**Avoiding catastrophic climate change: technological possibility and political barriers.**

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It's a pleasure to be with you here this evening to deliver a Keele World Affairs Lecture for the second time. Just over four years ago I also joined you, but that was in the days of Covid so both I and the audience were only online. So, it's a particular pleasure to join you this evening in person.

In 2020 I entitled my lecture "T*echnological optimism, behaviour change and planetary boundaries"*: and I addressed the question of whether in order to limit climate change to manageable levels we had to significantly limit consumption and live more frugal lives, or whether technology would provide most of the answer. Whether, as it were, Greta Thunberg is right or Bill Gates

Broadly speaking, though with an important reservation exception related to food and land use[1], I came down on the technologically optimistic side. But I also said that while technological progress was almost certain to deliver a close to zero carbon economy at low cost over the long-term, I feared that we would not get there fast enough to avoid severely harmful global warming.

This evening, I would like to return to that theme, and to consider the danger that while available technology makes it possible to build a zero carbon economy fast enough to limit global warming to "well below 2 C", political barriers (in the widest sense of the word political) may well prevent us doing that. And to sum up my messages upfront, I will address

1 www.kwaku.org.uk/Documents/Techno%20optimism%20behaviour%20change%20and%20planetary%20boundaries%20Nov%202020.pdf

four issues and reach four summary conclusions.

- First, latest emission and temperature trends – very very bad.
- Second, technological trends and long-term economics – far more favourable than I dared hope 15 years ago.
- Third, humanity's inherent ability to cooperate to achieve collective long-term benefits – always imperfect and probably becoming more so as the world of politics is changed by social media
- Fourth, the immediate political situation – very very bad.

But I will end with some ideas for how we can maximise the chances of success in a situation where failure cannot be accepted.

## Emissions, concentrations and temperatures

First, then, trends in emissions, concentrations and the climate. The evidence is clear, the science is certain – rising concentrations of greenhouse gas emissions in the atmosphere (primarily $CO_2$ and methane) inevitably produce rising global temperatures, and over the last 150 years, rapidly rising concentrations have been driven primarily by man-made emissions, with fossil fuel use the most important factor, but red meat production and deforestation also important.

$CO_2$ concentration levels, which varied in a range of about 180 to 300 ppm (Slide 1) over the last 1 million years during which humans evolved from our ape ancestors and became the dominant species on earth, have now increased to about 420 ppm.

… and so far, we have not even seen any reduction in the rate of growth (Slide 2)

As a result, and as predicted by climate models, global temperatures have risen and in 2024 for the first time exceeded +1.5°C above pre-industrial levels (slide 3).

And that global warming is producing extreme local weather effects which have huge adverse consequences for human welfare – floods and droughts across many regions of the world in 2023 (Slide 4), again in 2024 (Slide 5) and already in 2025 (Slide 6)

Now of course we must recognise that 2024's temperature was increased by a strong El Niño effect and 2025 may see a slight decline. As a result, we have not yet exceeded +1.5°C on a 10-year average rolling basis.

But we will, because we have not yet even begun the significant reduction in $CO_2$ and methane emissions which will be required to slow the growth of atmospheric concentrations and thus the resulting temperature. (Slide 7) At COP 26 in Glasgow and again at COP 30 in Dubai (though notably not really at COP 31 in Baku) there was a strong focus on the need to limit global temperature rise to +1.5°C.

But I think we have to be honest – we are not going to achieve that. My own judgement is that the best we can now achieve might be to limit the temperature increase to say 1.7°C above pre- industrial levels, in line with the Paris commitment of "well below 2°C", but not in line with the aspiration of a 1.5°C limit.

But in its latest World Energy Outlook, the International Energy Agency's best estimate is that on current policies in place across the world, we will end up with about +2.4°C warming, and that was before the dramatic changes in US policy already introduced by Donald Trump.[2]

Warming of 1.5°C will deliver the results we already see: each 0.1°C above that will produce still more extreme weather effects with severe consequences for human welfare in particular in low income countries. We should always be wary of hyperbole, but I think it is reasonable to say that +2.5°C would be truly catastrophic for human welfare, but is a possibility by the end of the century.

