Mitigation of climate change

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In the accompanying lectures you've heard about the science of long-term climate change, and global warming in particular. I've spiced the science with personal comments on action I think should be taken. The IPCC (Intergovernmental Panel on Climate Change) have a complete working group (WG3) studying the economic and societal implications of global warming. Their reports of 2007 (part of AR4, the 'Fourth **A**ssessment **R**eport' of the IPCC) and 2014 (AR5), coming after the scientific reports, have made a serious impact on the world stage. This piece takes up some of the points made by the IPCC group that in turn echo similar thinking in many countries around the world. I hesitate to call this piece a 'guide', for I've laced it with personal comments, too. You're free to agree or disagree with them.

Let me begin with a short digression on what science can and cannot do for us. Science can not only unravel the causes of climate change but it can make predictions for the future based on that understanding, within limits. Science can't tell us what to do in our present circumstances, because there are ethical, political, economic and other judgements to be made on that. Climate change can be presented as a threat to the environment, as a threat to national economics, as a threat to well-being in many parts of the world, as a threat to security. How these various issues are weighed against each other is not a matter for science. Hopefully, with increasing accuracy as the years pass science can predict how the world climate system is likely to respond to, for example, target levels of CO_2 concentrations and the speed at which they are implemented.

There is a lot of emphasis these days on individual responses to global warming, with exhortations to turn down our thermostats, stop flying on continental holidays, switch off the standby function of your TV and so on, with the justification that if we all did this it would make a significant difference. First, any strategy that requires everyone to do the same thing is doomed. If we all stopped eating sweets and sweet food then tooth decay would be largely an ailment of the past and large numbers of intelligent people who now spend their days filling and extracting teeth would be released for a more imaginative social contribution. If we all obeyed the law then the police force could be largely disbanded, prisons closed and social workers targeted at problems less self-inflicted by society, and so on. It's pie in the sky. We won't all do the same thing to alleviate a well-defined problem. Secondly, global warming is indeed a global problem and the response needs to be a coordinated response of societies and nations around the globe; indeed, a world response. Thirdly, the personal responses such as the carbon-footprint lobby advocate don't tackle the cause of the problem. Their policies are, by and large, policies of retrenchment. That is not what is needed. The cause of the problem is not the excessive use of energy *per se* but the release of sequestered carbon into the atmosphere. The world as a whole, no less, needs to tackle the cause of the problem. Tackling the cause means, amongst other things, developing a raft of alternative energy strategies that don't involve releasing CO_2 into the atmosphere.

I discussed some aspects of introducing alternative energy sources in the lectures. Fine aspirations are all very well but what will it cost to do something? Science, namely chemistry, physics, oceanography, meteorology, etc., etc., isn't the only tool in the bag that we can use to obtain relevant guidance. Economic modelling is another very important tool. It enables us to predict possible future consequences of actions that have yet to be taken. I'll introduce you to this aspect of the IPCC's work.

The IPCC's third working group have been gathering economic evidence for many years. Their 4th report '*Mitigation of Climate Change*' concentrated on the technological, environmental, economic and social impacts of climate change, what they might be, how much they might cost, the timescale of likely effective responses and many related issues. It is a daunting brief and given all sorts of political and social uncertainties in the world it's a brief where you might have expected that little useful could really be said. What comes across in the report is how much can in fact be said with confidence and with high agreement by the multi-national panel. What helps a lot is that local and national difficulties disappear in the noise when making global statements.

It is a measure of the genuine value and importance of the IPCC's work that in October 2007 the IPCC were awarded the Nobel Peace prize, along with Al Gore, *for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change.*

Their report recaps some of the science facts. **Between 1970 and 2004 global greenhouse gas emissions have increased by 70 %**. No-one can argue the facts. The largest growth contribution has come from the energy supply sector, an increase of 145%, followed by transport at 120%. During this period, global population has grown 69%. Carbon dioxide is the largest contributor to the growth of greenhouse gases in our atmosphere, hence the concentration on CO_2 issues.

Global greenhouse gas emissions will continue to grow over the next few decades. This is inescapable. You can see in the IPCC charts the expected CO_2 increases for the 6 different response scenarios that the IPCC described at some length several years ago. The most optimistic scenario that may be politically attainable is a stabilisation of CO_2 level at not less than double its pre-industrial value.

Economic mitigation potential could offset the projected growth of global emissions, or reduce emissions below current levels. Now we get to the nub of the issue: what opportunities are there to make a difference – the 'mitigation potential', in IPCC speak?

Bottom-up studies start with technologies and regulations, focus on specific sectors and estimate the economic effects of changes that could be made for specific costs. Since macro-economics isn't a precise art, there is obviously a range of predictions.

Top-down studies assess economy wide potential and mitigation options using globally consistent modelling. Again there is a range of predictions.

