Climate Emergency

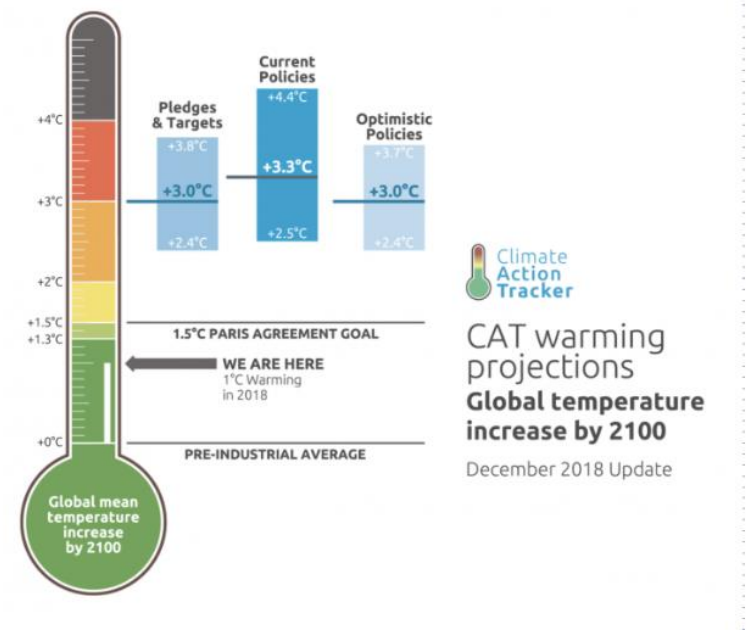
During 2019 we began a series looking the trends in the area of climate change through the STEEP lenses. This will be continued into 2020 as there are many areas to consider.

Climate Change – Climate Emergency

One of the clearest “megatrends” facing the world must surely be climate change – or “climate emergency” as many commentators are now calling it. Clearly there are a range of outcomes possible, from the ambition of a “less than 1.5°C” level of global warming from pre-industrial levels, to frightening suggestions of an increase of 6°C or more. But whatever the outcome we can be certain there will be major ramifications for the world, its people and its flora and fauna. And for organisations of all kinds.
We’ve decided to focus on this major issue in a new series of blogposts. We will cover the likely impacts of climate change on various parts of the global ecosystem, and address both “mitigation” (reducing emissions) and “adaptation” (coping with climate change already happening).

The International Panel on Climate Change, set up in 1968, is the main international body attempting to get global agreement on ways of reducing climate change. It achieved a notable success in 2015 with the Paris agreement, signed up to by **nearly 200 countries**, including the USA and China, with most ratifying the agreement in April the following year. The agreement aims to respond to the global climate change threat by keeping a global temperature rise this century well below 2°Cabove pre-industrial levels and to pursue efforts to limit the temperature increase even further to1.5°C. Unfortunately, the incoming Trump administration in the US announced on 1 June 2017, that the United States would withdraw from the agreement, with an effective withdrawal date of 4 November 2020.

An independent group, **Climate Action Tracker**, has analysed the pledges and policies put in place following the Paris Agreement, and it is clear that they are nowhere near the level necessary to hit the 1.5°C target, with 3°C being more likely – twice the target level.



So what would such a rise or worse actually mean? We shall look to answer that question in a number of areas:

- Climate change and the sea: sea-levels, acidification, coral bleaching, changing fish migration patterns
- Climate change and agriculture: pluses as well as minuses
- Impact of warming world on natural defences – methane sinks in Siberia, ice packs reflecting sunlight etc
- Extreme weather events
- Migration

What technologies could be effective in mitigating climate change? What upsides could there be?

- Renewables: solar/wind/tidal/bio/, progress, economics, battery storage
- Carbon capture and storage
- Transport: electric vehicles (including planes and ships), air taxis, Heathrow; commercialisation of space
- Other more innovative technology responses – cloud seeding

And what might the political and economic impacts be?

- **Stern report 2006**
- Future of fossil fuel industry: disinvestment, “keep it in the ground”, stranded assets, fracking
- Impact on finance sector – Bank of England warnings, insurance industry
- Political responses: new Green Deal, insulation, next COP event, street-level response; political impacts of climate change and climate change mitigation (including geo-political impacts on oil-producing countries)

Debate has focussed on achieving zero emissions by at least 2050, preferably earlier. But even achieving that is likely to be hugely disruptive, and we saw in a previous blog that **BP's energy forecasts** show this to be unlikely. Recently the climate emergency had a moment at the centre of public debate (at least in the UK) with the visit of Greta Thunberg, David Attenborough's powerful programme and the Extinction Rebellion disruption. And the Government has now committed to **net zero carbon emissions** by 2050.

If you have views on any of the issues in this field, please do contact us and we can give you the opportunity to express them.

Written by Huw Williams, SAMI Principal, published 19 June 2019

Climate Change and the Sea

One of the clearest areas impacted by the climate emergency is the world's oceans. Excess heat trapped in the atmosphere by greenhouse gases spreads into the oceans which absorb around a third of all manmade CO_2, and 90 percent of the excess heat created by those greenhouse gas emissions. Along with the warm air itself, the heat absorbed by the oceans melts ice in the polar regions, raising sea levels; melting glaciers also have an effect. The expansion of seawater as it warms contributes substantially to sea level rise, perhaps accounting for as much as 40%.

Satellite radar measurements reveal an accelerating rise of 7.5 cm (3.0 in) from 1993 to 2017. Forecasting sea level rise is challenging, depending on many assumptions. The International Panel on Climate (IPCC) have a range of warming forecasts, which predict a sea level rise of up to one metre by 2100. But more **recent studies** using more varied scenario planning have challenged that modelling and suggested that on current warming trends the seas would be as much as two metres higher by 2100 in even the median scenario.

At higher levels of CO_2 emissions, and warming sea levels will rise further. A **recent IPCC report**forecast global mean sea level rise to be around 10% higher with global warming of 2°C compared to 1.5°C by 2100. This difference implies that up to 10 million more people would be exposed to related risks of flooding, saltwater intrusion and damage to infrastructure. The higher rate of sea level rise at global warming of 2°C also reduces opportunities for adaptation. And remember that the Climate Action Tracker forecast based on the Paris Conference commitments was for a temperature rise of 3°C.

The **Met Office annual report** on climate change found that average sea levels around the UK have risen by 1.4mm a year since 1900 – equal to a rise of 16cm (6.3ins). Their mean projection for sea level rise in London by 2100 is 60cms, with an upper estimate of 1.15 metres. UK coastal flood risk is

expected to increase over the 21st century and beyond under all emission scenarios considered. “This means that we can expect to see both an increase in the frequency and magnitude of extreme water levels around the UK coastline.”

The effect of sea level rise on low-lying islands and coasts could be dramatic. As well as the direct effect and the salinization of farm lands, higher sea-levels lead to more extreme events such as flooding and storms. The **International Organization for Migration (IOM)** quotes Professor Myers of Oxford University who estimated that as many as 200 million people may become refugees from a combination of disruptions of monsoon systems, by droughts of unprecedented severity and duration, and coastal flooding. The **World Bank** suggested 140 million by 2050.

28% of Bangladesh’s 165 million people live on the coast. During the rainy season more than one-fifth of the country can be flooded at once. The number of Bangladeshis displaced by the varied impacts of climate change (eg cyclones, salt water incursion) could reach 13.3 million by 2050, according to a March 2018 **World Bank report**. The effect on South Asia as a whole could be as many as 40 million migrants.

Mumbai and other fast-growing coastal megacities in Asia are particularly vulnerable to climate-related flooding. Large parts of Mumbai are built on land that, 300 years ago, was mostly underwater. When the British, who took over in 1661, they connected a series of islands into a contiguous landmass and created a peninsula by filling in land gaps to connect the islands. So the city is only artificially higher than sea level. Twenty-one of the world’s 31 megacities (cities of 10 million or more) are on the coast, 13 of these are in Asia.
Pacific Islands like Kiribati are very vulnerable to sea-level rise. Kiribati is a system of islands across the Pacific, the majority of which lie a mere 5-6 feet above sea level. Kiribati could be uninhabitable in as little as 30 years, given the current pace of climate change.

In the US, research identifies 241 cities of 25,000 people or more that will require at least $10 million (£7.9 million) worth of sea walls by 2040 just to protect against a typical annual storm. Even the internet is under threat – thousands of miles of fibre optic cables are under threat in US cities like New York, Seattle and Miami, and could soon be out of action unless steps are taken to protect them.

In the UK, a report from the **Committee on Climate Change** (CCC) said existing government plans to “hold the line” in many places – building defences to keep shores in their current position – were unaffordable for a third of the country’s coast. In the 2080s, 1,600km of major roads, 650km of railway line and 92 stations will be at risk, the CCC found. Ports, power stations and gas terminals are also in danger. Holland, with 26% of the country already below sea-level, is working hard on adaptation technology.