All of which could make us a bit depressed.

## Technological possibilities and costs

But whenever I am in danger of being depressed about these prospects, my antidote is the good news that over the last 15 to 20 years, clean technologies have progressed and costs come down far, far faster than I dared hope when I became the first chair of the UK Climate

[2] https://www.iea.org/reports/world-energy-outlook-2024

Change Committee in 2008. So fast indeed that I am absolutely confident that **if** we could agree optimal policies and achieve at least a reasonable degree of international cooperation, we could undoubtedly achieve a zero carbon global economy by around 2060, at a cost to living standards in 2060 so small that we would probably not even bother to measure it.

Over the last 50 years the cost of solar PV has come down not 90%, not 99%, but 99.9%. And it will probably fall another 50% by 2030. (Slide 8) Meanwhile, the yield of a solar panel – how much solar radiation energy arriving on the panel can be turned into electric energy – has risen from 15% 10 years ago, to 25% today, and with new technologies such as perovskites will reach 35% sometime in the 2030s.

Indeed, as I make these indicative projections, my only fear is that I'm going to prove, yet again, ridiculously pessimistic. As we developed our first report at the UK Climate Change Committee in 2008, we were very proud of our careful fact-based analytical skills and thought carefully about how far the cost of solar PV might reduce by 2020. We estimated around 25%: the actual result was 90%.

But we were not alone in our failure to anticipate spectacular technological progress. This slide (Slide 9) shows in the light blue lines, the series of projections made by the IEA for future global installations of solar PV. The red line shows the actual result.

Lithium- ion batteries have also seen dramatic cost reduction, falling more than about 90% over the last 14 years (Slide 10). Between 2021 and 2022 there was a slight increase as result of temporary bottlenecks in critical mineral supply; but these bottlenecks were rapidly overcome by the development of new battery chemistries which dramatically reduced potential demand for nickel and cobalt and by announced investments in expanded lithium supply.

Looking forward reasonable projections suggest a further 50% cost reduction for lithium-ion batteries by 2030.

Meanwhile battery energy density, measured as watt hours per kilogram or per litre, is improving by about 7 to 8% per annum, which produces a doubling every 10 years: and that continual progress makes possible either rising vehicle ranges, or smaller batteries and thus lower cost.

A diesel or petrol car has an internal combustion engine and a petrol tank: an EV has an electric motor and a battery.

- Electric motors are massively superior to internal combustion engines in every respect: 3 to 4 times more energy efficient, far lighter, and with far fewer moving parts: they are therefore bound, once scale production has been achieved, to be far lower cost than internal combustion engines and to require far less maintenance.
- Batteries however have an energy density currently only around a 20th of petrol or diesel, and cost far more than a fuel tank.

But as batteries get cheaper and lighter, the total victory of EVs is just a matter of time. In China today, electric vehicles are already selling for less than the equivalent ICE vehicle and have lower running costs. This is the BYD Seagull, selling in China for $9800; and they will get still cheaper over time. (Slide 11)

And whereas six years ago, we believed at the Energy Transitions Commission that the decarbonisation of heavy goods traffic would be primarily achieved through the use of hydrogen fuel cell electric vehicles (FCEV) rather than Battery electric vehicles (BEV), every year of battery technology progress leads us to believe that battery electric vehicles will be the economic solution for ever larger trucks and longer ranges than we previously thought.

In road transport, the future is electric whether you are worried about climate change or not.

Battery technology progress and cost reduction is also the key to decarbonising power systems in many countries. Until now the cost of battery energy storage systems has trended significantly above the cost of electric vehicle batteries. But a dramatic fall in battery energy storage cost is underway. BloombergNEF's 2024 projection suggested a potential 35% reduction in cost by 2035. (Slide 12) But Chinese battery storage system cost are already well below BNEF's 2035 projection, having fallen 50% between 2023 and 2024.

In most of the world the cheapest way to produce a kilowatt hour of electricity is now with either wind or solar PV. So, the key question is no longer how to generate electricity, but what to do when the sun doesn't shine, or the wind doesn't blow.

