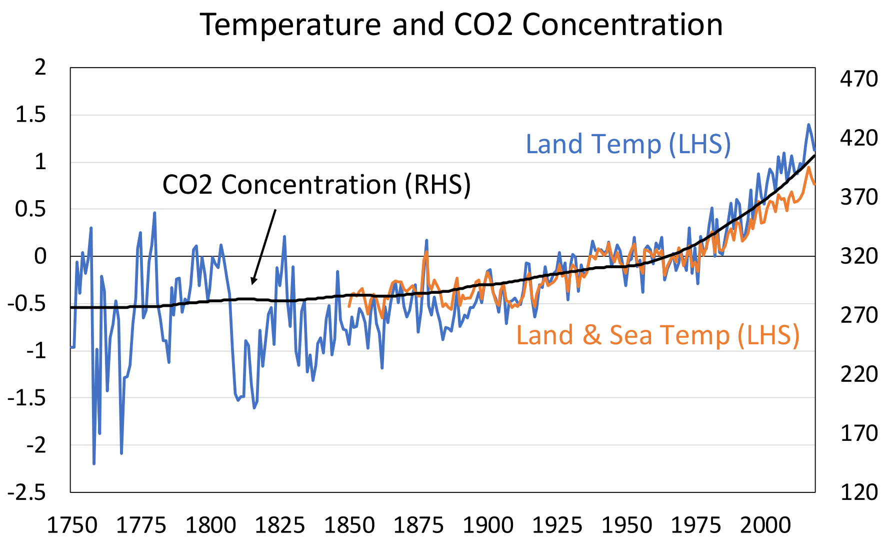
Graph 5



Temperature change (light blue) and carbon dioxide change (dark blue) measured from the EPICA Dome C ice core in Antarctica (Jouzel et al. 2007; Lüthi et al. 2008).

While ice core data are indicative of a link, to get a better, more accurate, picture requires better data. The ice core record of CO2 can be combined with the more accurate atmosphere record of CO2 (collected at Mauna Loa). This measure can be correlated with the direct air temperature record collected from the mid-1700s and air and sea temperatures from mid-1800s. In order to make statements about how much temperature has risen since the industrial revolution, it is important to span roughly equal periods of time before the onset of fossil fuel use and after. Global land temperatures were much more volatile in the pre-industrial era, largely due to measurement problems given the low number of weather stations, but there is no discernible positive or negative trend. In the period since the industrial revolution, both temperatures and CO2 rise closely together (Graph 6). This correlation suggests a possible link in line with the theory.

Graph 6



Source: http://scrippsco2.ucsd.edu/data/atmospheric_co2/icecore_merged_products
http://berkeleyearth.lbl.gov/auto/Global/Raw_TAVG_summary.txt

Does Correlation Prove Causation?

No. Despite the strong correlation between temperature and CO2 emissions, other variables might be responsible for changes in temperatures. A commonly mentioned variable is sunspots. Sunspots are storms on the Sun's surface that are marked by solar flares and hot gassy ejections from the Sun's corona. Scientists believe that the number of spots on the Sun cycles over time, reaching a peak—the so-called Solar Maximum—every 11 years or so. Some studies indicate that sunspot activity overall has doubled in the last century. The apparent result on Earth is that the Sun glows brighter by about 0.1 per cent now than it did 100 years ago.

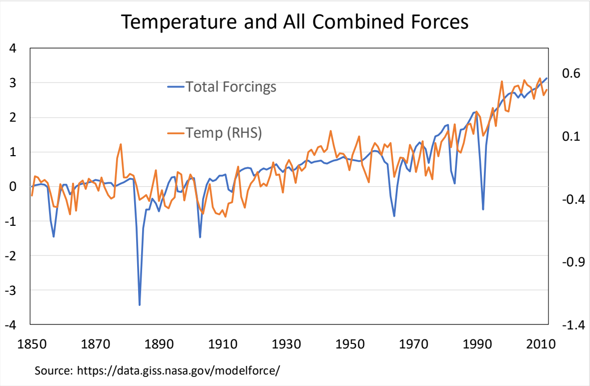
Volcanoes can also impact climate change. During major explosive eruptions huge amounts of volcanic gas and ash are injected into the stratosphere. Most of the injected ash falls rapidly from the stratosphere and is removed within several days to weeks. But volcanic gases like sulphur dioxide can cause global cooling. Sulphur dioxide rises into the stratosphere where it condenses into sulphate aerosols. The aerosols increase the reflection of radiation from the Sun back into space, cooling the Earth's lower atmosphere or troposphere. Scientists estimate that Mount Pinatubo, which last erupted in 1992, cooled global temperatures by 0.5°C (See USGS).

