Christians in Science Lecture 15 at St Paul's Church Camberley 29th October 2019

Professor Joanna Haigh - 'Climate Change'

Before her retirement earlier in 2019 Dr Joanna Haigh, CBE, FRS, FRMetS was Professor of Atmospheric Physics at Imperial College London and co-Director of the Grantham Institute for Climate Change and the Environment. We were extremely fortunate to have such an expert in the field of Climate Change (CC) as a speaker and Professor Haigh (JH) gave us both a comprehensive and comprehensible illustrated talk on this extremely important subject. There was a great deal of interest in her subject as was evident from the numbers attending (about 250). In her talk JH covered six aspects of CC – namely the factors influencing the climate, the evidence for CC, the 'physics' of weather and climate, possible future climate scenarios, possible decarbonisation pathways and finally international and UK policy.

Professor Haigh commenced her talk by showing the all-important slide of the 'recent' (1850-2018) rise in global average temperature, most of this occurring in the 20th century. While the rise of approximately 1º C may not seem very much it is very significant in global terms and this upward trend is continuing apace. The major factors affecting our climate are the radiated energy from the sun – pretty well our total energy source – and the composition of the atmosphere, the latter determining the proportion of the sun's energy that is radiated back into space from the earth (mainly as heat (infrared radiation)) and/or absorbed. In the atmosphere the main so-called Greenhouse Gases (GHGs) are water vapour (a relatively constant feature at 0-4%) and carbon dioxide (CO_2). GHGs trap a proportion of the earth's radiated (infrared) energy in the atmosphere, which as a result warms and radiates some of this energy back to the surface (and some into space), which in turn becomes hotter than it would otherwise be – the well-known Greenhouse Effect (GE). Because of its chemical structure CO_2 is an uniquely good absorber of infrared radiation and additionally just happens to absorb energy at the peak frequencies of the earth's radiation – a sort of 'double whammy' effect. And so, even at the low concentration of 0.04%, CO_2 plays a fundamental role in (a) keeping the earth considerably warmer than it would otherwise be (good), but (b) will cause further warming of the atmosphere if its concentration in the atmosphere rises further (potentially a problem). Professor Haigh showed that during the earth's history over, say, the last 400,000 years, the concentration of CO_2 has varied significantly but has always remained less than 300 ppm (0.03%) until the 20th century, during which there has been a sudden and marked increase from 315 ppm in 1980 to 410 ppm at present, an unprecedented rise of 30%, - and this upward trend is continuing. Some people have suggested that this variance is due to natural causes such as a change in the radiation coming from the sun. Such variations do occur during ice ages but over a timescale of 100,000 years or so, with the temperature drop of -8º C being amplified by a concurrent **fall** in CO_2 concentration (**below** 300ppm). JH showed that the earth's temperature tracks very closely the pattern of CO_2 concentration over time. Present CO_2 concentrations and the **rate** of temperature increase have **never** been observed at any time in **human** history. Computer simulations of the earth's climate including the effects of factors such as the sun's radiation, volcanic activity, the earth's relative 'brightness' (reflectivity) and energy transfer to and from the oceans, fit the observed temperature changes (1850-2010) rather well but **only** when the GE of the GHGs is factored in. The rise in the earth's surface temperature is, of course, an average figure – there is considerable variation across the globe with some areas hotter than average, some about the same and a few actually cooler eg the North Atlantic, an effect thought to be due to changes in deep ocean circulation. Precipitation (rainfall) will also be significantly affected. Other evidence for CC is the very significant reduction in the area of Arctic sea ice in summer. It is thought the ice in summer will disappear completely at some point creating a 'positive feedback' effect (yet more warming) due to a reduction in the energy reflected from the earth's surface. Sea levels have also been rising – by about 8 inches in the last 150 years - partly due to melting ice sheets and glaciers on land and partly to thermal expansion of the oceans. A further indicator of CC is the change in the distribution of summer temperature anomalies (extremes) in the Northern Hemisphere. These are becoming more frequent, and at higher temperatures, so that a 1:1000 high temperature event in 1950 is now a 1:15 event and the hot summer of 2018 will be 'normal' by 2050.

And so, Professor Haigh confirmed her view, and that of other scientists, that the principal cause of global warming over the past 250 years was the increasing concentration of GHGs in the atmosphere and that the evidence for this is **quite unequivocal**. Looking to the future, it is quite difficult to predict outcomes exactly. She showed the present distribution of GHG emissions by gas - with CO_2 (about 75%) and methane (about 15%) predominating – and their distribution by economic sector (electricity generation, industry, agriculture