And for much of the world – in particular the low latitude countries which account for most of global population and by 2050 and 2100 will account for a still higher share – the largest renewable resource is solar, and the balancing challenge is primarily not a seasonal one, but diurnal, day to night, how to keep the lights, and the fridges and the air conditioners going after the sun goes down.

In those countries, solar + batteries is going to be a revolutionary combination, to a far greater extent than most people have yet realised. On the 2024 summer solstice, The Economist magazine talked of the *Dawn of the solar rage,* and rightly so. (Slide 13) And that solar age will be hugely positive for human welfare in many currently low income countries.

Africa could in future, if the cost of capital were low enough (and that is very crucial issue to which I will return) enjoy 24-hour electricity supply via solar plus batteries at a lower cost than fossil fuel based power systems. And Africa's total solar resource could in principle deliver 50 times as much zero carbon electricity as total current global electricity demand and 14 times even the most extreme projection of what the whole world will need to run a completely zero carbon economy while delivering everyone the standard of living enjoyed only in the developed world today[3].

In high latitude countries like the UK, the challenge is more complex. Here our primary renewable resource is wind, and our biggest balancing problem is unpredictable seasonal variations in supply – how to meet electricity demand when anticyclonic conditions in the North Sea reduce wind power supply at a time and to a degree which cannot be precisely predicted in advance, and which way well coincide with high electricity demand, if we are electrify our residential heating with heat pumps.

To solve this challenge, we will need a more complex combination of technologies and business systems than required in sunny low latitude countries – including batteries, pumped hydro storage, and compressed air, some nuclear power, demand flexibility in response to time of day pricing, international interconnections, together with gas turbine capacity burning either hydrogen, or continuing to burn methane but with CCS supplied.

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[3] The Renewable Energy Transition in Africa , IRENA , www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/March/Renewable_Energy_Transition_Africa_2021.pdf, page 38

But these technologies are available, and they will make possible zero carbon electricity systems as much as 70 or even 80% dependent on variable renewables at total system costs comparable to and potentially lower than fossil fuel-based systems.

And the clean electricity which those systems will deliver will enable us to heat our homes at far lower operating cost than we face today, because electric heat pumps are 3-4 times more efficient at turning energy input into heat within the home, an advantage which will increase further with technological progress[4].

So, if we considered only our energy use in buildings, in road transport, and also in the many industries whose energy input is primarily electricity or low to medium temperature heat, I am totally confident that we could achieve by 2060 a global zero carbon economy delivering services and products to consumers at a lower cost than today's fossil fuel-based system.

In these sectors, the future is almost entirely electric, and an electrified energy system is fundamentally superior to a fossil fuel based one on every single dimension – efficiency, local environmental impacts, energy security, cost and climate change impact.

- Electric cars are four times as efficient as internal combustion engines at turning energy input into kinetic energy in the wheels: heat pumps are four times as efficient as gas boilers at turning energy input into heat within the home and that ratio will get higher overtime.
- And electricity is hugely superior in its local environmental impact – no air pollution, dramatically reduced noise pollution, and no blast of engine heat on summer streets to make uncomfortably hot cities even hotter.
- And as I described in my previous Keele lecture, the local environmental impact of the supply chain for an electricity-based system – the minerals we need for motors, batteries and wires – is hugely less than that imposed by today's fossil fuel-based system. Since my 2000 lecture, the ETC published in 2023 a report on *Material and resource requirements for the energy transition*[5]: our key conclusion was that while

[4] https://www.energy-transitions.org/publications/achieving-zero-carbon-buildings/

[5] https://www.energy-transitions.org/publications/material-and-resource-energy-transition/

there are temporary supply bottlenecks to be overcome and environmental impacts which need to be carefully managed, there is no shortage of the minerals needed to build a massively bigger global electricity system in an environmentally sustainable fashion.

Overall, at the ETC we believe that in a zero carbon globally economy, electricity will account for over 60% and perhaps almost 70% of final energy demand. This compares with around 22% today.