Other factors that affect global temperatures include:

- the albedo effect – white areas like ice and snow reflect sun back outwards rather than being absorbed;
- the orbital cyclical effect - the wobble of the earth on its axis can cause it to be warmer or colder; and
- land use – deforestation would lead to global warming, countered by the fact that clear areas reflect more light, cooling the planet.

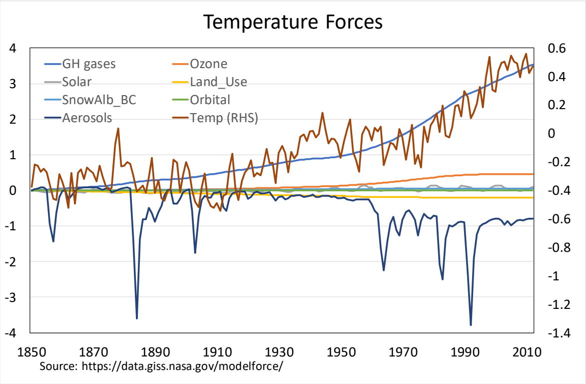
To estimate the impact of all these factors on temperature changes, they are converted into a similar energy measure, and plotted against temperature (Graph 7). Only one of these variables are related to the post industrialisation growth in temperature: greenhouse gases – mainly CO2 and methane (Graph 8).

Graph 7



Source: https://data.giss.nasa.gov/modelforce/

Graph 8



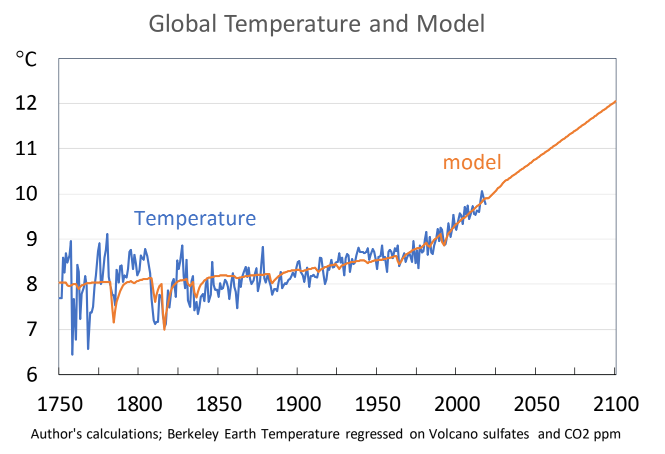
Source: https://data.giss.nasa.gov/modelforce/

What Does It Mean for Future Temperatures?

The Swedish scientist Svante Arrhenius, in 1895, predicted that if the amount of CO2 in the atmosphere doubled, global temperatures would rise between 5°C and 6°C. Remarkably, Arrhenius' prediction is just slightly above those generated by scientists in research institutes around the world using large, complex models of the climate. These models simulate the physics, chemistry and biology of the atmosphere, land and oceans in great detail and require some of the largest supercomputers in the world to generate their climate projections. The latest runs of the models suggest temperatures will rise between 2.8°C and 5.8°C for a doubling of pre-industrial CO2 levels.

A very simple model (a regression equation) that works out how much temperature changes are linked to CO2, volcanic activity and other variables yields similar results as the more complex models run on supercomputers. It shows a very close relationship between changes in CO2 and changes in the Earth's temperature. It also shows that volcanic activity is important to explain certain events, but does not have a long run impact on temperature. The regression does not reveal any evidence that changes in solar activity or changes in the Earth's orbit affect temperatures over this period. This simple model also predicts that should CO2 levels double from their pre-industrial period, temperatures will rise by around 4 degrees (Graph 9).

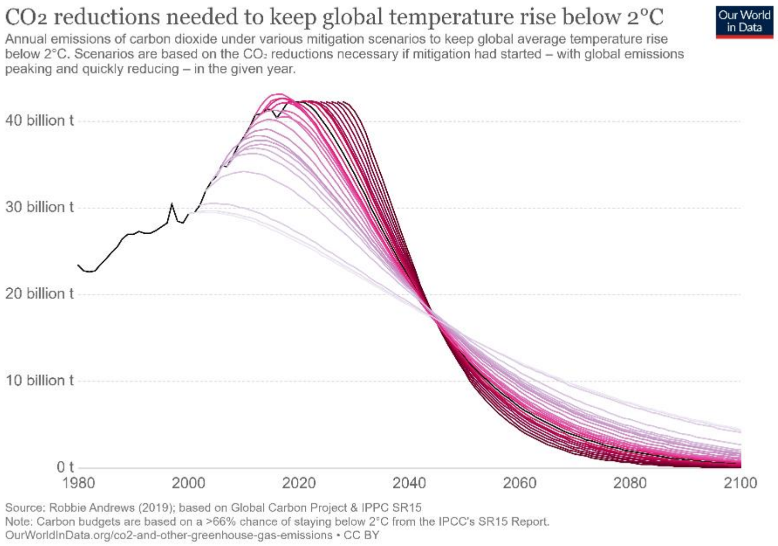
Graph 9



Author's calculations; Berkeley Earth Temperature regressed on Volcano sulfates and CO2 ppm