There are second-order effects too. The retreat of coastal forests as sea level rises is well documented. Tidal flooding and saltwater intrusion as well as flooding and wind associated with storms can kill trees. This creates a feedback loop where vegetation no longer provides a buffer against storm surges.

The oceans don't just soak up excess heat from the atmosphere; they also absorb excess carbon dioxide, which reacts with the seawater making carbonic acid. Increasing acidity has effects such as depressing metabolic rates and immune responses in some organisms, and causing **coral bleaching**. In 2016, bleaching of coral on the Great Barrier Reef killed between 29% and 50% of the reef's coral; in 2017, the bleaching extended into the central region of the reef. Ongoing acidification of the oceans may threaten future food chains. But it can have other surprising effects: **squid populations** are expected to rise because their faster breeding cycles enable them to adapt to changing environments faster than their predators. And **jellyfish** have experienced a population explosion in recent years.

Warming seas also change fish behaviour, impacting both the birds that feed on them and the fishing industry. Species such as cod, sea bass and king crab are expected to move further north. Fishermen in North Carolina, fishing for black sea bass, may have to travel 300 or 400 extra miles to find them. Climate change starved to death thousands of **puffins** in Alaska when the fish they eat migrated north with rising sea temperatures.

In our next post on climate change, we will look at effects on land. If you have views on any of the issues in this field, please do contact us and we can give you the opportunity to express them.

Written by Huw Williams, SAMI Principal, published 3 July 2019

Climate Change on Land

We looked at the impact of climate change on the sea in a recent blogpost. That included issues of coastal flooding, storm surges and salination. In this one, we look at the more direct impacts on land.

Image by Jody Davis from Pixabay

A **recent IPCC report** noted that warming is generally higher over land than over the ocean. Warming greater than the global annual average is being experienced in many land regions and seasons, including two to three times higher in the Arctic. Many ecosystems and some of the services they provide have already changed due to global warming.

If global temperatures rise by 2°C then we can expect increases in hot days in most inhabited regions, heavy precipitation in several regions and the drought and precipitation deficits in some regions. Hot days in mid-latitudes warm by up to about 3°C at global warming of 1.5°C and about 4°C at 2°C; cold nights in high latitudes warm by up to about 4.5°C at 1.5°C and about 6°C at 2°C . The number of hot days is projected to increase in most land regions, with highest increases in the tropics.

Risks from heavy precipitation are projected in several northern hemisphere high-latitude and/or high-elevation regions, eastern Asia and eastern North

America. Heavy precipitation associated with tropical cyclones is also projected to be higher.

And remember that the Climate Action Tracker forecast based on the Paris Conference commitments was for a temperature rise of 3°C.

PATTERN OF WARMING

Global average precipitation is expected to rise by about 3% to 5% by the year 2100 (IPCC) but this **will not be consistent across the world**:

- Much of the increase in precipitation is expected to occur at high latitudes.
- Low- and mid-latitude regions, are expected to suffer from more frequent and more severe droughts; dry conditions and warmer temperatures produce longer “fire seasons”.
- Increased snowfall near both poles may offset some of the melting of glaciers and ice sheets in these regions by adding fresh ice to the tops of these features.
- Some presently dry regions may welcome increased rainfall, but if this could manifest as heavy rainfall that causes flooding interspersed with more frequent droughts.
- Hurricane seasons may start earlier and end later, providing more time for storms to occur. Storms may move into higher latitudes as ocean waters warm – the unprecedented occurrence of Hurricane Catarina in the South Atlantic along the coast of Brazil in March 2004 may be an ominous portent of things to come.

EXTREME WEATHER

Global warming is projected to lead to an increase in extreme weather events. Higher levels of humidity create increasingly unstable weather patterns. More floods, storms and droughts; more wildfires. Asian monsoons become disrupted. Some places, notably Australia, experience many different extreme events in quick succession.

We will look into the likely patterns of extreme weather events in a future post.

MIGRATION

Populations at disproportionately higher risk of adverse consequences include disadvantaged and vulnerable populations, some indigenous peoples, and local communities dependent on agricultural or coastal livelihoods. Regions at disproportionately higher risk include Arctic ecosystems, dryland regions, small island developing states, and Least Developed Countries. Poverty and disadvantage are expected to increase in some populations as global warming increases (IPCC).

We will examine the impact of climate change on migration in a later post.

WATER

Research by the Met Office and Leeds University shows that global heating could bring many more bouts of severe drought as well as increased flooding to Africa than previously forecast. The continent will experience many extreme outbreaks of intense rainfall over the next 80 years, triggering floods, storms and disruption of farming. In addition, these events are likely to be interspersed with more crippling droughts during the growing season also damaging crop and food production. The wet extreme will get worse, but the appearance of dry spells during the growing season will also get more severe.

The rate **glaciers are melting** in the Himalayas has doubled in just 20 years, according to a study which examined 40 years of satellite data. Glaciers have been losing more than a vertical foot and a half of ice each year since 2000. Eight-hundred million people depend on seasonal runoff from Himalayan glaciers for irrigation, hydropower and water. There is currently more run-off during warm seasons but within the next few decades this will decrease as the glaciers lose mass, leading to water shortages. Similar effects are expected in the Andes.

ECOSYSTEMS

Impacts on biodiversity and ecosystems, including species loss and extinction, are projected to be higher at global warming of 2°C. Of 105,000 species studied, 18% of insects, 16% of plants and 8% of vertebrates are projected to lose over half of their climatically determined geographic range for global warming of 2°C . There are also increased impacts associated with other biodiversity-related risks such as forest fires and the spread of invasive species. High-latitude tundra and boreal forests are particularly at risk of climate change-induced degradation and loss, with woody shrubs already encroaching into the tundra and this will proceed with further warming. (IPCC)

AGRICULTURE

Warming of 2°C is projected to result in higher net reductions in yields of maize, rice, wheat, and potentially other cereal crops, particularly in sub-Saharan Africa, Southeast Asia, and Central and South America, and in the CO_2-dependent nutritional quality of rice and wheat. Reductions in projected food availability are larger in the Sahel, southern Africa, the Mediterranean, central Europe, and the Amazon. Livestock are projected to be adversely affected with rising temperatures, depending on the extent of changes in feed quality, spread of diseases, and water resource availability. (IPCC)

The recent heatwave in Europe caused **crop damage in France**, the European Union's largest grain growing nation. Grains such as rapeseed and wheat are in their crucial pre-harvest period making them more fragile to heat stress. Water restrictions, including for irrigation, are in place in one fifth of mainland France's 96 administrative departments.

The UK Climate Change Risk Assessment 2017 noted that climate change will present risks and opportunities for domestic production, with the resilience of UK food systems dependent on the stewardship of natural resources including soils. The report concludes that there is a need for policy intervention over the next five years to manage the potential impacts of these risks on food prices in the UK.

There are odd positive implications and new opportunities too. In some areas of Argentina, farming conditions will improve due to heavier rainfall in traditionally dry areas.

PESTS

The UK Climate Change Risk Assessment 2017 also describes how new and emerging pests and diseases – including invasive non-native species – have the potential to cause severe impacts on people, animals and plants. It concludes we need to improve our understanding of how climate change will affect the threat of pests and diseases.

Research suggests that even slight climate warming could **increase malaria risk** to hundreds of thousands, if not millions, of people in areas that are currently too cold for malaria parasites to complete their development. The rate of malaria transmission to humans is strongly determined by the time it takes for the parasites to develop in the mosquito. The quicker the parasites develop, the greater the chance that the mosquito will survive long enough for the parasites to complete their development and be transmitted to humans.

TREES

Trees absorb and store carbon dioxide emissions, so planting billions of trees across the world is by far the biggest and cheapest way to tackle the climate crisis. **Recent analysis** found there are 1.7bn hectares of treeless land on which 1.2tn native tree saplings would naturally grow. That area is about 11% of all land and equivalent to the size of the US and China combined. Tropical areas could have 100% tree cover, while others would be more sparsely covered, meaning that on average about half the area would be under tree canopy.

In practice, things are moving in the opposite direction.

Deforestation in Brazil's portion of the Amazon rainforest rose more than 88% in June compared with the same month a year ago, the second consecutive month of rising forest destruction under the new president Bolsanaro. According to data from Brazil's space agency, deforestation in the world's largest tropical rainforest totaled 920 sq km (355 sq miles).

The Congo Basin is the second-largest rainforest on Earth is also subject to deforestation. Not only does that mean that the forests are less able to take CO_2out of the atmosphere, carbon that has been locked up in the Congo's soils for hundreds to thousands of years is starting to seep out. Soils hold a tremendous amount of carbon—more than the atmosphere and living vegetation combined. About a third of that carbon resides in soils in the tropics, areas that are undergoing profound changes due to population growth, industry, and agriculture.

NEXT

In our next post on climate change, we will look at the impact of warming world on natural defences. If you have views on any of the issues in this field, please do contact us and we can give you the opportunity to express them.