But that still leaves sectors of the economy which are hard to electrify fully and which we sometimes call "hard to abate". These include:

- Heavy industrial sectors such as steel, cement and chemicals where we are not just using fossil fuels as an energy source, but where either:
    - there is a chemical reaction which itself produces CO2 (e.g., in the calcination of $CaCO_3$ to CaO in cement production, or in the use of the carbon in coking coal to reduce iron ore to iron);
    - or where in petrochemicals today's fossil fuel input is not just an energy source but a feedstock from which the molecules in the end products (e.g., plastics) are constructed.
- And shipping and aviation, where is no barrier to using electric motors – indeed they would be far more efficient than combustion-based engines – but where currently available battery energy densities make electric solutions only applicable today at short distances.

Despite these challenges however, there are technologies available which could enable us to get to zero carbon emissions by mid-century in every one of these sectors.

We could even today produce all of our steel using hydrogen as the reduction agent rather than coking coal, and using green hydrogen made via electrolysis of water using renewable electricity. We could use methanol as our shipping fuel and fly planes on sustainable aviation fuel.

And even in these sectors we will probably over time see a greater role for direct use of electricity: this year at the ETC we are analysing the increasing potential to electrify both medium temperature (say up to 400°C) and even high temperature (1000°C +) industrial heat: and by the second half of this century I suspect that direct metal oxide electrolysis will play a major role in primary iron and steel production.

But despite the technological possibilities, these sectors are harder to abate in economic terms, because in all of these sectors of the economy there is likely to be a "green cost premium", certainly for a long time and in some cases forever.

- In cement production, the only currently feasible solution which we could apply across the whole world is to use carbon capture and storage; and that is bound to increase the cost of cement, since it involves taking an existing process and adding a further step and thus further cost.
- In steel, CCS applied to coking coal blast furnaces or to gas based direct iron reduction (DRI) is an option, but again bound to increase the total production cost. And while it is **possible** that in the very long term, hydrogen direct reduction may become cheaper than coking coal-based production without CCS (if renewable electricity becomes very cheap and electrolyser costs decline) it seems probable that we will not reach that point for several decades.
- In aviation and shipping it is close to certain for at least the next three decades, achieving decarbonisation will entail a significant green cost premium, implying higher shipping freight rates and higher aviation ticket prices

Unlike in relation to road transport, and buildings, where the consumers of 2050 will gain a direct advantage from living in a zero carbon economy, they will probably even then need to pay more for steel, plastics, shipping and aviation, than they would in world where we did not fully decarbonise our economy.

But a crucial insight is that with one exception – aviation – the impact of the green cost premium is very small at the level of consumer expenditure because consumers don't actually buy steel or shipping, or plastics, or cement, but instead buy products or services which have shipping services, or steel, or plastics or cement embedded within them, but only accounting for a very small percentage of the total cost. (Slide 14)

- If achieving net zero shipping emissions meant that shipping freight rates in 2050 were even 100% higher than they would otherwise be – that would add less than 1% to a pair of jeans made in Bangladesh and bought in London.
- And if the ex-factory cost of plastics had to increase by 50% in order to achieve decarbonisation, the increase in the cost of a bottle of soft drinks would also be well below 1%.

In total therefore, the cost to living standards in 2060 of living in a global economy which does not use fossil fuels, or which only uses fossil fuels with CCS applied, will result from the balance of three effects.

- Significantly lower costs for consumers in everything to do with building energy use and passenger road transport.
- But marginally higher costs embedded in the price of products which require the input of cement, steel, plastics of shipping.
- And a significantly higher cost for aviation relative to what it would be if we continued to use fossil fuels – though worth noting that this may still be a lower cost than aviation today, since the higher cost of sustainable aviation fuel could be more than offset by improved energy efficiency in a new generation of planes.

In 2021, the Energy Transitions Commission had a shot at estimating what this balance of cost reductions and cost increases might be, and concluded that the cost to living standards in 2060 of achieving a net zero economy and therefore limiting climate change might be as low as 0.5% of GDP in that year,[6] which if the global economy were growing at 2% per capita would imply reaching in December 2060 the level of conventionally measured GDP per capita which we would otherwise achieve in September that year.

