The Middle Way

A briefing for business on the status of global warming

OUR RAPIDLY WARMING PLANET

A perspective on its progression at the start of 2019

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The concept and its implications

The purpose of this briefing is to provide a snapshot of recent scientific assessments on the current status of global warming, from entities such as the *United Nations Intergovernmental Panel on Climate Change* (IPCC-October 2018); the World Meteorological Organisation (January 2019); the Global Carbon Project; and the International Energy Agency which, with *BP (UK),* has collated world energy data for 50 years (February 2019).

Although the world's scientific community has tracked the progress of global warming for 30 years, the composite body of scientific literature and data on atmospheric warming, climate change, and ocean dynamics is now enormous, complex, and subject to dynamic recalibration.

The concept of global warming centres on the growth in the energy level at the surface of the Earth, in the lower atmosphere, and in the top 700 metres of the ocean. The process is being driven exclusively by the emissions of greenhouse gases by humans, and since 1980 largely by one gas, carbon dioxide.

The pace of change is reflected by the fact that the energy level at the surface of the Earth more than doubled from 1.5 Watts/sq. metre in 1979 to 4.0 W/sq.m in 2015. (IPCC). It is tracking to at least 6.0 W/sq.m if our business-as-usual consumption of fossil fuels (coal, oil and gas) persists.

The energy that has accumulated elevated the global average temperature by 1.0^{0}C between 1880 and 2018. As a consequence, 20 of the last 22 years were the hottest ever recorded for the planet. (WMO).

Human-induced global warming has caused changes in the climate system that include (IPCC Ch. 3, p. 177):

- an increase in the frequency, intensity and amount of heavy precipitation,
- more heatwaves on land, and an increase in the frequency and duration of marine heatwaves
- more ocean wave surges; and more intense and longer lasting storms, hurricanes and rain squalls in tropical and sub-tropical zones. (For example, storms with wind speeds higher than 250 km/hr have tripled since 1980 (Steffen etal, Feb 2019).

Significant impacts have also occurred in the oceans around the world, and in the last 25 years in particular, that have included

- a permanent deterioration in their chemical balance and biodiversity,
- acceleration of the rise in local sea levels
- acceleration of the melting of the ice sheet in the Arctic Circle. Added to this is the revelation in late 2018 that the Western Antarctic ice sheet is now melting more quickly as well.

The pace, scope, and severity of the impacts had been expected to be predictable while the temperature at the surface of the Earth remained below 2.0^{0}C above that which prevailed as a global average before 1880.

That was until October 2018, when the IPCC confirmed that the global surface temperature actually needs to be kept below +1.5^{0}C if the most severe impacts are to be avoided. Catastrophic changes are threatened as the planet-wide energy level moves towards +2.0^{0}C, many of which would be irreversible.

About 20% of the world's population now lives in regions where +1.5^{0}C has been exceeded during at least one season. Nevertheless, there is no international consensus on how to stop the growth in carbon emissions.

This is a cause for concern because the IPCC estimates that maintaining the surface temperature below +1.5^{0}C across all parts of the globe would require current global fossil fuel consumption to fall by 45% before 2030. Should our current emissions profile continue, this threshold could be reached by 2040 (IPCC, p.81)

The loss of food and water security in extreme heat and drought-stressed regions could cause the movement of up to 140 million climate change migrants by 2050 if the emissions aren't contained (World Bank). The socio-economic costs of inaction are inestimable.

However, a swift and severe world-wide transformation away from carbon intensive energy sources could create overwhelming economic and social impacts, especially in developing nations, that would need to be managed.

The role of greenhouse gases

The cumulative emissions of greenhouse gases and the global mean surface temperature response have an approximately linear relationship. Their link was first reported in the late 1950s.

Between 1880 and the end of 2018, the activities of humans emitted about 2200 billion tonnes of greenhouse gases, comprising 1540 from fossil fuel burning and cement manufacture; and 660 from land-use activities.