The United Nations' International Panel on Climate Change (IPCC)'s summary of the evidence submitted from the scientists running the complex climate models led it to conclude that if we want to limit the planet's temperature increase to only 1.5°C above pre-industrialisation period by the end of this century, we will require CO2 emissions to fall immediately. More realistically, the target of limiting global temperature rises to below 2°C will still need to see immediate reductions in emissions but over a longer period. The longer global agreement to abate takes, the harder it is to meet the target (see Graph 10 estimates of paths under different scenarios).

Graph 10



CO_2 reductions needed to keep global temperature rise below 2°C

Annual emissions of carbon dioxide under various mitigation scenarios to keep global average temperature rise below 2°C. Scenarios are based on the CO_2 reductions necessary if mitigation had started – with global emissions peaking and quickly reducing – in the given year.

Source: Robbie Andrews (2019); based on Global Carbon Project & IPPC SR15
Note: Carbon budgets are based on a >66% chance of staying below 2°C from the IPCC's SR15 Report.
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions • CC BY

So What? What are the Consequences of Global Warming?

The science and evidence that suggests temperatures are rising due to addition of C02 to the atmosphere is compelling. But nobody knows exactly what this means for our standard of living. The Earth has seen periods of high temperatures in the past. Warmer weather may be good for some countries with lots of land locked under snow and ice (like Canada and Russia), and civilisation as a whole does better in warmer periods than ice ages. For example, aborigines in Australian almost died out during the last ice age around 20,000 years ago.

But there are significant costs of warmer temperatures. The sea level rises and warmer ocean temperatures lead to greater storm frequencies and intensities. For instance, global sea levels rose by a total of more than 120 metres as the vast ice sheets of the last Ice Age melted back. The average rate of sea-level rise was roughly 1 metre per century (see Stanford et al). The IPCC reported in 1992 that “A one metre rise by 2100 would render some island countries uninhabitable, displace tens of millions of people, seriously threaten low-lying urban areas, flood productive land, contaminate fresh water supplies and change coastlines. All of these impacts would be exacerbated if droughts and storms become more severe” (IPCC). Warming of the ocean has already contributed to longer and more frequent marine heatwaves in the Tasman Sea, southeast Australia and Tasmania. Marine heatwaves are linked to coral bleaching in the Great Barrier Reef and damage to kelp forests (National Science Climate Advisory Committee 2019).

In 2006, it was estimated that approximately 3 per cent of addresses in Australia are within three kilometres of the shoreline in areas less than five metres above mean sea level (Senate Inquiry 2018). Large parts of the Gold Coast would be uninhabitable.

Another large and potentially devastating cost, for which we also have no estimate, is the cost of what happens due to the acidification of the oceans. As we burn fossil fuels and atmospheric carbon dioxide levels go up, the ocean absorbs more carbon dioxide to stay in balance. But this absorption has a price: when carbon dioxide reacts with seawater carbonic acid is created, making the ocean more acidic. A more acidic ocean will result in the death of corals and many sea animals that humans, and other organisms, need as food.

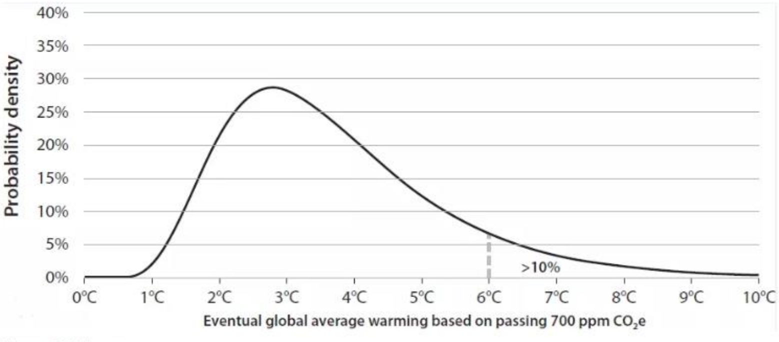
A study by the University of Melbourne has estimated the costs of climate change across the whole Australian economy in the hundreds of billions of dollars in 2030 and at more than A$5 trillion in cumulative damages by 2100, even excluding many costs of flood, fire and environmental losses (Kompas et al. 2019; in Climate Change Authority 2020).