etc). It would be necessary to predict the future for all these major sectors. The IPCC (The International Panel for Climate Change) have made various projections based on different primary energy mixes (coal, oil, gas, nuclear, renewables etc) but even under the 'best' of these where emissions trend downwards to zero, the concentration of CO_2 remains high due to the long-lived, stable nature of the gas – 'if you put CO_2 into the atmosphere it tends to stay there'. Under the best scenario the surface temperature rise (from 1950) is contained at about 1.5º in 2100 and under the worst at about 4.5º. There will, of course, be considerable variation across the globe with the biggest change being seen in the Arctic region. Under the worst case scenarios there will be more very hot regions, the Mediterranean will become drier, the tropics wetter and sea levels will rise by up to 1.0 metre. If current emissions are maintained, ie we do little to mitigate CC, there will be rather dire consequences with many areas becoming uninhabitable due to high temperatures, water shortages or in other areas flooding, and many plant species will be lost. JH's clear message was that we need to drastically reduce global GHG emissions quickly and, if possible, adopt measures to physically **remove** CO_2 from the atmosphere ('geoengineering') and certainly from the waste gases of industrial units such as fossil-fuelled power stations that produce CO_2.

So, what can we do? Professor Haigh referred to the UN conference on CC in Paris in 2015 (so-called COP21) where 183 countries, including the UK and USA and representing 97% of the world's population, **unanimously** agreed to **try** to keep the average global temperature rise below 2º by 2100 and if possible below 1.5º. This may sound an impressive achievement, but the reality is that if all the countries' INDCs (Intended Nationally Determined Contributions) were adhered to, the effect on GHG emissions would be relatively slight. JH compared GHG emissions up to year 2030 based on (a) current projections and COP21 pledges, and (b) on the levels of emissions that would be necessary to begin to constrain the rise in global temperature to either 1.5º or 2.0º by 2100. The differences between the two sets of projections represent the so-called 'global emissions gap(s)' and these are very large indeed, **and** the USA is threatening to withdraw even from the COP21 agreement. Generally speaking, to achieve the COP21 **goal** of a 1.5º global temperature rise by 2100 the world will need to start to reduce emissions **now** (2020) from their peak, and **rapidly,** so that net emissions by year 2050 are effectively zero. 'Net zero' implies that any emissions that are still occurring – and this is likely to be the case – will have to be balanced by mechanisms (carbon capture (CCap)) that extract CO_2 from the atmosphere in some way. Any delay in reaching peak emissions implies a greater need for CCap later. Another way of looking at the future is to think of it in terms of the 'available carbon budget' and the 'carbon countdown' as defined by the IPCC (the International Panel for Climate Change). **Whatever** is thought to be an acceptable/achievable temperature rise and whatever is projected to be the level of GHG emissions (the carbon budget), **at some point** in the future (the carbon countdown in years) **the emission of GHGs will simply have to STOP,** or at least a net zero position will have to have been reached. Otherwise, the CO_2 concentration in the atmosphere will continue to rise (as CO_2 is so stable) and further warming will take place. In short, the greater the current emissions are the sooner they will need to stop, and this pointin time is **very** close if we are to achieve the desired constraint of a 1.5º rise. In practical terms, electricity generation needs to be decarbonised through the greater use of renewable sources such as solar, wind, hydro and nuclear power ('clean' in terms of GHGs), coupled with the electrification of transport and heating and increased use of carbon-neutral biofuels. CCap will also be needed – 'a technical challenge' - the simplest and easiest example of this being afforestation and reforestation of areas where trees have been cut down. The absorption of CO_2 by other varieties of vegetation could also prove helpful. The technical challenge is to develop strategies ('negative emissions technologies') for 'sucking CO_2 out of the atmosphere' which are both practical and capable of being scaled up quickly to the massive degree required. It **may** be feasible to extract CO_2 from the air, liquefy it and pump it underground or into deep sea levels, to 'green' the deserts, or to place giant reflectors into space etc. Professor Haigh touched on the scale of emissions by country and how that has changed since the mid 20th century. The amount of emissions by the 'developed' nations has not in fact changed significantly while that of China, in particular, and India has increased considerably. The USA (16%), China (29%) and India(7%) currently have the highest emissions (**the UK is about 1%)** but on a per capita basis Saudi Arabia and Australia followed by USA and Canada are the 'worst offenders' with India's per capita value being only about 1/10th of that of the USA. These statistics indicate the scale of the problem faced by the world, its politicians and scientists.

Towards the end of her lecture Professor Haigh turned to the political situation in the UK and to what we as individuals might do. On the face of it the UK is not doing too badly (NB the UK only emits about 1% of **total global** emissions) with gross GHG emissions falling quite steeply in the period 1990-2015 and now being below the level they were in 1890. The Climate Change Act was passed in 2008 committing the UK to