Written by Huw Williams, SAMI Principal, published 17 July 2019

Climate Emergency: feedback loops and tipping points

In the first two posts on the climate emergency, we covered projections of the impacts of global heating on sea and on land. Obviously the modelling involved in producing these projections is complex and based on a number of assumptions, producing a range of likely outcomes. But the most complex and uncertain areas of the views of the future are – as is the case for most foresight work – the non-linear effects of feedback loops and tipping points. Outcomes can spiral away from the central projection in very unpredictable ways, meaning that we have to consider a much wider range of scenarios for the future.

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One of the more well-known climate emergency feedback loops is the "**albedo effect**". Albedo – or "whiteness" – is a measure of the reflectivity of a surface. The greater the reflectivity the less of the sun's heat is absorbed in the planet and its atmosphere. The underlying concern is that as global heating melts the ice caps, exposing the darker ocean surface to sunlight, the water warms up. This melts the ice from underneath, and humidity also increases; water vapour is a powerful greenhouse gas. The seas that become exposed have lower reflectivity, absorbing more heat and accelerating the loss of ice in a vicious circle.

This effect is amplified because the Artic is warming twice as fast as the planet as a whole, and its temperature has already risen by 2°C since pre-industrial levels.

The issue isn't quite that simple, because as the oceans absorb heat, levels of water vapour increase and more clouds appear. Clouds themselves will reflect heat away from the planet. Deforestation increases albedo because topsoil is more reflective than forests. Burning wood creates black carbon in the atmosphere which if it settles on ice reduces albedo. Algae and other organisms that begin growing on the ice sheet again reduce reflectivity. It's a complex dynamic mix of trends and forces.

There's also an effect due to the amount of snow. Ice is darker than snow, and when there is fresh snow, you have a very bright reflective surface – that gives an opportunity for a geo-hack which we'll discuss in another post.

A related "tipping point" – literally – is the collapse of Greenland and Antarctic ice-sheets. A major collapse would increase sea-levels substantially. If all of the Greenland ice were to melt, global sea levels could be expected to rise by about 25 feet. However, this would take hundreds of years at the current rates of melting. But predicting their behaviour is not straightforward – the **Greenland ice-sheet is slipping much faster** than expected over what should be unsuitable terrain .

Another feedback loop is melting permafrost releasing methane,one of the most dangerous greenhouse gases. In Northern Siberia last year the ground rose up to form **7,000 large bubbles** of methane gasses rising into the empty spaces created by melting permafrost. The pressure is building up inside these bubbles and the gas could be released. The gas contains up to 1,000 times more methane and 25 times more carbon dioxide than the surrounding air. The bursting of these bubbles will release even more gas into the atmosphere, causing more warming and melting permafrost.

Permafrost in the **Canadian Arctic** is thawing 70 years earlier than predicted. Rapid thawing could release vast quantities of heat-trapping gases, unleashing a feedback loop that would in turn fuel even faster temperature rises. "Thawing permafrost is one of the tipping points for climate breakdown and it's happening before our very eyes," said Jennifer Morgan, executive director of Greenpeace International.

As we pointed out last time, there is a massive amount of carbon locked in soils, which hold more carbon than the atmosphere and living vegetation combined. Brazil's **President Bolsanaro has reacted harshly** to criticism about deforestation saying "The Amazon belongs to Brazil and European countries can mind their own business because they have already destroyed their own environment". So the risks here increase exponentially.

Next time we'll look at how the climate emergency is creating more extreme weather events.

Written by Huw Williams, SAMI Principal, 25 July 2019

Climate emergency – extreme weather events

Image by Gerd Altmann from Pixabay

It is hard for most people to envision how an additional 2°C of global heating might affect daily life – what's wrong with a few nice summers? Predicted sea-level rises happen over timescales so long that building better flood defences might be thought to be easy.

But the average change in the climate manifests itself in greater variability in weather and more extreme weather events. Heatwaves and fires, floods and storm surges, droughts and water contamination are causing greater loss and damage. Of course, many weather extremes are the result of natural climate variability (including phenomena such as El Niño). Even if there were no anthropogenic changes in climate, a wide variety of natural weather and climate extremes would still occur.

The **IPCC** say that globally, since 1950, the length or number of warm spells or heatwaves has increased there have been more heavy rains, though there are strong regional and subregional variations in the trends. There has been a trend to more intense and longer droughts in southern Europe and West Africa, though central North America and north western Australia the droughts have become less frequent, less intense, or shorter.

Looking forward the IPCC models suggest it is *virtually certain* there will be increases in the frequency and magnitude of warm daily temperature extremes and decreases in cold extremes. The length, frequency, and/or intensity of warm spells or heat waves will increase over most land areas. The frequency of heavy precipitation or the proportion of total rainfall from heavy rainfalls will increase in the 21st century over many areas of the globe.

The **UN warned** that we are now seeing one climate crisis disaster each week, and argued for greater and immediate in plans for adaptation, as well as

reducing emissions. New standards for infrastructure, such as housing, road and rail networks, power and water supply networks are needed to make them resilient to more extreme conditions.

A **Pentagon report** reveals that more than two-thirds of operationally critical military installations are threatened by the effects of climate change over the next 20 years. The main impacts came from recurrent flooding, drought, and wildfires. Examples include increased flooding at the Langley Air Force Base, drought conditions at several DoD bases in Washington DC damaging infrastructure, and wildfire at Vandenberg Air Force Base in southern California affecting space launch complexes. They were also concerned about effects around the world – for example recurrent flooding at the Naval Base in Guam is limiting capacity for a number of operations and activities including submarine squadrons.

Wildfires. In Northern Europe, between **20 and 200 times** more area burned than normal, with fires raging as far north as the Arctic circle. Climate change is estimated to have lengthened fire seasons across a quarter of the world's vegetated land surface. In the **Western U.S**., large fires are now almost seven times more likely to occur than three decades ago, forest areas burned have doubled since 1984. Also, as the world urbanises, the interface between fire areas and habitation increases, with greater risk to life and property. The fires of 2017 and 2018 cost the insurance industry more than $15 billion each year, forcing reinsurers to reconsider their view of wildfire losses and raising the prospect of large numbers of homes becoming uninsurable. Wildfires in the Arctic are at "unprecedented levels" with areas of Siberia, Alaska, Greenland and Canada engulfed in flames and smoke, and strong winds have made this year's fires particularly bad.

Heatwaves. This July's heatwave in Europe has **set records** in 3 countries, and is linked with several deaths. There are also the effects of variability of temperature increase locally. Temperature rises in many major cities would far exceed the global average of 2°C. A **recent study** suggested that, instead of just 2°C, Madrid's temperature would rise by 6.4°C, London by 5.9°C and New York's by 4°C. London could suffer from the type of extreme drought that hit Barcelona in 2008, when it was forced to import drinking water from France at a cost of £20 million.

Monsoons. Nearly half the world's population live in areas affected by monsoons. In India around 75% of rainfall occurs in the monsoon season, making any variation in its behaviour critical for agriculture, livelihood and basic survival. Monsoons are triggered by a contrast in temperature between land masses and oceans, which triggers a reversal of wind patterns, causing an increase in precipitation. As temperatures increase as a result of climate change, monsoons are altered, and levels of rainfall are skewed. **Monsoons are becoming more unpredictable and irregular**, entering periods of reduced rainfall in certain regions, specifically southern Asian regions, and is projected to worsen in the future. In 2018, rainfall increased, causing floods and landslides.

Floods. The IPCC noted in its **special report on extremes**, it is increasingly clear that climate change "has detectably influenced" several of the variables that contribute to floods, such as rainfall and snowmelt. In other words, while our warming world may not induce floods directly, it exacerbates many of the factors that do.

Storms/hurricanes. Researchers in **North Carolina** examined hurricanes Floyd, Matthew and Florence and found that the probability of them occurring randomly in such a short period of time is just two per cent. Six out of the seven largest hurricanes since 1898 occurred in the last 20 years. This frequency is probably caused by "increased moisture carrying capacity of tropical cyclones due to the warming climate".

Attribution. Despite the evidence of an increase in extreme weather events *on average,* a problem that climate scientists have always faced is saying whether any specific event is caused by global heating, rather than just being a natural outlier. This has left room for doubt to be sown in the minds of the public. To address this "**attribution science**" is developing new approaches. Increasing computer power, combined with a massive increase in data points, has enabled more sophisticated simulation modelling that can begin to show the direct effects of climate change.

Many studies have shown that climate change has increased the scale of a weather event – eg greater rainfall in Hurricane Harvey. But some have begun to show that a weather event would not have happened at all were it not for global heating. The World Weather Attribution project has made real and significant advances in isolating the climate signal in the costly impacts of extreme events, in both developed and developing countries.

Written by Huw Williams, SAMI Principal, published 7 August 2019

Climate emergency – migration

*Image by **Gerd Altmann** from **Pixabay***

We discussed the effects of global heating on the planet in recent posts. This time we focus on how climate change migration, both within and between countries, will bring new challenges and tensions to populations.