Currently, 85% of the emissions each year are carbon dioxide derived from fossil fuel burning. The other sources include:

- methane from agriculture, natural gas production and the breakdown of landfill waste; and
- the impact of deforestation and other land-use changes that reduce the capacity for carbon reabsorption by terrestrial vegetation and soils.

Carbon dioxide emissions

The world consumed 13 billion tonnes of energy in 2017, 85% from the burning of coal, oil and gas [BP, 2018]. The remaining 15% came from renewable sources such as solar & wind (4% together), nuclear, and hydropower.

The world released 42 billion tonnes of greenhouse gases in 2018, net of reabsorption by plants. The global distribution of the 37 bn.t. of carbon dioxide from fossil fuels saw [BP 2018] :

- the top 5 emitting countries release 58%
- the next 11 countries release a total of 18% (with 400-800 million tonnes each); and
- the remaining 177 UN countries collectively release a total of 24% (each with < 400 mt).

Annual *gross* greenhouse gas emissions, which ignore the reabsorption by plants, are now 50 billion tonnes, and this will continue during the 2020s.

But even taking into account the existing international commitments made under the Paris Agreement to reduce this figure, gross emissions are, in fact, projected to be up to 58 billion tonnes per annum by 2030 [IPCC, p.20].

This means that the best available measures will not only fail to constrain emissions, they will not even respond to the pressure from global GDP growth that will progressively increase the total world energy demand by up to 30% in 2040.

The implications of this imbalance are disturbing. IPCC modelling shows that the maximum carbon emissions in 2030 should not exceed 30 billion tonnes, if there is to be a reasonable chance that steps taken to mitigate global warming after that date will be effective.

One qualification is that the carbon intensity of the future electricity consumed will drop, largely as a result of the extensive investments being directed towards the coupling of new battery technologies to solar and wind energy. Other energy sources like pumped hydropower could also play a role (but less so hydrogen, nuclear, new large hydropower systems, or biomass conversion).

A recalibration published in February 2019 now expects alternatives to fossil fuels to supply up to a third of the total world energy demand by 2040. [BP 2019]. Plummeting costs of solar for electricity generation in particular, have destroyed the argument that a low carbon energy future would be prohibitively expensive [CSIRO-AEMO], but there will nevertheless be an extended period of catch-up for developing countries, and especially India.

But world-wide debate during the 2020s will continue to pivot around the long-term burning of coal for power generation and steel-production, because they require large baseload energy supply capacity. The decarbonisation program in these sectors will be helped by the substitution of natural gas for coal since it has lower carbon emissions per megajoule of energy input. Whether or not this is a transition step in a longer-term strategy away from fossil fuels, or a form of permanent restructuring, remains to be seen

For instance, half of 530 coal plants that had been in operation in the US were either retired in 2017 or were committed to retirement. The change came largely from the significant move towards the use of gas as the primary energy source. No new coal fired plants are being considered there, but neither is a structured move towards renewables a visible policy of the Trump administration.

Some of the most effective initiatives to reduce carbon emissions over the past two decades have capitalized on the implementation of energy efficiency technologies and management practices to minimize the carbon intensity of goods and services across a wide range of industry sectors. These processes will continue, but any significant pay-off will only come in the future from a radical change in the nature of the primary energy inputs to a lower carbon content.

The oceans

The insidious changes occurring in the oceans are striking, and could progressively dominate the future direction and impacts of global warming. (IUCN)

Although there was been little public interest in the topic, the reality is that the top 2000 metres of their waters absorbed 30% of the anthropogenic carbon dioxide emitted over the past century (IPCC p.178).. They have also stored more than 90% of the excess heat generated by the greenhouse effect over the past 50 years. IUCN).

In doing so, the oceans have prevented a calamitous increase in the Earth's temperature. One estimate is that the heat stored down to 2000m. would have increased the temperature of the lower atmosphere by an incredible 36^{O}C, and not the +1.0^{O}C that has been recorded since 1880. (IUCN)

Most striking however, is that the planet-wide ocean heat content grew by 40% in the period since 2014 when the IPCC released its last assessment. Data published in November 2018 identified an enormous uptake of heat energy between 2017 and 2018 .(Cheng). The relevance of this turbo-charge for sea level rises and ocean chemistry remains to be determined, but it is clear that the growing ocean heat content is creating three problems.