How much you can achieve depends on how much you are prepared to pay, so different options are costed in terms of a level of 'carbon price', quoted in US $ per tonne CO_2 equivalent emission avoided. A few options to save using CO_2 can be implemented at no cost, but not many. More options cost something but will be worth it to save producing CO_2 even if the carbon price is only $20 per tonne. Other more expensive options are only worth it if the carbon price is higher. The 'high-end' options will save emissions if the carbon price is $50 to $100 per tonne. In short, the higher the carbon price, the more is the economic mitigation potential. $50 per tonne of CO_2 equivalent is about $25 per barrel of crude oil. Hence at today's price (nearer $100 per barrel when I wrote most of this but updating some of the text in 2015 it has fallen to less than $50 per barrel) for crude oil there is huge mitigation

potential. For a closer to home example of what one tonne of CO_2 emission means, a mid-range car will travel about 4000 miles (6400 km) in emitting 1 tonne of CO_2 and it will cost you about £500 in fuel at the pump at today's prices in Britain. Of course, most of that cost is tax.

The economists have divided the commercial market into **sectors** that have a commonality of purpose and methods in so far as energy and greenhouse gases are concerned. These sectors are: *energy supply*, *transport*, *buildings*, *industry*, *agriculture*, *forestry* and *waste*. All sectors and global regions have mitigation potential.

For each sector, mitigation policies have been costed and their total potential assessed. The costing has taken account of the economic management of countries. The world has been divided broadly into 3 economic categories: the OECD countries - essentially the so called industrialised western nations, with market driven economies - the EIT countries - largely the former USSR countries and SE Asia, countries that have **e**conomies **i**n **t**ransition between centrally planned economies and market force economies – and the rest. Let me quote from the IPCC a few sectorial examples to give a flavour of mitigation potential.

Buildings. Mitigation developments include: *efficient lighting and daylighting; more efficient electrical appliances and heating and cooling devices; improved cooking stoves; improved insulation; passive and active solar design for heating and cooling; alternative refrigeration fluids; recovery and recycle of fluorinated gases.* – among the key mitigation technologies are *integrated design of commercial buildings including technologies such as intelligent metering that provides feedback and control; solar photovoltaic cells incorporated into buildings*.

Energy supply. Mitigation developments include: *improved supply and distribution efficiency; fuel switching from coal to gas; nuclear power; renewable heat and power (hydropower, solar, wind, geothermal and bioenergy); combined heat and power; early applications of Carbon Dioxide Capture and Storage (CCS) (e.g. storage of removed CO_2 from natural gas).* – among the key mitigation technologies are *CS for gas, biomass and coal-fired electricity generating facilities; advanced nuclear power; advanced renewable energy, including tidal and wave energy, concentrating solar, and solar photovoltaics.*

Transport. Mitigation developments include: *more fuel efficient vehicles; hybrid vehicles; cleaner diesel vehicles; biofuels; modal shifts from road transport to rail and public transport systems; non-motorised transport (cycling, walking); land-use and transport planning; Carbon Dioxide Capture and Storage (CCS) (e.g. storage of removed CO_2 from natural gas).* – among the key mitigation technologies are *second generation biofuels; higher efficiency aircraft; advanced electric and hybrid vehicles with more powerful and reliable batteries.*

These examples put some substance on generalities and hint that the economic analyses, both top-down and bottom-up, have been carried out in some detail.

Economists appreciate that mitigation isn't all about costs, with the only pay-off being carbon dioxide reduction. Costs aren't simply measured in currency either, for there are impacts on many other areas in which we operate, classed as 'synergies', if they are beneficial, and 'pay-offs' in they represent a cost. In the energy sector, for example, among the synergies are *improved air quality*, *increased supply security*, many new *employment opportunities* and *reduced costs* that come with increased efficiency initiatives. New employment prospects are a synergy in every sector. I haven't mentioned yet a key concept that in one sense is the

'killer concept' behind the whole response to global warming, i.e. the concept that on its own makes mitigation worthwhile. That concept is *sustainability*. In brief, alternative energy policies have the prospect of being sustainable. Oil and coal based economies are not sustainable.

One area in the news just recently has been the competition between farming for biofuel use and farming for food. In India, where there is the combination of a high population and the threat of drought over large areas, there is already a significant debate on how much land should be devoted to biofuels. The easy response is that if drought is a serious issue then sunshine must be plentiful and hence solar power is the better route than biofuel. However that may be, you can see that mitigation in practice means national decisions and not individual decisions, emphasising a point I made earlier.

A lot of work still needs to be done on the science of climate change but in comparison even more work needs to be done on R&D (Research & Development) associated with new technological challenges. R&D doesn't get done unless there is a policy to do it, and money for it. Multinationals have money but one of the bottom lines is that it is not their prime responsibility to have concerns for society as a whole. Global warming affects society as a whole, indeed the world as a whole, and hence the responsibility for creating the financial and legislative climate for change falls squarely on governments and international bodies. The IPCC owes its existence to international co-operation but as a whole, governments have not been investing in new energy technologies on behalf of society. The poor statistic from around the globe quoted by the IPCC is that government funding for most energy research programmes has been declining for nearly two decades and is now about half of the 1980 level. Perhaps the pressure on governments to invest in research and development has not been big enough. Spending time on carbon footprints is not sending the right message to the right people.