The UN International Organisation for Migration (IOM) produced a substantial "**World Global Migration**" report which suggested that in 2015 there were an estimated 244 million international migrants globally (3.3% of the world's population) — an increase from an estimated 155 million people in 2000 (2.8%[1]). Climate change is not the only driver of migration – economic prosperity, inequality, demography, violence and conflict play their part. However, in 2016 (as in previous years), disasters triggered by climate and weather-related hazards, such as floods and storms, displaced nearly 5 times as many people as conflict and violence. Of course, historically people have often been displaced by severe weather, but we can clearly identify an increase in such events.

Sea level rise, extreme weather, and erratic droughts or flood may displace large sums of people but in the eyes of global law they are not, as of now, "refugees" per se, and so do not have the same rights as those fleeing conflict. Populist reaction may force Western governments to resist them being given that status.

The UK military think-tank, the **Wavell Room**, identified challenges in coping with those displaced by climate change. The regional destabilisation caused by migrants (whether from climate change or conflict) creates a breakdown in law and order, and the emergence of criminal people traffickers exploiting vulnerable people in camps. As an example, Pedro Sula, in Honduras, has an almost complete lack of state control and serves as a node for drug trafficking into the USA. Similar situations in multiple cities across North Africa would pose a direct threat European security.

States under pressure may look to Russia or China for support with arms and finance to maintain order in an increasingly stressed security environment. Climate refugees not only risk empowering repression, but also providing a pretext for the entrenchment of the West's strategic competitors in Africa. The UK will be faced with a strategic dilemma; to pursue a strategy based on international security by opposing Russian and Chinese interests, or to follow humanitarian instincts.

For domestic political reasons, and irrespective of the actual security threat, European nations will invest more resources into policies which keep climate refugees off the continent The Hungarian Government erected a wire fence on their border with Serbia in 2015. So it may even be that, just as the EU signed a deal with Turkey to restrict migration into Europe, it may seem appropriate to co-operate with China in diverting migrant flows.

Policy responses could be increasing funding for Frontex, the EU border agency, or providing support for national missions such as the Italian Operation **Mare Nostrum**. **Operation Barkhane**, the French anti- insurgent operation with 3,000 troops in Mali, may also serve as a model for how European nations might attempt to create stability in the Sahel. Stationing British troops in Africa may be a more effective way of reducing migration than more defensive and reactive policies.

However, most climate migration will be within countries. The **World Bank** conducted a major piece of research into the likely patterns. In Sub-Saharan Africa, South Asia, and Latin America, which together represent 55 percent of the developing world's population, something over 143 million people – or around 2.8 percent of the population of these three regions – could be forced to move to escape the "slow-onset" impacts of climate change (water stress, crop failure, sea level rise). "Rapid onset" events such as floods and hurricanes could significantly increase these numbers. The poorest people and the poorest countries are the hardest hit, and their migration will likely overwhelm the infrastructure of destination areas. Others, even more vulnerable, will be unable to move, trapped in increasingly unviable areas.

In all three regions, migration is projected primarily from coastal zones and also from rain-fed cropping areas, indicating that climate impacts on crop productivity in these regions may potentially disproportionately affect farming households. Migrants will gravitate towards cooler highland areas that will become even more densely populated.

In Sub-Saharan Africa some 86 million people may be internally displaced by 2050. In East Africa, migration hotspots include northern parts of the Ethiopian highlands; parts of western Uganda, southern Rwanda, and southern Malawi; and coastal stretches of Kenya and Tanzania. These hotspots reflect deteriorating water availability and crop yields in out-migration areas. In the coastal zone, declining land availability, reflecting sea level rise and storm

surges, is also a factor. Migration is largely toward the south-eastern highlands of Ethiopia, the Lake Victoria basin, and the region near Lilongwe, Malawi.

By 2050, 40 million people may become climate migrants in South Asia. Migration will be substantial from the eastern and northern Bangladesh and the northern part of the Gangetic Plain, as well as some spots of the broader Gangetic Plain, the corridor from Delhi to Lahore, and even Mumbai. Migrants head to the Gangetic Plain and western Bangladesh. These areas begin to spread and intensify all over South Asia, with large migration destination areas seen throughout India's regions, especially in the south. In Bangladesh migration will be predominantly from the east to the west.

Latin America may see 17 million climate migrants. Mexico and Central America could potentially see dramatic increases in climate migration toward the end of the century, because of steadily worsening impacts for water availability and crop productivity. People will leave the hotter, lower-lying areas of Mexico and Guatemala and move toward climatically more favourable Central Plateau of Mexico and the highlands of Guatemala. People will also leave low-lying coastal areas along the Gulf of Mexico and the Pacific coast of Guatemala. Some cities, such as Monterrey and Guadalajara in Mexico will see climate outmigration. Rainfed cropping areas are likely to see declines in population as a result of climate out-migration. In contrast, pastoral and rangeland areas are likely to see increases.

Even in the US, by the end of the century, sea level rise alone could displace 13 million people including 6 million in Florida, according to **one study**. States including Louisiana, California, New York and New Jersey will have to grapple with hordes of residents seeking dry ground.

The World Bank argue that these internal migrations need not be a crisis. Migration can be a sensible climate change adaptation strategy ***if*** managed carefully and supported by good development policies and targeted investments. ***If,*** as well as reducing GHG emissions, countries integrate climate migration into national development plans and invest now to improve understanding of internal climate migration, many of the worst effects can be avoided. It is hard to feel confident that these strategic actions will actually be taken.

This is the last of our analyses of the impacts of the climate emergency. The next set of posts will look at some of the things we can do about it.

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[1] *Definitions of economic, climate change and disaster/conflict migrants are difficult to make and vary between sources.*

Written by Huw Williams, SAMI Principal, published 21 August 2019

Climate emergency – energy generation

*Image by **PIRO4D** from **Pixabay***

In previous posts we've looked at the impacts of global heating assuming we don't do enough to mitigate it. We're now going to look at some of the technological solutions, first in the area of energy generation.

Getting to "net zero" carbon emissions means drastically reducing the use of fossil fuels in energy generation, because that sector represents 25% of emissions. In **BP's 2019 Energy Report,** their Chief Economist concluded: "There is a growing mismatch between societal demands for action on climate change and the actual pace of progress, with energy demand and carbon emissions growing at their fastest rate for years. The world is on an unsustainable path."

Fortunately, substantial progress has been made in the use of renewables and the economics of these energy sources are improving rapidly. The challenge is creating the political will to implement them quickly enough.

At the end of May the UK, for the first time since the Industrial Revolution, went **2 weeks without using any coal** in its power systems. Wind and (to a much lesser extent) solar power are providing 30% of the UK's power today and are forecast to be providing 70% by 2030. However, G20 countries generally have **tripled coal power subsidies**. The coal industry is increasingly unprofitable in comparison with renewables, so these subsidies are more about employment support – avoiding coal miners going out of work. The issue is socio-political rather than technological.

Offshore wind projects have seen costs halve in just two years. **BEIS estimates** its costs as £106 per MWh; onshore is cheaper at £63 per MWh, cheaper than solar (£65) and all other sources. Again, the issues around expanding wind-power are socio-political rather than economic/technological.

A **recent study** found that maximizing onshore wind potential could enable Europe to generate 100 times more electricity than it currently does. That's enough to cover energy demand for the entire world from now until 2050. But that again omits consideration of practical, political constraints.

Wind-power suffers from a number of drawbacks: wind variability, meaning that storage is needed; wind-shadow effects (adding new turbines reduces the performance of others); and local heating (wind turbines push warm air downwards).

Despite growth in recent years, solar photovoltaics power is only a small proportion of energy generation – less than 1%. However, **costs of solar are falling**: in Europe, the price per MWh is expected to decline to between €40 and €60 in 2025 and further decrease to as low as €20 in 2050, making it among the cheapest sources of energy. Solar systems could grow to supply 5% of global electricity consumption in 2030, rising to 16% by 2050. This would avoid the emission of 4 Gt of carbon dioxide annually.

Solar also suffers from variability of supply, but innovative approaches are looking to address this.

- Belgian scientists have combined **solar panels with generating and storing hydrogen** as a more efficient and cheaper solar energy storage system than batteries.
- **Energy Vault** is a venture that stores excess solar farm electricity by using giant cranes to lift and stack 35-metric-ton bricks, thus storing it as potential energy. When the energy is later needed, software tells the system to lower the bricks, and that spins generators to send electricity back into the grid. The system can respond within a millisecond.
- **Malta** is building a grid-scale energy storage technology that stores electricity from solar sources as heat inside large tanks of high temperature molten salt and as cold in large tanks of chilled liquid.

One of the oldest renewable energy sources, **hydropower**, is, ironically, itself being threatened by climate change. Rivers that once ebbed and flowed with seasonal regularity have grown erratic. In Brazil, record drought triggered blackouts in 2015. In California, output from dams has swung wildly from year to year. And in Europe, Spanish utility giant Iberdrola SA's hydro output reached a record high in 2016, then plunged 57% the following year. As one energy adviser put it: "The challenge is the future doesn't look like the past." Quite.