The first is the visible heat stress experienced by tropical coral reefs that threatens their survival within 30 years. About 90% of those that exist today will disappear if global warming continues (IUCN, p.179). The Great Barrier Reef is, in particular, witnessing more frequent and severe bleaching events that are progressively challenging its capacity to recover. (Hughes).

An increase in the frequency and intensity of marine heat waves at the ocean surface is depleting critical coastal ecosystems such as the mangroves, seagrasses and salt marshes in tropical and subtropical zones. These systems and the reefs are not only critical breeding grounds for many species of marine life,(IUCN) but are also estimated to have sequestered more than three billion tonnes of carbon dioxide. (WMO, 2019) Their survival is vital.

Second, the biodiversity of the oceans is at risk from the deterioration in the chemical balance of their waters. The acidity of the ocean is now 30% greater than in pre-industrial times, and its interference with ocean carbonate chemistry is weakening the ability of molluscs, corals, and krill to build and maintain their calcium-based exoskeleton and internal skeletal structure.(IUCN; IPCC).

Krill present a special challenge because they are microscopic crustaceans that exist in vast numbers and populate the bottom of the food chain. Modelling is being conducted to determine their vulnerability to the increasing acidity. Preliminary estimates suggest that they could diminish at a rate that will threaten the survival of whales who consume them by the ton, within the next few decades. They are also congregating in the colder southern seas to escape the warming northern waters, which reduces their availability elsewhere.

Seas with areas of abnormally warm water are more susceptible to incidents involving depletion of dissolved oxygen that can lead to large fish kills. They have now been recorded at 500 sites across the world, compared to only 50 around the middle of the 20th century. (Breitung).

Both types of chemical change not only reduce the diversity of the natural marine life, but also threaten the future of the world's commercial and subsistence fishing.

Third, the base height of the seas has risen from the warming of their waters, and the effect is already being seen at low-lying islands in the South Pacific. Extensive coastal inundation is also occurring along North Eastern USA, while the European Union estimates that it has 100,000km of coast-line vulnerable to future inundation.

The rise of the global ocean baseline over the past 25 years is equivalent to that which was recorded over all of the century before it. (Jevrejeva, Nerem).

But the *pace* of the rise is increasing, not only from the growing ocean heat content, but also from the recent addition of large volumes of water from the melting of the ice sheets and glaciers in the Arctic Circle. Its effect is discussed below, but the implications are that the sea level rise between 2020 and 2050 will be twice that between 1900 and 2020. Most is locked-in already by the existing ocean heat store. (IPCC +1.5).

Put differently, parts of the planet will face sea level rises over the next 30 years that will be 70% greater than those seen in the past 120 years. And a failure to contain carbon emissions early enough could generate sufficient energy in the oceans to witness average levels rise by 1.3 metres in 2100, which would be calamitous. Major cities such as Shanghai, Tokyo, San Francisco, London and New York could be submerged well beforehand.

The cryosphere

Although the world's two polar ice caps are often perceived as two static regions of ice, they are dynamic systems that have been in an equilibrium with their surrounding seas for millennia.

For instance, the massive ice sheets partially melt in their summer months and then refreeze in winter. Glaciers move towards the ocean at predictable speeds, and ice cliffs calve and drift out to sea as icebergs. But that was until around 1980 when the equilibrium started to alter under the growing radiative forcing of global warming

The Arctic Circle has since exhibited a more rapid change, and has warmed at twice the speed of the rest of the planet. The melting that has resulted caused it to lose 286 billion tonnes of ice, each year, from 2001.(Dahl; Nerem).