five-year legally-binding carbon budgets with the aim (Theresa May as PM) of being 'carbon-neutral' (net zero emissions) by 2050. In terms of electricity generation **capacity** our renewable sources (wind, solar, hydro and nuclear) have reached a level which slightly exceeds that of fossil fuels (coal, gas etc). However, we are still subsidising fossil fuel industries and the government has shelved the Swansea Barrage Scheme. As with the rest of the world, the UK needs to further decarbonise power generation, electrify transport, and improve buildings' insulation. The introduction of 'heat pumps' and hydrogen as a fuel may prove beneficial but the UK also needs to reduce agricultural emissions such as methane, increase tree planting programmes and to develop CCap facilities. The UK is committing about £1 billion/year to help developing countries address CC impacts which is a positive move. However, the UK has the biggest fossil fuel subsidies in the EU and is the biggest **net importer** of CO_2 emissions per capita amongst the G7 countries, through the many imported goods we buy, effectively offsetting our indigenous reduction of GHG emissions. Businesses are generally supportive of agreements such as the COP21 accord but want the government to set out clear policies on CC and to support innovation in clean technology. A task force led by the Governor of the BoE is calling for 'climate-related financial disclosures' and for shareholders to be informed re the climate risks incurred by companies. Many institutions and organisations are considering divesting from companies which do not conform to CC guidelines or have high emissions. JH listed nine things that **individuals** could do to lessen CC effects - such as reducing the amount of flying we do, and likewise our use of cars by walking and cycling more (with positive health benefits), monitoring the use of gas and electricity in our homes, eating less beef and lamb, planting trees, and, perhaps most importantly, talking about CC to others and lobbying our councillors and MPs re the importance of CC and the need for political action.

Professor Haigh concluded her talk by saying that:

- the fundamental physics of global Climate Change (CC) is well understood and established
- regional effects of CC across the world do vary but indications of change are clear in many areas
- the world is currently 1ºC warmer than in pre-industrial times and is well on the way to the 1.5º C 'dangerous change' threshold
- global decarbonisation of energy and industry is necessary to constrain global warming
- international agreement is moving in the right direction but not fast enough. Many stake-holders (including businesses) understand that swift action is necessary.

In the Q/A session that followed her talk, Professor Haigh answered many questions with clarity and good humour. There was (still) some scepticism expressed over the claim that the rapid warming of the world was due to human activity. There have been periods of climate warming in mediaeval times and even in 2000 there was something of a 'pause' in the upward trend. JH replied that this was true but there has never in history been such a rapid temperature rise over a 100 year period and the slight anomaly in 2000 was simply a 'blip' or natural variation probably due to transfer of energy into and out of the oceans. Since then warming has resumed its upward pathway. There were questions on how individuals and countries like the UK can mitigate CC. JH reiterated her 9-point advice as to how individuals can play their part in constraining CC by generally using less energy in their homes and in their use of transport and by recycling waste – it may not make a huge difference but at least it sends out a clear message. Electrification of transport and power sources will help and shouldn't be too difficult to achieve. Planting more trees is also a good idea but in the UK we will have to plant an awful lot of them to compensate for our emissions. Other sorts of carbon capture will be needed as well. Storing CO_2 as a liquid may prove possible but scaling-up will be a challenge. Biofuels (carbon-neutral) to replace current petroleum-based fuels and possibly 'artificial trees', designed to 'mop up CO_2', may also prove useful. She agreed that poorer developing countries were more likely to be affected by CC than the richer nations, certainly in the short term – examples being the desertification of sub-Saharan Africa and flooding of low-lying islands in the Indian Ocean and parts of Bangladesh. Should we be concerned about 'positive feedback loops' reinforcing global warming? Yes, we should, although there is quite a bit of uncertainty regarding these 'loops'. Certainly, the loss of Arctic ice will reduce the earth's reflectivity of the sun's radiation but the effect of clouds is more uncertain. Will the melting of the Arctic Sea ice additionally have an effect on the Gulf Stream, possibly causing it to 'switch off'? The Gulf Stream is an example of an 'overturning circulation' which provides warmth at higher latitudes such as the UK. The Met

Office think that this is not likely to happen although there is a suggestion that the Gulf Stream is slowing. What about the effect of the world's rising population – is this not likely to exert a positive 'per capita' effect on emissions such as CO_2? Yes possibly, but as nations get richer they tend to have fewer children and there is a suggestion that the world's population will 'tail off'. There were a number of questions regarding the position and policies of the larger companies such as the oil multi-nationals. Is it not the case that companies like Shell and BP have a disproportionate influence on governments and might not decarbonisation lead to a situation where there are many 'stranded assets'? There was even a suggestion that JH was being rather disparaging with regard to large companies which after all provide a lot of money for governments! On the latter point, JH said that this was not the case and that she had in fact very good relations with the oil companies. Large companies 'were not stupid' and were aware of the changes that lay ahead and that the world would have to move away from the use of fossil fuels. They know they will have to change their 'business models' eventually but are awaiting government policy guidelines. The use of 'carbon offsets' by some companies, in order that they can claim to be 'carbon-neutral' overall, had some value but was not a permanent solution.

John Russell thanked all those who had made the evening event possible and said that an edited (video) version of the talk would be made freely available. There would also be workshops on Climate Change in February/March 2020 for church adherents and other interested parties. John Wood thanked Professor Haigh for her informative and wide-ranging talk.

John Wood