While these costs are large, they do not take into account even larger costs from "Black Swan" events. These events are unknown outcomes of extreme warming, but with potentially catastrophic consequences. Some of these events might include the shutdown of the Thermohaline Circulation – ocean currents that gives Europe its warm climate, the irreversible melting of the Greenland and West Antarctic ice sheets, and the possible rapid release of significant amounts of methane from the tundra. We have not observed these events in the measured historical record and hence economists cannot provide estimates of the economic damages from such events. This is called the "Fat Tails" problem.

The Fat Tails Problem

There is lots of uncertainty about how high temperatures will be by the end of the century. The IPCC provides a range of 1.5°C -4.5°C. Temperatures may be higher than 4.5°C, but they are not likely to be lower than 1.5°C, given we have already seen a 1.1°C rise. This type of distribution gives rise to "fat tails". In a normal distribution of risk, there is an even balance of risk to the upside or downside around an average. With climate change, there is virtually no probability of temperatures being lower than 1°C above average in 100 years. But the risk of very high temperatures is quite high; a temperature exceeding 6°C has a ten per cent probability. This is shown as the "fat tail" of the distribution to the right of centre (see Graph 11).

Graph 11
Probability distribution of *climate sensitivity* to a doubling of atmospheric CO$_2$



Wagner & Weitzman

The last time the world witnessed periods where global average temperatures were above 6°c or so above the pre-industrial period was during the Eocene epoch - 55–34 million years ago. "During these warming periods, the Earth was ice free, while palm trees and alligators lived near the North Pole. More than half of today's human population would be living in places where, at least once a year, there would be periods when death from heat stress would ensue after about six hours of exposure. Human life would become debilitating and physical labour would be unthinkable. The massive unrest and uncontainable pressures this might bring to bear on the world's human population are almost unimaginable" (Weitzman 2011).

To put the small probability that the costs of climate change could be catastrophic in perspective, engineers routinely evaluate risks of projects. “At 90% this is a 1 in 10 chance of failure, three orders of magnitude greater than normal engineering design” (Climate Change Authority 2020). Similarly, a one in ten chance of catastrophe is much higher than some risks we take out insurance policies for.

Insurance

Insurance is usually used to cover the “small chance, but big problem if it happens” type events. We take out insurance for small risk of fire, collision and theft. Why? Is it alarmism to think about these events? If there was a 10% chance of contracting a fatal virus, would we try to take some preventative measures now or to wait for science to give us a cure? The recent Covid-19 virus pandemic gives some interesting insights. Some scientists estimate that the general population has only a 1 per cent chance of dying of Coronavirus once infected (see BBC). Nevertheless, this small risk has led to the largest peacetime disruption to the global economy of all time. The economic and social costs of counter measures such as social isolation and business closures is estimated to be in the trillions of dollars, with some estimating that the unemployment rate could rise to Great Depression levels (see Vox).

So even if the risk of catastrophic global change is small and a long time away doesn’t mean we should ignore it. The best response is to take out insurance just in case. In the context of climate change, there is a 10 per cent chance that temperatures could rise by more than 6°C. It might make sense to spend a little now to ensure very large costs this temperature rise would cause in the future are avoided.

Science will Save Us

Maybe. Or maybe not. Science always seems to have come to the rescue in the past. One view is that if carbon in the atmosphere is the problem, then clever engineers will build a machine that can suck it out again. In fact, engineers and scientists have been working on just such a device. It is called “air capture” (see article). But even air capture of carbon dioxide is not likely to be a silver bullet. Carbon capture usually is used to scrub out carbon from smokestacks (where there is lots of carbon) and treats it so it doesn’t go into the atmosphere. This does not reduce the carbon already in the atmosphere. Air capture, once implemented at scale, can slow the rate of further changes, but many of the intervening climatic changes will indeed be irreversible (Wagner & Weitzman). Ocean fertilisation takes CO2 out of the air by growing more plants in the ocean. More trees will do the same thing. But these systems need to continually expand to keep up with our growing emissions so they are probably not sustainable.

Other technical solutions include geo-engineering, where sulphur particles are injected into the atmosphere to block the Sun rays from reaching the Earth. Geo-engineering techniques may work for a while, but they all have one thing in common: they do not remove CO2 from the atmosphere. And they could have strong side effects. Sulphur particles come back down as acid rain. Climate engineering is risky: it comes with risk of unintended consequences that might be as bad as original problem it was trying to solve.