Tidal power has its supporters too. Although the Government rejected subsidies for a tidal barrage in **Swansea Bay**, a private company is now planning to build it within 6 years. The predictability of the tides means it doesn't have the

storage challenges of wind and solar. The Institution of Civil Engineers suggest that, because **the Severn Estuary** has the second highest tidal range in the world, tidal power in the Severn could produce a total of about 7% of the country's energy needs.

Geothermal energy is used in over 20 countries. The United States is the largest producer of geothermal energy in the world, and hosts the largest geothermal field, in California. The field is spread over 117 square kilometres and formed of 22 power plants, with an installed capacity of over 1.5GW. The energy source is also prevalent in Iceland where it produces 25% of the country's energy from five geothermal power plants. Geothermal energy does emit CO_2(one-sixth of the produced by a natural gas plant) It has also been associated with other emissions like sulphur dioxide and hydrogen sulphide.

Bioethanol fuel is mainly produced by the sugar fermentation process. Most bioethanol is produced from sugar cane (Brazil), molasses and corn (USA), but other starchy materials such as wheat, barley and rye are also suitable. It is a high-octane fuel, often blended with petrol to enhance performance. R&D activities focus on using lignocellulosic or woody materials, which are more abundant and less expensive than food crops and have a higher net energy balance.

However, whilst the drive for clean energy is under way, and costs are reducing, coal and natural gas are here to stay for the foreseeable future. China's more ambitious plans include building between **300 and 500 coal fired plants** between now and 2030, for instance. The **World Coal Association**, whilst placing a new focus on carbon capture and "clean" coal technologies, makes the point that coal power is the quickest and cheapest way "to provide access to base load electricity and is a critical building block for development". Coal is also political: both the United States and Australian administrations are firmly pro-coal because of a combination of sentimental and employment factors; "**artisanal mining**" (ie informal mining by individuals) is a vital part of economies around the developing world.

Alternatives to fossil fuels exist and so the goal of "net zero" emissions is achievable. The question is whether we want it enough to make the necessary changes.

Written by Huw Williams, SAMI Principal and Jonathan Blanchard Smith, SAMI Fellow and Director, published 4 September 2019

Climate emergency – Carbon Capture and Storage; new nuclear

Image by Gerd Altmann from Pixabay

Despite the progress on renewables we noted last time, coal and other fossil fuels will remain a key part of the energy mix for many years. They provide more reliable base load electricity and are also often associated with political considerations. China and India are stuck with coal for decades yet.
This means we need to look at ways of taking carbon out of the emissions generated by fossil sources.

Carbon Capture and Storage (CCS) is a process that captures CO_2 from large sources such as a cement factory or power plant and stores it in an underground geological formation. Although this technology has been around for over 40 years, its efficacy is still debatable. The Sleipner gasfield in the North Sea, which started capturing carbon emissions in 1996, removes around 1m tonnes of CO_2 every year. The use of CCS could reduce CO_2 emissions from the stacks of coal power plants by 85–90% or more.

Critics say large-scale CCS deployment is unproven and decades awayfrom being commercialised. There is a risk of leakage during the extremely long storage time required. There is an "energy penalty "– the reduction in overall plant efficiency due to the carbon capturing process – as much as 40 percent of the energy produced by a power station.

"Direct Air Capture" is a process of removing CO_2 directly from the air. Combining DAC with carbon storage could constitute a form of climate engineering if deployed at large scale. However, this area is still in its infancy. Other approaches may encourage CCS by making it more financially attractive, using some of the CO_2 as a valuable raw material. Examples include using CO_2 in fertilisers, beer bubbles and building blocks. Carbon usage firms could be carbon-negative: taking in more CO2 than they put out. Tataplans to refine the carbon emissions to make a high-grade liquid version of carbon dioxide

which will help make sodium bicarbonate, or baking soda, which is in high demand by the pharmaceutical sector to help treat conditions from heartburn to kidney disease. It is also found in ear and eye drops.

More directly we could turn to natural ways of removing $CO_2$from the atmosphere – by planting trees. As trees grow, they absorb and store carbon dioxide. New research estimates that a worldwide planting programme could remove two-thirds of all the emissions that have been pumped into the atmosphere by human activities. This would require 1.7bn hectares of treeless land on which 1.2tn native tree saplings would naturally grow. At the very least, stopping deforestation would be hugely beneficial.

Nuclear energy is often touted as a "zero-carbon" energy source. However, the scale of the developments themselves has a high-carbon load, and the virtually indefinite waste storage requirements are daunting. New small-scale reactors using thorium are much safer and very low in harmful radiation – thorium is also widely available. One study suggested that the overall potential, thorium-based power "can mean a 1000+ year solution or a quality low-carbon bridge to truly sustainable energy sources solving a huge portion of mankind's negative environmental impact". Canada, China, India and Germany are all interested.

Finally, there is fusion energy, often described as "always 30 years away". 35 national governments from around the world are collaborating on ITERin Europe, a massive system designed to demonstrate the scientific and technological feasibility of fusion energy, funded to the tune of billions of dollars. But several companies continue to invest significant sums in new approaches. Optimists believe that we are five years away from the first proof-of-concept fusion energy demonstration plant and 15 years from a commercial roll-out at scale.

Written by Huw Williams, SAMI Principal, published 18 September 2019

Climate Emergency – Transport Initiatives

Image by PIRO4D from Pixabay

In 2016, the transport sector contributed 27% of total EU-28 greenhouse gas emissions. Transport emissions fell from 2008 to 2013 but have since climbed and are close to the 2007 peak. The Committee on Climate Change 2019 progress report highlighted surface transport sector as a major contributor to the UK's greenhouse gas emissions and, therefore, a key area in need of intensified policy focus.

A major area of progress has been in the development and promotion of electric vehicles. All major motor manufacturers have EVs on sale or in production – Reuters found that car makers plan to spend at least $300 billion on EVs. Deloitte projects an Electric Vehicle 'tipping point' when price parity with internal combustion engine (ICE) vehicles – without a subsidy – is reached in 2024, or in 2021 if the current subsidy is maintained. An additional 21 million electric vehicles (EVs) will be on the road globally over the next decade, according to the Deloitte analysis.

China is the world's largest EV market, accounting for more than half the world's purchases of electric cars. Most are built by BYD (the world no. 1 producer of plug-in vehicles, 10% owned by Warren Buffet) and aimed at the middle market.

However, some argue that EVs alone are not the solution to urban mobility, and what is needed is a combination of EVs and public transport. The Science and Technology Select Committee said: "In the long-term, widespread personal vehicle ownership does not appear to be compatible with significant decarbonisation."

On the railway, Network Rail is piloting a scheme that powers trains using power from its own solar farms. The falling cost of solar power technologies means these subsidy-free solar farms could supply electricity at a lower cost than the electricity supplied via the grid. A quarter of the UK's trains run solely off diesel, but the government wants them all gone by 2040. By

2025, Indian Railways expects to meet a third of its electricity demand from renewable energy sources by building 1.1GW from rooftop projects and 3.9GW worth of large-scale trackside solar farms.

Regional routes which carry relatively few passengers are unlikely to be electrified soon. For such routes hydrogen trains could be the answer. 'Hydroflex' is a test train where the technology is being developed and will begin testing on the UK mainline in March.

The International Maritime Organization (IMO) estimates that carbon dioxide emissions from shipping were equal to 2.2% of the global human-made emissions in 2012 and 15% of global NOx emissions and expects them to rise 50 to 250 percent by 2050 if no action is taken. The IMO strategy aims to reduce the total annual GHG emissions by at least 50% by 2050 compared to 2008. A particular concern is the use of bunker fuel, a sulphur-rich fuel which contains more than 3,500 times as much sulphur as diesel fuel, and which has been estimated to cause premature death and childhood asthma in portside communities. Moves to low-sulphur fuels are set to cut in from January 2020. Liquified natural gas may be a low-emission solution.

Several small solar powered boats and ferries exist, but to date large-scale solar ships have not taken sail commercially. A partnership between Eco Marine Power (EMP) and the Japanese ship owner Hisafuku Kisen K.K. of Onomichi is testing an integrated rigid sail and solar power system for ships. The rigid sails of solar panels are mounted on the covers of large bulk carrier ships and also include wind turbines.

The aviation sector is perhaps the most challenging. Carbon dioxide emitted by airlines increased by 32% from 2013 to 2018, according to a study by the International Council on Clean Transportation. Although more fuel-efficient planes mean that emissions per passenger kilometre have been reduced by more than 50% since 1990, total emissions have grown as passenger numbers have grown.

Unlike EVs, electric planes are much more of a challenge because of the the power/weight ratio: battery technology simply has not yet advanced enough to make air transport use feasible. However, manufacturers – not just companies like Boeing and Airbus, but a host of tech firms, particularly for urban air mobility – are looking to build electric aircraft that could be clean and silent enough to make shorter air hops possible without large airports. The e-Fan X, a collaboration between Cranfield with Airbus, Siemens and Rolls-Royce, will convert a small passenger jet to demonstrate the potential for wider commercial use – this is due for trials in 2021.