During 2025, we will update that calculation. Given technological trends, it is possible that our new may be lower still and perhaps even negative. And even if our previous calculations were a dramatic underestimate – say by a factor of 10, these costs of achieving net zero

[6] *Making Mission Possible* , Energy Transitions Commission , 2020 https://www.energy-transitions.org/publications/making-mission-possible/

would still be very small compared with the adverse costs which unconstrained climate change will impose.

So, if we focussed only on technological possibility, we could be a lot more cheerful.

If we lived  in a world of complete international peace and governed by a benevolent dictator who could impose optimal policies – I have not the slightest doubt that we could build a zero carbon globally economy by 2060, that by the time we got there, the cost to consumer prosperity would be so small we would hardly bother calculating it, and that this would enable us to limit global warming , if not to +1.5C , then certainly to +1.7C.

Or to put it another way, if there were above us a  benevolent deity and if she were to send angels in the night to steal and carry away most of our fossil fuels, leaving us only with the amount that we could safely burn while still keeping the temperature increase below +1.7C – I have not the slightest doubt that free market processes of competition and private investment would take us to a zero carbon economy at a very low eventual cost.

## Human nature, rationality and political impediments

But we do not live, and I presume will never live, in a world of benevolent rational global government. Nor do I personally believe that there is above us a benevolent deity.

And in the actual world run by imperfect human beings, non-technological impediments stand in the way of achieving a net zero emission economy fast enough to avoid potentially catastrophic climate change.

In understanding those impediments, we must start by recognising that **getting** to net zero is not costless. Which may at first sound like a contradiction of what I have said about the costs to global living standards. So, let me make clear a crucial distinction:

- Once we have achieved the transition, the cost penalty of living with a zero carbon energy system versus a high carbon one will be trivial, and quite possibly negative.
- But to get there we have to invest significantly more than we otherwise would. And more investment, will tend to mean less consumption for a period of time.

For the UK, that point is made clearly by this slide (Slide 15) from the UK Climate Change Committee's 6th Carbon Budget report, which show investment costs above the line and operational savings below, with a net cost reduction by 2050, but significant net costs during the transition. And what is true for the UK is true globally.

(Slide 16) Broadly speaking in 2020 the world invested about $1 trillion per annum in new clean technologies. By 2023, according to IEA figures, that had already risen to around $1.6 trillion, but by the 2030 it needs to rise to about $4tr, with the lion's share of that investment needed to build much larger and zero carbon electricity systems. That $4 trillion – partially offset by reduced fossil fuel investment – will need to be maintained for 15 to 20 years, before falling off once the new energy system has been built.

Relative to total global GDP over that period that will be a manageable 1.5-to 2%, but it's still significant, and someone has to pay. And that is true at both the micro and macro level:

- Heat pumps will enable householders in colder high latitude countries to heat their houses at lower running cost: but to get to that end point they have to make an investment, and that must tend to mean some sacrifice of individual household consumption.
- And at the macro level, the current generation has to bear some investment cost in order that the future generation can enjoy a world where climate change has been limited to a manageable though still harmful level; and that must tend to mean some reduction in aggregate cross economy consumption.

The scale and duration of such consumption reductions can be reduced by two factors.

- In some but not all economic conditions, increased investment can pay for itself rapidly via increased induced economic growth.
- And increased investment in clean technology can in some cases be offset not only by reduced fossil fuel investment, but by lower investment in other non-energy sectors of the economy. In China in particular, there is a huge opportunity to reduce wasteful investment in property and related construction: as a result, China could

easily increase its already high investment in clean technologies while simultaneously increasing the level of personal consumption[7].

But we need to recognise and openly admit that getting to net zero will entail some small reduction in current consumption in order to avoid the far larger costs which unconstrained climate change would impose.

And our fundamental problem is that imperfect human beings often find it impossible to accept investment which delivers benefit to the whole of society, even if that benefit is worth massively more than the cost incurred.