How Did We Get Here? The Problem as Economists See It

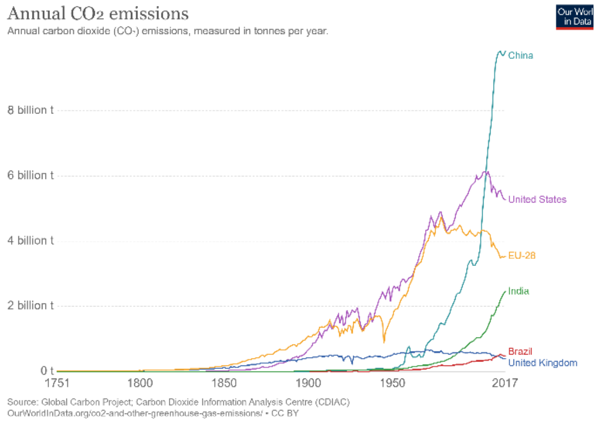
Economist have long identified the problem of climate change as an externality. Externalities arise when people or businesses do not bear the full costs of their actions on others. Externalities are present in many industries in many countries. Pollution is a clear negative externality, where companies do not pay for the cost its air or water pollution it is causing to the wider community. There are some positive externalities. A lighthouse guides ships safely to a harbour, but it cannot exclude any ship that does not pay for the lighthouse.

Climate change is the mother of all externalities. It is truly global (it doesn't matter who or where carbon is emitted) and no one bears any direct cost or repercussion for emitting. If you cut your emissions, and I raise mine, total emissions remain the same, and there is nothing you can do to stop me. The lack of private market incentives not to emit carbon mean that the social cost of emissions is borne by neither businesses nor consumers but by future generations in the form of higher global temperatures.

What to do?

One option is to do nothing. Australia emits only around 1 per cent of the global carbon emitted into the atmosphere. Even if Australia cuts its emissions to zero tomorrow, the effect on the global annual emissions will be practically zero. Most countries are facing the same reality; only a handful of countries account for the bulk of CO2 emissions. The biggest emitters today are China, the US and Europe in that order (see Graph 12). But possibly a better measure is cumulative CO2 emissions. That is, the US was allowed to use fossil fuels over 200 years to achieve its high standard of living today. China and India argue that they are unjustly singled out for carbon emissions when their cumulative total is a lot less than the US (see Graph 13).

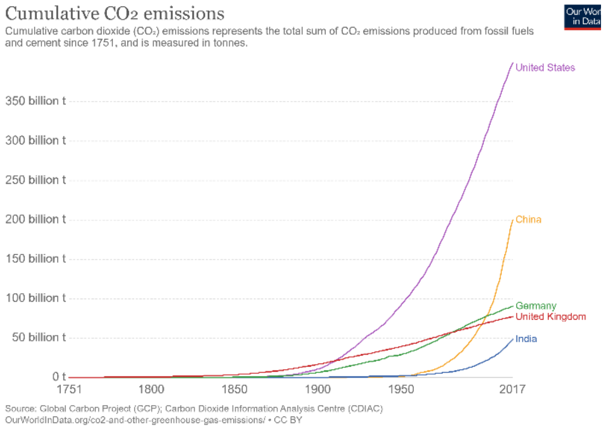
Graph 12


Annual CO2 emissions

Annual carbon dioxide (CO₂) emissions, measured in tonnes per year.

Source: Global Carbon Project; Carbon Dioxide Information Analysis Centre (CDIAC)
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/ • CC BY

Graph 13


Cumulative CO2 emissions

Cumulative carbon dioxide (CO₂) emissions represents the total sum of CO₂ emissions produced from fossil fuels and cement since 1751, and is measured in tonnes.

Source: Global Carbon Project (GCP); Carbon Dioxide Information Analysis Centre (CDIAC)
OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/ • CC BY

Source: Our World in Data

To cut global emissions will require cooperation of a truly epic scale. Can Australia really lead the world by example – show other countries how to cut emissions without harming your economy and expect other nations may follow? After all, Australia is only one of 195 of all the world's countries.

The Economist's Solution

It is easy to conclude that economics, or capitalism to be more precise, is the problem. But just wishing we would slow down carbon emissions is not going to work. Voluntary action is great but is not likely to be enough. We need capitalism, with its incentives, innovations and entrepreneurial powers to drive solutions for climate change.