A UBS report suggested that there is a market opportunity of some US$178bn, with over 16,000 hybrid electric planes over 2028-40 (chiefly general aviation, light business jets and regional aircraft). Not only do these reduce emissions, they offer c20% lower operating cost savings per trip relative to the 50-70-seaters in service.

Sustainable fuels were a major hope for aviation, but with concerns over biofuels, the focus has shifted to the potential of domestic and industrial waste. A Virgin service claiming to be the first to be partly powered by recycled waste crossed the Atlantic last October

Solar power is another option being explored. In July 2016, Solar Impulse 2 completed a 16-month round-the-world trip. Boeing's Aurora Flight Services have developed a high-altitude solar-powered autonomous aircraft called Odysseus. This autonomous plane is an ultra-long endurance high-altitude platform and could be used to provide internet access or 5G in remote areas, and for climate research.

Finally, hydrogen-powered planes could prove the most suitable. A Dutch company, AeroDelft, is developing Project Phoenix, a liquid hydrogen-powered aircraft (more specifically, a motor glider), and with a range of 2000km. Intelligent Energy's Project Rachel is a hydrogen fuel-cell powered octacopter, with a 6-liter tank of hydrogen gas, which can stay aloft for 70 minutes of continuous flight, while carrying a 5-kg (11-lb) weight. A similar UAV around the same weight running lithium batteries could be expected to fly for only around 12 minutes.

Airships could be a viable option for cargo transportation – which would also serve to relieve some of the maritime fuel burden. Since they would fly above the cloud base, they could also take advantage of reliable solar power.

Although battery technology has improved tremendously, a more attractive option may be hydrogen. Electrolysing water, including sea water, to create hydrogen and oxygen is a very effective way to store energy. Hydrogen and oxygen can be fairly easily be stored and transported, and so should provide a viable alternative for cars, other road vehicles, ships and possibly aeroplanes.

Hydrogen is the preferred fuel for the 2020 Tokyo Olympics. The 6,000-unit Olympic village will run on hydrogen fuel and the Tokyo Metropolitan Government has reserved $350m in a special fund to subsidise H2 fuel cell cars and fuelling stations. Toyota plans to roll out 100 hydrogen fuel cell buses to shuttle visitors between venues. Even the Olympic torch will be powered by hydrogen.

A significant contribution to minimising transport use of fuels would, of course, be to minimise transport. Fuel saving strategies such as car sharing and more efficient public transport, non-fuel options such as cycling and walking, and the very design of cities themselves to minimise commuting distances, all have their part to play. Many initiatives across the world, ranging from small scale to large, are currently in development.

Written by Huw Williams, SAMI Principal and Jonathan Blanchard Smith, SAMI Fellow and Director, published 2 October 2019

Climate emergency - innovative technology responses

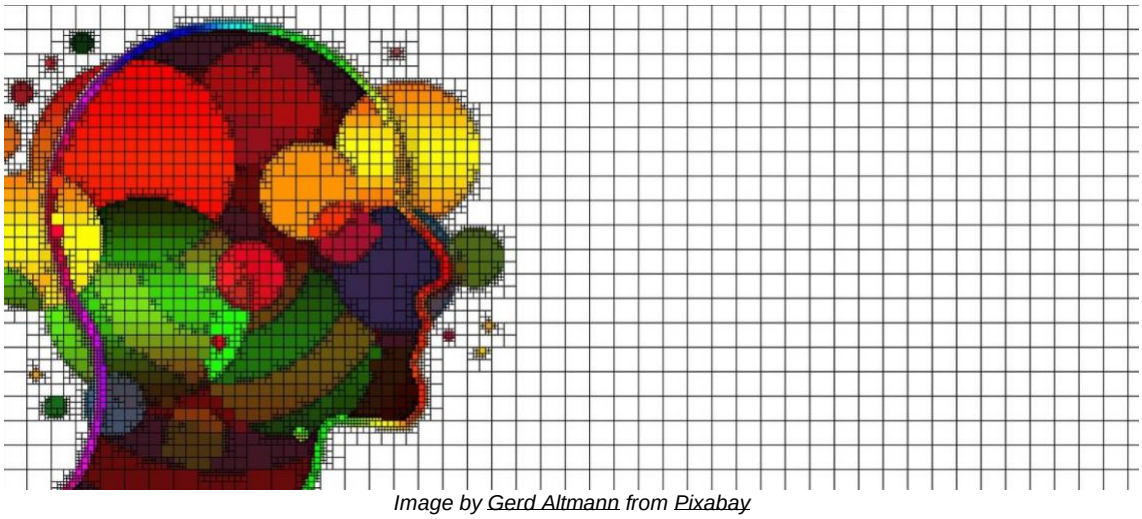

Image by Gerd Altmann from Pixabay

It may well be that de-carbonising the power networks and electrifying transport are not sufficient to keep global temperature rise below the "safe" level of 2°C. So some are turning to more radical ideas, such as geo-hacking, and alternative foods.

Geo-hacking (or, less dramatically, geo-engineering) involves interfering directly in our climate systems, to disrupt the effects of increased CO_2. One such approach is Solar Radiation Management (SRM) that aims at reducing the temperature of the atmosphere by blocking part of the solar energy that reaches the Earth by injecting particles, such as volcanic ash.

A similar project, sponsored by Harvard University, involves the release of calcium carbonate particles from a steerable balloon some 20 kilometres above the southwestern United States. The team hopes to release small plumes of about 100 grams of calcium carbonate into the upper atmosphere and then study how the particles disperse. The scientists will also watch for changes in atmospheric chemistry and how light scatters.

A different approach is to use the albedo effect – reflecting the sun's rays. Spraying trillions of tons of snow over west Antarctica could halt the ice sheet's collapse. Another proposal is to spray seawater into the air to help form clouds that reflect sunlight and cool the planet. Or perhaps we could fertilise oceans with iron to speed up the growth of phytoplankton and thus take up CO_2, some of which would sink into the deep ocean as carbon when the organisms die.

The UN set up a group (GESAMP) to look into options for marine geo-engineering. These included:

- Iron fertilisation across 10 per cent of the Earth's oceans by utilising every merchant ship in the world

- Adding lime to 10 per cent of the oceans to enhance alkalinity, increase CO2 uptake and counter seawater acidity
- Drawing up cool, nutrient-rich water from the depths with large pipes to create an artificial upwelling that provokes algal blooms while also cooling the ocean's surface
- Injecting liquefied CO2 into the seabed in depressions and trenches where it can be stored for 1,000 years
- Increasing the ocean's reflectivity by drawing up cold water to increase Arctic ice thickness, or by adding foams, micro-bubbles or reflective particles to the surface
- Brightening marine clouds by spraying fine seawater into low lying stratocumulus clouds to increase their reflectivity and reduce surface temperatures
- Farming seaweed on a large scale before entombing it deep in the ocean to sequester its carbon, or process it for biofuels.

You've probably already started wonder whether such approaches make sense, or worse could have major unintended consequences. GESAMP recognised that there is a dearth of hard information on geo-engineering and intend to commission research into the implications.

A second approach is to change the food we eat to reduce eco-effects, in particular replacing rainforests with pasture for animals. 26% of global GHG emissions come from food, 58% of which is from meat, 29% just from beef and lamb. An IPCC report describes plant-based diets as a major opportunity for mitigating and adapting to climate change — and includes a policy recommendation to reduce meat consumption.

Not everyone agrees. The NFU argue there is no need to reduce beef consumption, instead they suggest we can offset three-quarters of the UK's agricultural emissions by growing fuel for power stations and then capturing and burying the carbon dioxide. The IPCC had concerns about bio-energy on the grounds that it competed too directly with the population's food requirements.

Alternative foods are also being proposed. Insects produce less greenhouse gases and require less feed and water; they have more protein per 100g than meat, and more iron.

A report from Barclays suggested that this could become big business – sushi was once regarded as "yuck" in the West, insects could overcome that hurdle too. Ocado are already selling bags of roasted crickets. A firm called Bug Farm Foods has developed VEXo, a protein from insects that can be used like minced meat, and has even opened an insect restaurant – Grub Kitchen.

Alternatively we could grow meat in a laboratory or factory. By 2012, 30 laboratories from around the world had announced that they are working on cultured meat research, and there was a live demonstration of an artificial burger in 2013. A start-up company called Future Meat Technologies recently raised $14m to build a production facility. There have even been tests carried

out at the International Space Station that led to the production of beef, rabbit and fish tissue using a 3D printer. Barclays estimate that "alternative meat" could take 10% of the global meat market in 10 years.

And of course, as well as helping reduce carbon emissions, such approaches address the ethical issues around meat consumption.

All of the above issues raise a wide range of social, technological, economic and political factors, which we regularly encounter through our foresight work.