They can, if the threat is immediate and frightening and if the need for response can be linked to emotive concepts such as national identity. As a percentage of GDP all of this investment needed to limit climate change is a tiny faction (something like a 1/15$^{th}$ or 20$^{th}$) of the consumption sacrifice which the parents and grandparents of people in this room made in order to defeat Nazism: but even to mention that consumption sacrifice seems wrong when the far greater sacrifice was in lives lost.

But faced with a long-term, complex threat to all of humanity, with no emotionally motivating external enemy, we could fail to achieve what is technologically possible.

- Even in relation to their own individual welfare, many people find it difficult to make sensible long-term solutions, dramatically discounting long-term benefits relative to short-term costs.
- And climate change is in economist's terms an "externality", with the benefits of mitigating climate change diffusely enjoyed by all humanity while the specific costs of mitigation are faced by specific people or companies.
- And that creates a severe collective action problem – that it only makes sense to accept any mitigation costs if you can be sure that multiple other people and companies across the world, in different countries with different political systems, will do likewise.

[7] https://www.energy-transitions.org/publications/achieving-a-green-recovery-for-china/

Wide area externalities and collective action problems can limit our ability to address any common global problem. But in addition, there are at least four specific features of the economics of climate change, of today's pattern of technological development, and of the nature of modern politics, which create particularly acute challenges.

*First distributional effects* which mean that while the overall investment cost of the transitions is small, the balance of costs and benefits varies significantly between different households. Here in Britain people living in houses with plenty of garden space for a heat pump, or off-street parking to charge an electric vehicle at domestic electricity prices, can gain big and soon from the UK's energy transition, but those with space constraints on heat pump installation and no off-street parking will face significant costs for quite some time. And across the world differences in the cost of finance have a huge impact on the balance of costs and benefits: richer people with money in the bank sufficient to install a heat pump or buy a more efficient air conditioning system or buy an EV, will often enjoy operational costs savings which outweigh interest income foregone ; those who can only borrow at high interest rates will often find investments uneconomic.

*Second, differences in cost of capital* between countries are also hugely important. Political and economic risks, whether actual or perceived, mean that the cost of both debt and equity capital is far higher in many developing countries than in richer developed one. And the cost of capital matters a lot in the energy transition, because it's an inherent feature of many green technologies, and in particular zero carbon electricity generation – whether wind, solar, hydro or nuclear – that they require large up front investments in order to enjoy close to zero marginal cost of production.

If sub-Saharan Africa enjoyed the same cost of capital for renewable energy projects as Northwest Europe, say 4% real for a mix of equity and debt, solar plus batteries would beat fossil fuel in many locations today: but if the cost of capital is 10% it can still make sense to invest in gas turbines, and if higher still to buy a diesel gen set – keeping the upfront costs as low as possible but tying the user into an expensive and dirty fuel well into the future.

*Third, geopolitical tension and economic competition* can impede our ability to gain the benefits of technological progress and of cost reduction. I talked earlier about the amazing progress that the world is making in improving the performance and reducing the cost of key clean technologies: but in almost all of the key technologies one country dominates -China (Slide 17)

In a world of total geopolitical harmony and rational behaviour, the fact that Chinese companies will now sell you solar PV panels for 9 cents per peak watt versus a US production cost around 25cents, or could offer small EVs into the European market at less than 15000 euros, or will sell a containerised total battery solution for around $120 per kwh storable versus close to $200 just 2 years ago – would all be causes for celebration.

But in the real world we live in today, fears of Chinese domination and of threats to local jobs, can result in tariffs and investment restrictions which threaten to slow the pace of global energy transition.

*Fourth and finally, one of the biggest political barriers to effective action on climate change is the nature of modern politics* and in particular the impact of the social media revolution.

- We face a long-term challenge whose nature and potential magnitude can only be assessed by expert scientists using sophisticated models; but we live in an age when with scientific expertise is often denied and derided by effective communicators using powerful media channels.
- And we need to gain agreement to cooperate nationally and internationally to share the initial investment costs of getting to net zero, but social media by the very nature of its algorithms, creates self-reinforcing beliefs within and antagonism between different groups within society, reducing the prospects for cooperation.

At the ETC we are very aware that our natural language of communication is the sort of lecture which I'm now giving, logical, fact-based and I hope convincing to the 350 people in this room, and the several thousand who may read the online version.