Just as economic theory on externalities has been around for decades, so too has been the solution. Arthur C Pigou in 1920 pointed out that the way to solve an externality is to internalise it by making the polluter pay for the full cost to society of the polluter's emissions. For climate change, the way to do it is to make polluters pay for each tonne of carbon emitted. If the government requires emitters to pay for each tonne emitted, the payment can be thought of as a tax. The result of paying a price per tonne emitted would be that the incentive to emit changes. Firms will treat the new payment like other business costs and aim to reduce it to increase profit margins and/or gain market share. Over time, low-emissions producers will gain market share over high-emissions producers. But in the short term, energy companies would likely pass on the tax to consumers. The higher price is an incentive for customers to use less fuels that have emit the most carbon. Consumers and companies will substitute towards low-emissions energy sources due to their cost advantage.

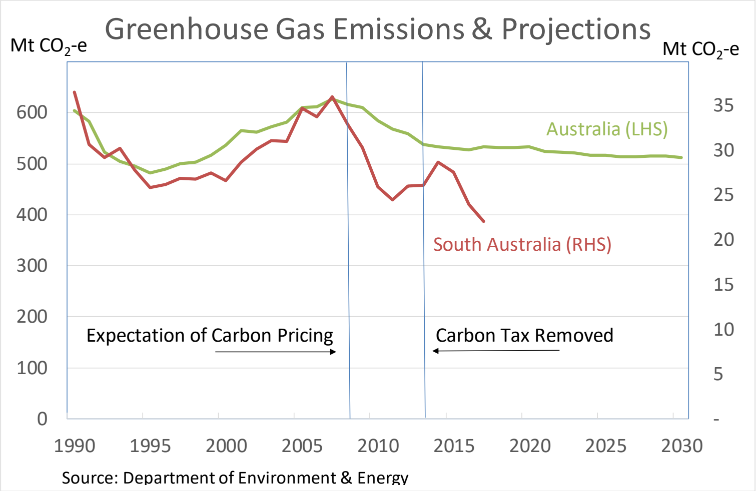
The old joke about getting 5 economists in a room and you will get 6 opinions does not hold in the case of a carbon tax. In 2019, an exceptionally large number of notable economists wrote an open letter to the Wall Street Journal supporting a carbon tax. It is the largest public statement by economists in history.

Introducing a carbon tax was the key plank. But the economists went further and proposed that any taxes raised should be given straight back to the taxpayer, in the form of a weekly or monthly payment. The taxpayer is made whole – the tax paid by the consumer is exactly offset by a cash payment. The point is that the tax changes consumer's incentives. If your neighbour decides to drive his SUV to the shops rather than walk, then he will hand over hard cash for the privilege through higher petrol prices. On average, the tax raised at the pump is paid back to him, and he is no worse off. But if you instead decide to walk to the shops, or drive your electric car, you get to keep the cash. A carbon tax directs people's spending away from carbon-based activity towards lower cost energy alternatives like solar or wind generated electricity.

A carbon tax becomes even more compelling should oil prices continue to fall (see Helm 2017, 2020). Falling oil prices reduces the cost advantage solar and wind now have, and may increase demand for fossil fuels. One possible solution is for the carbon tax to move inversely with the world oil prices. If the underlying petrol price is falling, then consumers will be able to absorb a higher tax at the bowser which leaves the price they pay constant. If a carbon tax is not introduced, it might be possible to achieve a similar result by increasing the fuel excise levy by the same amount as the fall in world oil prices. This will leave the price motorists pay at the bowser constant, and ensures renewables remain competitive with fossil fuels for transportation.

Australia's short experiment with carbon taxes suggest that they were effective in reducing emissions (Graph 14). "In its two years of operation, carbon pricing encouraged less emission-intensive power at every margin, just as it was designed to do. Rooftop solar in households and small businesses grew rapidly from about 2010. It continues to do so, supported by new programs in some states after the repeal of carbon pricing" (Garnaut 2019).

Graph 14

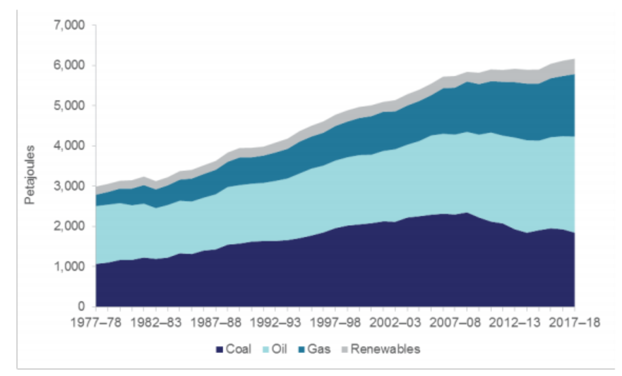


Source: Department of Environment & Energy

Some have argued that a carbon tax is no longer needed because the use of renewables is happening anyway, largely due to the falling price of solar panels. But electricity generation is only one element of energy production. Coal, oil and gas dominate energy use in Australia (Graph 15). South Australia has been lauded for achieving 50 per cent of its electricity use from renewables, but in terms of total energy use, renewables are still only 10 per cent (Graph 16).