Written by Huw Williams, SAMI Principal, published 16 October 2019l

Climate emergency economics – Stern Review

Image by Nattanan Kanchanaprat from Pixabay

In recent posts we've looked at the effects of the climate emergency, and at some technologies that might help mitigate them. In the next few posts, we'll look into the economic and financial implications.

The seminal study into the economics of climate change was the Stern report, published in 2006. Commissioned by the then Chancellor, Gordon Brown, Sir Nichols Stern was asked to lead a team of Treasury economists to examine the economic challenges of climate change. It used a technique known as "integrated assessment modelling" to estimate the total impact on the economy. This technique spans multiple academic disciplines, including economics and climate science, and also energy systems and land-use change.

The Review first estimated the effects of "business as usual" on greenhouse gas emissions and global temperature rise. Its forecast of a 5°C rise was at the upper end of IPCC forecasts. It argued that positive feedback loops could lead to runaway growth in carbon emissions. The costs of the impacts of climate change were then assessed by a Monte Carlo simulation model. Factors such as the discount rate (the weighting given to future generations) and unequal impacts across the world (global equity) are also taken into account – Stern gave more weight to these than previous studies.

The Review's central message was that climate change is a serious threat to human welfare that demands urgent global action now (*ie in 2006*). It warned that the effects on the economy and social cohesion could be on a scale similar to the world wars and the great depression. It put the costs of climate change at between 5% and 20% of global GDP each year, now and forever. On the other hand, the costs of reducing greenhouse gases to avoid the worst effects could be just 1% global GDP each year.

The report unequivocally called for urgent collective global action to reduce greenhouse gas emissions. It argued for a carbon price or tax, ideally broadly

similar around the world. Its language and arguments for urgency were uncompromising. It called climate change “the greatest market failure ever seen”.

Naturally, such a strong message caused strong reactions. PM Tony Blair said it demonstrated that the scientific evidence was “overwhelming” and the consequences “disastrous” if the word failed to act. Economists from the World Bank, the International Energy Agency and the CBI, as well as many academics warmly supported its conclusions.

Others were more cautious, accepting the need for action, but questioning the urgency. Some however argued that the report was too conservative, pointing out that the feedback loops were very difficult to assess.

Negative reaction was equally strong. The inherent uncertainties of the climate science, and the difficulties of producing economic forecasts for such long time periods were used to challenge the conclusions. Stern was criticised for “taking the most pessimistic assumptions” and underestimating what development and adaptation would do to impacts. Others argued that co-ordinated international action would not be possible. Former Chancellor Nigel Lawson warned of “eco-fundamentalism”.

Economists focused on the choice of discount rates. A higher discount rate will make future damages look small, thus there is less need to reduce emissions today; while a lower discount rate will make future damages look larger, driving greater urgency. It seems that getting agreement on an appropriate rate cannot be achieved through any direct analysis, and fundamentally becomes an ethical question: the value one puts on the needs/rights of future generations. Stern took the view that intergenerational justice would require the constraint that future generations enjoy a quality of life at least as good as that enjoyed by the current generation.

The costs of mitigation – of reducing emissions – were also challenged. Several economists argued they would be much higher “We will actually have to sacrifice a great deal to cut emissions dramatically”.

In the years since the Stern Review, there has been a greater acceptance of the need for “urgent” action. Global agreements through the Paris accord demonstrate some willingness to address the issue, setting targets for “zero-carbon” emissions. But agreement on goals is not the same as action.

There does seem to be an increasing consensus that action is needed – that the costs of inaction are if anything higher than thought, and that new technology is reducing the costs of action.

Earlier this year in a lecture at MIT, Stern himself remained convinced of the need for action. He expressed some optimism, saying that policymakers are now much more likely to believe that we can combine continued economic growth with zero-emissions technology. However, he emphasised that “Net zero

is fundamental. That's not some strange economist's aspiration. The net zero is the science. If you want to stabilize temperatures, you're going to have to stabilize concentrations. Stabilizing concentrations means net zero."

Despite its significant impact on public opinion, the Stern Review demonstrates the difficulties of modelling a complex physical system and its interactions with a complex economic one over a long time period with many uncertainties. It showed that even sophisticated and rigorous modelling hides inherent assumptions and ethical standpoints. As foresight practitioners we appreciate the effort to evaluate, but would argue that it shows the limits of deterministic forecasting. Instead we would argue for a more scenario based approach – which would also lead to a call for action on climate change.

Written by Huw Williams, SAMI Principal, published 13 November 2019

Climate Crisis – Implications for the Fossil Fuel Industry

Image by Gerhard Gellinger from Pixabay

Assuming, perhaps optimistically, that governments really do get a grip on "zero-carbon" policies and that the costs of renewable energy continue to fall significantly, where does that leave the traditional fossil fuel industry?

Coal is effectively dead. More than 100 leading global financial institutions have pulled the plug on funding, imposing restrictions on investments into the sector. In India renewables were not just marginally, but 20% or 30% cheaper than new coal, even two years ago. British coal plants are shutting down ahead of a 2025 ban. Even in the US, more electricity was generated from renewables than coal for first time ever this June – as in the 36 countries of the OECD overall. 'The fate of coal has been sealed. The market has spoken'. We could see the end to the use of coal globally by 2050.

Oil and gas are not yet in that position, but the trends don't look good for those industries either. Financial markets are becoming concerned that oil companies' market values, based on reserves yet to be exploited, may be exaggerated.

A recent Carbon Tracker report says oil and gas companies are on track to spend $6.5trn (€5.89trn) on new production by 2030. That would be in line with a world where global warming is limited to 2.7°C rather than a 1.6°C pathway. Under the 1.6°C scenario, oil and gas production would need to reach $4.3trn (€3.89trn), creating a $2.2trn (€1.99trn) gap of potentially stranded assets. In effect, every oil major is betting heavily against a 1.5°C world and investing in projects that are contrary to the Paris goals. Investors are likely to increasingly challenge companies' spending on new fossil fuel production.

The Paris Agreement's 2°C objective requires a carbon budget of cumulative greenhouse gas (GHG) emissions that cannot be exceeded. The budget for 2011–2050 is around 1100 GtCO2 (gigatonnes of carbon dioxide), while global fossil fuel reserves hold around three times this amount. This implies that 33%

of oil, 49% of gas and 82% of coal reserves need to remain underground. The 1.5°C target translates into an even smaller carbon budget.

Oil companies remain in denial. Shell – pioneers of scenario planning who should know better than to rely on one preferred future – suggests these arguments are a "red herring". They argue that "a bigger risk is prematurely turning your back on oil and gas."

Saudi Arabia is also confident – or is it just looking longer-term? It is selling small shares in the state-owned Aramco oil company for the first time, and investors seem keen on the potential profits. Why is it selling? Because it is trying to reduce its reliance on oil. The aim is to diversify the country's economy in the next decade under a programme dubbed Vision 2030, making use of the country's vast desert for solar power generation. Long-term geo-politics will look very different if oil is no longer the driver of the world economy.

The EIB, the largest public bank in the world, announced this year that it would end lending to new gas projects, having already curtailed funding for coal and oil. This would free up more money for renewable energy developments. However, a final decision was deferred at the October meeting. Executives of the bank, which is owned by EU member states, said the plan was still on course and would probably be approved next month. EIB sees itself becoming the "EU Climate Bank".

In the UK, 300 MPs are backing a campaign calling on the £700m Parliamentary Pension Fund to divest from fossil fuels. A survey of around 100 institutional investors said that they plan to triple fossil fuel divestment rates over the next decade. They plan to move $920 billion (£725.9bn) out of fossil fuel investments in the next ten years.

If the fossil fuel industries are to be under such pressure, then the investment community and the whole financial system will face repercussions. We will look more into this, and the actions of central bankers to address it, next time.

Written by Huw Williams, SAMI Principal, published 21 November 2019

Climate Crisis and the Finance Sector

Image by Arek Socha from Pixabay

Mark Carney, Governor of the Bank of England, argued that the financial sector must be at the heart of tackling climate change. He is one of the leaders of 34 central banks and supervisors that joined forces in 2017 to create the Network for Greening the Financial System (NGFS). In an open letter, Carney discusses the recent NGFS report that calls for action by the finance sector to support the market and regulators in adequately assessing the risks and opportunities from climate change. He argues this is necessary to avoid a "Minsky moment" – a sudden collapse in asset prices.

Together with François Villeroy de Galhau, the governor of the Banque de France, Carney also suggested that companies that don't adapt will go bankrupt. US coal companies had already lost 90% of their value. Banks were also at risk –" those banks overexposed to the sunset sectors will suffer accordingly".

The Bank of England has said up to $20tn (£16tn) of assets could be wiped out if the climate emergency is not addressed effectively. As long ago as 2014, Carney was arguing that the "vast majority of reserves are unburnable".

Guy Debelle, Deputy Governor of the Reserve Bank of Australia, discussed how climate change affects the objectives of monetary policy. Short-term climate related shocks to the economy – droughts etc – can be safely excluded from policy consideration, but we are now seeing a *trend* in weather events whose impact is ongoing. For businesses and financial markets, the challenge is understanding the climate modelling and conducting the scenario analysis to determine the potential impact on their business and investments.