The loss led to only 30% of the world's sea level rise since 1993 coming from the growing ocean heat content: 43% came from the melting of Artic ice sheet and the remaining 27% from melting of the glaciers in the region. (CSSR)

Scientists had been less concerned about the situation in Antarctica, which shed an average of 40 billion tonnes of ice mass annually from 1979 to 1990. But recent assessments have shown that this grew to 252 billion tonnes annually between 2009 and 2017 (Rignolt) .

Most of the growing melt occurred in Western Antarctica and little came from the east where the vast mass of ice is located. However, a sustained temperature rise of 2^{0}C would cause this region to melt too. (Shepherd)

The IPCC is to report in August 2019 on the implications of global warming for the oceans and cryosphere.

The complex involvement of soils, vegetation and land use patterns

One of the most complex and least understood aspects of global warming is the relationship between the world's terrestrial vegetation and soils, and the level of carbon dioxide and other greenhouse gases in the lower atmosphere.

As shown earlier, around 30% of the accumulated atmospheric carbon from human-induced gas emissions comes from land-use and land change practices. But although this source can be high in agrarian, non-industrialised countries, they represent only about 12% of current annual global carbon emissions.

World-wide programs have also been implemented to protect and enhance native grasslands, wetlands, and forests to preserve the biodiversity that underpins all life on the planet. These natural environmental assets also absorb and hold carbon with varying levels of effectiveness, so human actions that remove them or interfere with their normal functioning represent actions that accelerate global warming.

At the same time, other land-use practices such as urbanization, agriculture and animal husbandry generate carbon dioxide and two other greenhouse gases: methane and nitrous oxide. Both have a strong short-term global warming potential and can be prominent in agrarian regions. (Methane is also released by decaying vegetation and from natural gas production sites, so is receiving significant research attention.)

Whilst the chemistry of the carbon flux between the land and the atmosphere is reasonably well understood, It is very hard to be quantified at the global scale because there is wide variability in localised synergies between factors such as:

- the prevailing climate during a specific season;
- the type and productivity of the dominant soils, grasses and plants in the area; and
- the relevance of the local and regional topographies that determine where and how variable weather patterns exert their influence.

A paper published in late 2016 (Griscom) provided one example of how the carbon flux through the world's vegetation and soils could be quantified:

Absorption by plants & soils	9.5 (-)
Emissions from terrestrial environment	
o Agriculture incl. animal husbandry	6.0 (+)
o Land use change & deforestation	5.0 (+)
Net emissions from the land sector	1.5 (+)

(annual billion tonnes CO_2- equivalence)

But there is a twist. Proposals for investments in land-use improvements will need to be reconciled against the declining biosequestration capacity of the terrestrial environment as it continues to warm.

There is evidence that the more hostile and less predictable climate patterns already being experienced, could rapidly degrade both the quality and productivity of soils and vegetation and hence the rate at which they absorb carbon sustainably.

So investments in land-use change management may not offer the longer-term payoff needed, and certainly not within the 10-15 years available for containing emissions before the opportunity to avoid the most severe impacts of global warming is lost.

On the other hand, the IPCC argued that even if the world managed to attain zero carbon emissions by 2050 – one of its key recommendations - the period 2050 to 2100 would require negative annual global emissions for that goal to prevail at the end of the century. And new biosequestration investments would be an unavoidable component of any strategy for achieving it.

Supporting this goal is the fact that there are significant biodiversity enhancement co-benefits from the improvement of natural features like wetlands, native grasses and natural forests. Global warming is causing the world to face the highest rate of extinction of animal plant and insect species in the history of civilization, so any measures that slow this must be seen as positive.

The story also has implications for global food and water security. World agricultural productivity will itself decline under the stressors of extreme heat, prolonged droughts and other destructive weather-related impacts of climate change. A parallel deterioration in soils and native vegetation will amplify the loss.