Graph 15

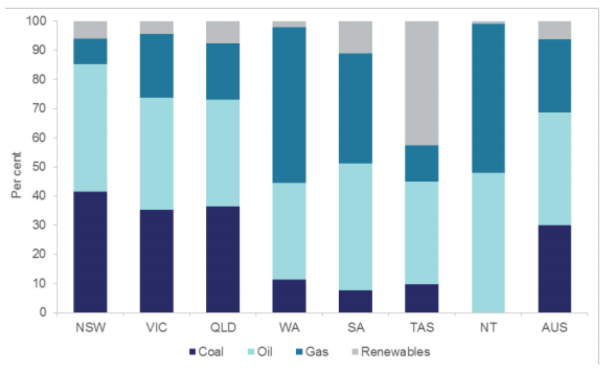
Figure 2.2: Australian energy consumption, by fuel type



Source: Department of the Environment and Energy (2019) *Australian Energy Statistics*, Table C

Graph 16

Figure 2.10: Australian energy mix, by state and territory, 2017–18



Source: Department of the Environment and Energy (2019) *Australian Energy Statistics*, Table C

Source: Australia Energy Update 2019

Breaking down emissions by industry, transport is the single largest sector of fossil fuel consumption at around 30 percent. Road use is three-quarters of transport demand followed by air transport. Lower costs of solar will help with electricity consumption, but does not much affect transportation, unless motor vehicles become electric. And electric planes are not on the foreseeable horizon. A carbon tax would change the price of renewable electricity relative to oil, speeding the switch to electric vehicles, reducing the demand for oil and spur new research efforts into alternative fuels like hydrogen. It will also reduce demand for air travel as some people eventually substitute towards electric trains and cars.

Can small countries make a difference?

The risks of climate change were known for many years. However, the numerous international committees beginning with Kyoto and the latest being Paris have been failures in curbing CO2 emissions, let alone reducing them. Even if the Paris commitments are met, the global temperature will almost certainly exceed the two-degree target later in the twenty-first century.

These agreements fail for the simple reason that there are irresistible incentives for countries to "free ride" on the efforts of others to reduce emissions. Free riding occurs when a party receives the benefits of a public good without contributing to the costs. In the case of international climate change policy, countries have an incentive to rely on the emission reductions of others without making costly domestic reductions themselves. If Australia kept the carbon tax while other countries did not, Australian-made products and exports would be more expensive than similar products made in other countries. Australian consumers would simply substitute domestic goods for foreign goods, and the amount of global carbon emitted would not change.

The Nobel prize winner in economics, William Nordhaus, proposes a solution to this free riding problem. Start a Climate Club of countries that have a carbon emission plan: either carbon taxes, emission trading schemes or a combination of both. The club members trade freely among themselves. If other countries do not have a carbon tax, they are outside the club. If these countries wish to trade with the club, they would be penalised with a carbon "tariff". Under this plan, imports from non-participants into a country would be taxed at the border by an amount that would be equal to the domestic price of carbon times the carbon content of the import. If that proves too difficult to calculate, a simple flat tariff on all imports from a non-member would work. The point is to provide powerful incentives for countries to be part of the Climate Club.

A "tariff" on goods and services that are imported from non-member countries would enhance the competitiveness of domestic firms that pay a carbon tax than their global competitors that do not pay the tax. Job losses at home would be avoided. It would also create an incentive for other nations to adopt similar carbon pricing so they can join the club. For example, seeing no advantage in not pricing carbon, China would be more likely to speed up its own experiments with emissions trading schemes (see Blundell-Wignall). A form of the Climate Club idea is being considered by the European Commission which is assessing the introduction of a 'carbon border tax'.

Australia has a comparative advantage in producing clean energy from solar and wind relative to other countries. Australia could be home to an increasing proportion of energy intensive manufacturing, like aluminium. Policies that speed the transition away from fossil fuels towards renewables (like a carbon tax) could shift these industries to Australia, increasing employment and incomes (Garnaut 2019). The Climate Change Authority concludes that "our abundance of clean energy will give Australia a natural advantage in the global low-emissions economy. We could export clean energy through sub-sea cables and as hydrogen. We could produce energy-intensive goods like low-emissions steel and aluminium. We could become a hub for low- and zero-emissions manufacturing and processing, and for 'green' financial services, and there is long-term potential to export carbon offsets from the land. The potential for new jobs and flow-on benefits to regional communities is substantial. The Authority is firmly of the view that strong measures to tackle and prepare for climate change will enhance Australia's economic prosperity—it is not a case of sacrificing one for the other." (Climate Change Authority 2020)