The IMF also discussed how central banks are taking action in a range of areas within their mandates. The key points they identified were:

- the adjustment needed for the transition to low carbon sources will have a substantial impact on prices, and carbon-intensive industries;
- developing a coherent set of global standards is priority, requiring international cooperation on issues such as developing more harmonized disclosure standards and regulatory policies;
- there could be a role for "green quantitative easing" programmes, through the purchase of bonds funding energy-efficient/renewable projects.

In Singapore, the regulator (the Monetary Authority of Singapore – MAS) put out guidelines on environmental risk management for the financial sector. MAS is concerned that climate change threatens to leave some assets stranded and catch financial institutions off-guard.

MAS also sees opportunities for the financial sector to "nudge" the real economy towards becoming more green,

The insurance industry is also becoming increasingly concerned as climate related risks grow. Wildfire risk in particular is causing concern. The fires of 2017 and 2018 cost the sector more than $15 billion each year, forcing reinsurers to reconsider their view of wildfire losses as moderate and predictable, and to develop new wildfire models, and innovative risk transfer solutions.

Munich Re even suggested that large numbers of homes could become uninsurable. The 2018 Californian wildfires caused losses of $24bn (£18bn) leading Munich Re to view the only sustainable option being to adjust risk prices– "some people on low and average incomes in some regions will no longer be able to buy insurance." Increasing premiums in high wildfire risk areas, or lowering them for fire-resistant construction could be effective signals to reduce fire costs.

The Lloyd's Market Association even runs masterclasses that provide "a better understanding of climate change in the context of insurance, which will be useful in anticipating and mitigating emerging exposures, improving wordings, and developing new products".

Power companies are also vulnerable. The Californian power utility PG&E filed for Chapter 11 protection in the "first climate change bankruptcy" caused by $30bn of liabilities due to a series of wildfires linked to its equipment. Hundreds of billions of dollars have been wiped off the value of power utilities by the rise of renewable energy, which has disrupted electricity generating market economics and turned the incumbent business model on its head.

Banks and asset managers will need data that allows them to evaluate the transition and physical risks to which corporations in their portfolios are exposed. So, they will demand it. Companies will increasingly find themselves having to make climate-related disclosures.

The FSB's Task Force on Climate-Related Financial Disclosures, set up in 2018, is a multinational group pushing for greater transparency of the risks companies face. It is developing voluntary, consistent climate-related financial risk disclosures for use by companies in providing information to investors, lenders, insurers, and other stakeholders.

The Task Force will consider the physical, liability and transition risks associated with climate change and what constitutes effective financial disclosures across industries

There are calls for companies to consider the issue of climate change on their balance sheets. Richard Murphy of City University argues for "sustainable cost accounting" requiring that every company provide in full, and upfront, its cost of transition to being a net zero-carbon emitter.

However, not everyone is taking this on board. The world's top three asset managers oversee $300bn fossil fuel investments. The two largest asset managers, BlackRock and Vanguard, have also routinely opposed motions at fossil fuel companies that would have forced directors to take more action on climate change.

So what will be the effects of climate risks on asset values? Are the top asset managers taking too short-term a view? Will political pressure build sufficiently to turn voluntary codes into compulsory ones? Boards will be expected to address climate change risk, with all its uncertainties, taking different future scenarios into account in their financial planning. Just the sort of thing that SAMI, with its Board governance and scenario planning capabilities, can help do. As COP 25 begins, is it not time to begin work on this now?

Written by Huw Williams, SAMI Principal, published 4 December 2019

Planning for climate change: lessons from the US Army War College

Image by Aline Dassel from Pixabay

There are problems with getting to grips with climate change. The remoteness of the data, and of those people who generate it, makes quick and easy understanding quite difficult. There are many people and groups who benefit from rubbishing the conclusions of experts. There are as many people who have decided that, in the words of UK minister Michael Gove, "we have had enough of experts". And, of course, the gravest consequences seem a long way off. In a time when most people are not even planning for their own pension, how are they to get to grips with concepts of sea level rise in 2100?

Were it better known, the US Army War College report on the implications of climate change for the US Army, released in October this year, should be the breakthrough in getting people to understand the real, immediate risks. It is written for one of the few state bodies still to retain genuine respect and affection. Its authors range from the US Army to NASA to the Defence Intelligence Agency. It deals with real consequences and real situations. It is clear, and unambiguous. It is absolutely terrifying.

Quick headline? Within twenty years, climate change impacts could cause the collapse of domestic water, power and food systems. War, mass migration and disease on a large scale could break out. The military itself could collapse. All of these consequences take place in America itself – and all will impact countries round the world where the US Army has to operate.

The thoughtfulness of the analysis is impressive. It is the first place I have seen a proper assessment of the impact of salt water intrusion into coastal areas and changing weather patterns on the availability of fresh water in the context of supplying large numbers of people: "a significant logistical burden" added to the already complex problems of managing a force on the modern battlefield.

One has a certain sympathy for the authors when they say "It is useful to remind ourselves regularly of the capacity of human beings to persist in stupid beliefs in

the face of significant, contradictory evidence." The paper simply accepts that climate change is happening and will happen: "The analysis assumes, based on the preponderance of evidence available, that significant changes in climate have already occurred, likely to worsen in the years ahead." Being concerned with effects rather than causes gives the authors an intellectual freedom precisely because they do not need to defend their base assumption that climate change exists. This feels quite revolutionary, as if we are finally moving on from arguing about why something is happening and onto how to deal with it.

The report addresses three challenges.

Challenge 1: The Physical environment.

Rising seas will change coastal geography, displacing many millions, rendering coastal cities and farmland uninhabitable. Military installations on the coast will be put out of action (indeed, a forefather of this report was a US Navy analysis a few years back on how to defend ports and harbours against the rising sea).

The **opening of the Arctic** will raise geopolitical issues which simply did not exist when the top tenth of the world was enclosed in ice. Methane release, the desire to get at the fifth of the world's hydrocarbon reserves currently sequestered in the Arctic, the opening of sea lanes all make the Arctic a point of particular concern. Additionally, "Russia's current Arctic plans include the opening of ten search and rescue stations, 16 deep water ports, 13 airfields and ten air defense sites." – enough to give any commander cause for concern. The distribution and prevalence of **endemic diseases** will change, including malaria, dengue fever, Chikungunya, Leishmaniasis, Lyme disease and Zika. **Fresh water** will be less available: "By 2040, the global demand for fresh water projects to exceed availability." There will be a decrease in **food security** and in food security, with knock on effects on social order ("During a global food crisis in 2007-2008, social unrest was reported in 61 affected countries."). There will be an increase in **extreme weather**. There will be **stress to the power grid**.

Challenge 2: The Social, Economic and Political environment

As if the challenge 1 section were not sufficiently intimidating, the authors analyse what the implications are. Intriguingly, they view the social factors in a way that demands a response from the US military itself – in a society concerned about climate change, how does one of the most polluting organisations, dependent entirely on fuel oil, respond? Brief, pithy analyses of the responses of the market, of regulation and of technology, all point up the authors core message: climate change is more than just change, it is also how an organisation responds to change.

Challenge 3. Organisational confusion

"During this study, we were struck by how much many people knew about parts of the phenomena, but we were also surprised by the lack of a holistic view of the problem, and a sense of how some areas would relate to each other. Climate change is a common cause linking a disparate set of challenges, but we currently have no systemic view to assess and manage risk. In contrast, in China, systems science and engineering is considered so important to the future of China that this is a course of study required for all cadres in the Chinese Communist Party's Central Party School in Beijing."

In other words, there is no structured response currently in place for this very real thing coming down the track. There are lots of studies ("In the past two decades, the DoD has been under increasing pressure from Congress to prepare strategies, plans and capabilities necessary to ensure preparedness for the wide array of potential impacts on weather resulting from climate change.") but no joined-up thinking.

A set of recommendations for the issues identified is brief, practical, time-defined, and prioritised. And a conclusions section basically says "even if this isn't exactly what's going to happen, something like it is, and we must be ready".

For us at SAMI, it is a good to see such forthright acts of foresight. We moved climate change last year from one of our drivers of change to a factor in every study we do: no longer a possible but an actual. That felt then like a principled decision, but it is reports such as this one which make clear that we were right. Foresight and futures work looks at a range of things that might happen, preparing scenarios and possible alternate futures to enable our clients to think about and prepare for the future such that they can make "robust decisions in uncertain times".

Implications of climate change for the US Army is a model of how reports should be written. Not a word is wasted. It is brief, logical and compelling. It is also terrifying, more so because it is not a wake up call, but a reasoned list of events, their consequences, and the actions needed to deal with them. Get past the title, and read it. I suspect it may be one of those papers that we end up citing widely in ten years' time – unfortunately, probably wishing we had followed its recommendations when we still had time.

Written by Jonathan Blanchard Smith, SAMI Fellow and Director, published 12 December 2019