You used to see the argument, especially by the 'business-as-usual' supporters, that the cost of mitigating global warming exceeded the damage that global warming would do. That argument has been blown out of the water by the IPCC's assessment. The net costs of mitigation estimated by a wide variety of recognised economic models is, according to the IPCC report, less than 1% of world GDP, and likely much less. Some models predict a net gain in world GDP by 2030 if achievable mitigation policies are followed. You can believe the figures or not, but it is on figures such as these that governments have to make choices.

There is one further issue not spelt out in detail by the IPCC that should make a global impact, if it has not done so already. Risk is assessed as the product of the probability of an event happening multiplied by the consequences if it does. For example the probability of your house burning down is small but the cost if it does is huge so the total risk is significant and worth insuring against. The probability of you being hit by a meteorite is fantastically small and even though the possible financial consequence will be severe it's not worth insuring against since the product of the two factors is still small. You get the idea. Global warming science tells us that the probability of global warming by a large amount (say 6°C or above) is very small but the consequences of such a change to patterns of rainfall, drought and climate in general would be catastrophic in almost every sphere: environmental, economic, political, national security, public well-being and in many parts of the world, the issue will be the continuation of life itself. It is doubtful if the governments of the world could avoid international anarchy if such a large climate change came in a moderately short time (say by the end of this century). Hence by the definition of risk, the risk of this one scenario is large.

Governments cannot afford to ignore it. The only 'insurance' against this scenario is to initiate alternative energy policies as a matter of some urgency. The bottom line is that the prospect of global warming cannot be ignored.

You can read the IPCC's words, see their accompanying diagrams and numerical detail, and download their reports at http://www.ipcc.ch/ipccreports/index.htm.

We've come a long way from meteorology. If you look again at climate predictions for later in this century you'll see that although global evaporation and rainfall will increase, the models generally predict hotter and drier bands around the world at sub-tropical latitudes. These cover swathes of North and South America where a lot of food is now produced, bands across Africa both North and South of the equator including the Mediterranean region, India and some of SE Asia, all huge population centres. As a result serious problems are likely to develop in food production and water management that will lead to major issues of poverty, health and security. It is these secondary influences that take global warming so far up the priority list of problems to be tackled, not simply a change in personal experience of the weather. Indeed, if you look back at the rise and fall of civilisations over the last 4000 years, a good argument can be made that climate change has been a major contributor to the demise of powerful empires from Asia, Europe and through to the Americas. Periods of extended drought lasting decades or even centuries have reduced the availability of water in well populated areas and caused catastrophic food shortages. Death, disease and anarchy have destroyed the cohesion of once powerful nations. Nowadays we should have more understanding, more foresight and more adaptive technology to combat climate change but all of this will mean little if the knowledge isn't converted into timely decisions.

Unfortunately there are substantial parts of the world with huge populations that have very limited capabilities of adapting to any climate change. These include much of Africa, for various reasons, Asian megadeltas and other regions too. The social stress created by crop failures, heat-waves, flooding, reduction in fresh water, spread of diseases and other catastrophes induced by global warming have the potential to destabilise not just the affected areas but the world order. Climate change is just one influence among a catalogue of unsettling issues in many of these areas that include over-population for the resources available, food shortage, un-sustainable land use, military activity and other factors too. One can't single out climate change as the sole cause of instability, any more than one can single out CO_2 as the sole cause of global warming. In truth, society in many parts of the world has not adapted well to the vagaries of today's climate and its natural variability. The sensitivity of a substantial fraction of the world's population to the social effects of additional climate change means that for many people mitigation of climate change, whatever the underlying reason for the climate change, is a matter of urgency. This is perhaps a surprising conclusion, given that humans are the most adaptable animals on the planet. However, the adaptability of individuals is altogether a different matter from the adaptability of several billion people around the world interlinked in a complex web of societies. The climate change issue is not primarily a matter of meteorology and local weather but it is an issue about the necessary adaptive changes in global human society.

On a more positive note, there's an argument with some evidence to support it that the 'out-of-Africa' migration of our ancestors around 100,000 years ago was a response to climate change in East Africa. At least the evidence is consistent with this, though not proof, which will be hard to establish. So climate change may be the reason we're all where we are in the world. If I've made global warming mitigation and adaptation sound like a huge problem,

then we should remember the old management chestnut that problems aren't problems but opportunities. The radical change in society, worldwide, needed to adapt to the new order brings immense business opportunities for those who take them on. Boardrooms may not make big decisions for altruistic reasons but they will make decisions to sustain future profits. In our society, getting big business on-side is essential and this will not happen by advocating policies of retrenchment but by emphasising opportunity, even if that is only a 'synergy' of the main issue. Even poor countries can't ignore the importance of international business in making climate change mitigation work. I'm convinced that, one way or another, housing, heating, transport, working practices, the way we live our lives in 50 years time, or perhaps I should say on behalf of my generation our children and grand-children live their lives, will be significantly different. The changes needed will affect everyone and change the shape of society. I'm not sure if David Attenborough was right to say in his much watched TV programme that global warming is the 'greatest problem facing mankind' but it's certainly the issue that's likely to have the biggest impact on our future.

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