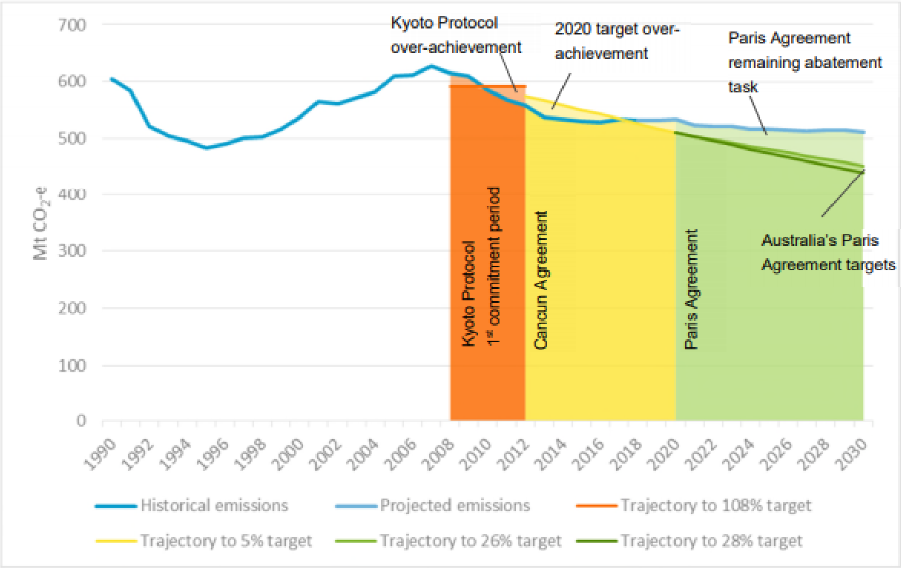
The faster Australia joins with other countries in adopting a carbon price and overcoming the free-rider problem through the use of a Climate Club, the faster Australia can take advantage of its comparative advantage in clean energies.

The Australian Government's Current Position

While economists worldwide are almost universal in their support for a carbon tax, the policy has been polarising politically in Australia. It was repealed in 2014 by the Coalition following it victory in the 2013 election. The view that killed it off was that it unfairly placed Australia at a competitive disadvantage among its trading partners that did not have a similar tax. Instead, the federal government instituted a number of other policies. A key plank is its $2.55 billion Emissions Reduction Fund which supports projects to improve energy efficiency, capture methane from landfills and store carbon in forests and soils. The government claims it has achieved more than 190 million tonnes of emissions reduction at a price of less than $12 per tonne – a price lower than the axed carbon tax. It is also investing in new renewable technologies, and energy storage like the "Snowy Hydro 2.0," which acts as a battery for surplus green energy.

As part of the Paris Agreement, Australia has committed to reduce emissions by 26 to 28 per cent below 2005 levels by 2030. Based on the Government's emissions projections, Australia's cumulative emissions between 2021 and 2030 need to be reduced by almost 400 million tonnes of CO2. This is equivalent to total emissions from industry and product use, or more than a third of current transport emissions. Analysis by the United Nations Environment Programme indicates Australia is **currently not on track** to meet its emissions reduction target (Graph 17) (Climate Change Authority 2020).

Graph 17



Source: Climate Change Authority based on DoEE 2019i

Conclusions

The evidence that global temperatures are rising due to the combustion of fossil fuels creating greenhouse gas emissions is compelling. The economic costs of a warmer climate are not known with any precision, largely due to the risk of low probability but extremely high cost events like the melting of ice sheets that could prove catastrophic for Australia and the world. Economists do not have a good way of measuring such costs or when they will occur, but that does not mean nothing should be done about climate change right now. Quite the contrary, one can think of a carbon abatement policy as a form of insurance: society would be paying an insurance premium now to avoid a low-probability catastrophe. Given the long life of CO2 in the atmosphere and the irreversibility of climate change under many scenarios, a gradual approach could prove very costly. Quick action now could save very large costs later.

Australia's current policies do not appear to be sufficient to bring long term declines in emissions. A return to a carbon tax might be the best solution. Australia is a small player in the global sphere, but if Australia joins a carbon club with other similar nations, for example, and penalise non-participants, Australia could then exert considerable influence, based on self-interest, on other countries to follow suit. A quick transition to clean fuels could see Australia take advantage of its comparative advantage in renewable energies, and see growth in energy intensive industries. It is quite possible that Australia would be on a faster growth path with a faster transition to clean energy.

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