Non-linear risk exposures

Global warming is fundamentally a planet-wide, uncertain, and long-term phenomenon. Caution should be exercised before impacts at any specific location are attributed to climate change-related weather events, because local circumstances can have a dominating influence over their scope and scale. (World Weather Attribution)

Notwithstanding this, the progression of global warming is not only well established, but it is also clear that an increase in significant physical impacts is now unavoidable. The evidence suggests that extreme weather patterns could be far more frequent as early as 2030 (IPCC+1.5), and especially in Australia.(Steffen, 2019).

There are three compounding features that make the global warming phenomenon innately complex:

(1) Extreme weather patterns can act as threat multipliers for adverse outcomes that occur within natural weather cycles. Droughts can be longer or hotter; storms fiercer and less predictable; or abnormal surges in local seas elevated to deadly storm or wave surges by the higher ocean baseline.

(2) The occurrence of two climate-related incidents in swift succession can be devastating. A wildfire that has caused wide-spread forest loss can soon be followed by a rain deluge that denudes the newly bared soil surface – overwhelming the capacity of emergency service providers to protect people and property in the region of impact.

    Or when an extreme rain squall causes estuarine flooding, the ocean storm surge associated with it can prevent the pooled water draining out to sea. The speed of the inundation through urban settlements in a river delta can result in tragic losses.

(3) It's impossible to exclude the emergence of a "Hothouse Earth" pathway arising when the Earth's surface temperature passes a threshold level.

Steffen and his colleagues in Canberra and Stockholm published a controversial paper in August 2018 that posited the notion of a run-a-way climate system being triggered when the planet's surface energy reached a dangerous level. The effect would be a new unpredictable, unstable and irreversible global weather profile.

It would be driven by a breakdown in the 'quasilinear relationship between cumulative carbon dioxide emissions and global temperature rise'; and could involve multiple 'tipping elements' that could activate a 'domino-like' cascade of extreme impacts. The authors considered that the system's trajectory could trigger this at +2^{0}C.

The message in the paper was reinforced two months later with the release of the IPCC +1.5^{0}C report, which warned that even a short-term overshoot of that temperature would likely produce irreversible impacts. It also now saw the +2^{0}C threshold being exceeded later in the century, but noted that this would have catastrophic impacts.

The business case for action

The inevitable transition to a low carbon world will be expensive, and will see the financial costs of the risks pass disproportionately to countries, industry sectors and corporate enterprises that fail to respond early enough for them to remain globally competitive.

These entities will progressively bear the transfer of the costs through mechanisms such as:

- transparent or hidden prices on carbon
- increased insurance premiums;
- damage to brand or corporate reputation;
- international trade penalties, or restrictions on the trade in carbon intensive products and services.

Corporate entities are increasingly facing the need to publish risk management and mitigation plans that address the most likely specifics of their exposure to climate change across their value-chain.

These plans should then include analyses that not only address identified threats, but also take account of the uncertainties that will inevitably be associated with an increasingly volatile environment. The threat of early business interruption over the next decade, and to corporate resilience in the longer-term, is now sufficient to warrant the inclusion of financial projections.

Various methods for conducting these are now available in the financial literature [(TCFD)], and are especially being used by firms in the oil and gas industries with high climate-related risk exposure.

The importance of doing so is also being recognised in Australia. For example, a joint statement by the Australian Accounting Standards Board and the Australian Auditing and Assurance Standards Board in December 2018, advised that climate risks are now a material consideration for disclosure in financial statements, even if they are small in magnitude. *(https://www.auasb.gov.au).*

This was followed by the release in February 2019 of the Australian Securities Exchange Corporate Governance Council's *Corporate Governance Principles and Recommendation*s, that comments on how corporate Boards should disclose how they identify and manage climate-related risks. *(https://www.asx.com.au)*

And finally, the insurance and global re-insurance sectors are investing heavily in methods for characterising the types of circumstances where the progression of extreme weather events and other impacts of the warming planet will increase their risk of loss.

Their response will be not only be reflected in the pricing of the risk-cover they offer, but also on the possibility that they will not offer any cover at all where the risk-exposure is unacceptably high. The latter in particular could create regional socio-economic consequences.

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