But hundreds of millions of people now gain their information about climate change from Internet browsing, and tens of millions gain their information from websites which exist at the intersection between the Manosphere, anti-VAX groups, wellness influencers, far right politicians, and conspiracy theorists (Exhibit 18)

Surveys still suggest a strong majority of people in most countries, including the US, believe rightly that climate change is real, man-made and that we must act to constrain it. But vocal and organised minorities are often more powerful in politics than the silent majority.

## The Trump problem

All these problems are of course close to inherent; international cooperation is always highly imperfect; all processes of technological change have distributional consequences: and if we knew how to reduce developing country risks and capital costs, we have would done it years ago, even if we cared not at all about climate change.

But at least until now there has been some international consensus, embedded in international agreements supported by almost all countries, that we face a common problem, and must each contribute to its solution.

And over the years following the Paris climate conference of 2015, a steadily increasing number of countries and companies made commitments to reach zero emissions by a specific date – 2050 for all rich developed countries, and typically 2060 for developing.

And those pledges were often at least partially reflected in policies which boosted the deployment of key clean technologies, and as a result accelerated the cost reductions which come from scale and learning curve effects. True those policies still put us, according to the IEA, on a path to perhaps 2.4°C warming by the end of this century. But before COP21 in Paris, estimates of the warming implied by current policies were often well over +3°C.

But the election of Donald Trump is huge setback to that consensus, to that momentum and to the prospects for limiting global warming to well below 2°C.

It is of course important not to overdo the gloom. The US is only 15% of global emissions, and the setback to US emission reduction efforts may only last four years. And I am sure we will hear again many US states, cities and companies saying, as they did in 2016, that “we’re still in” to the Paris process, even if the federal government is not, though I rather fear that the number of companies doing this will be somewhat less than in 2016.

But anyone who believes that it doesn't make a difference when the US president and many of his supporters and key officials believe that climate change is a liberal hoax, is living in a fantasy land. Trump's Presidency will seriously set back global efforts to limit climate change.

- Yes, some of the early stage subsidies created by the Inflation Reduction Act may be kept, in part because they have created their own vested interests, but we will not see the further reinforcement of those policies which was already essential if the US was to achieve its emission reduction commitment of 48- 52% by 2030.
- Prospective US investment in clean technology development and deployment will reduce, which means that we will not see the US joining China as a major driver of technological progress and cost reduction, as seemed possible if the policies of the Inflation Reduction Act had been maintained and reinforced.
- The US will not now provide significant support to the flows of capital required at adequate cost into low income developing countries; indeed, events in Washington this week suggest that the Trump administration intends to provide no help to developing countries for any reason other than short term transactional advantage to the US.
- And the fact that the US is drawing back from its commitments to the Paris process, may encourage other countries to do the same, even if they formally stay within it.

At the beginning of last year, I thought that with further progress on national policies and international cooperation, we might just still be able to limit global warming to +1.7C, and that a limit of less than 2°C was still likely. But the election of Donald Trump alone makes me raise my gut feel estimate of the best we can achieve to something like 1.9°C, and with a greatly increased chance of the really catastrophic effects which would result from warming of say 2.5°C.

To get a bit more specific than that gut feel, we need to look at estimates of the remaining "carbon budget", the cumulative amount of $CO_2$ which scientist believe could be omitted and still leave us with a 50% chance of limiting global warming (on a rolling average basis) below a given temperature level. (Slide 19)

The IPCC AR6 analysis suggested that at the beginning of 2020 the budget for a 50% chance of a 1.5°C limit was 500 Gt. But five years of emissions at about 40Gt per annum have reduced that to around 290 Gt, and some latest scientific analysis suggests a lower budget of about 160Gt. The equivalent figure for a 50% chance of a 2°C limit would be about 1050 giga tons, and for a 1.75°C limit roughly halfway in between – about 600 Gt.

Which at the current rate of annual emissions would be exceeded within 15 years. We have to start rapid global emission reduction soon to have any chance of achieving well below 2°C. And we have to do so in the world where the US Federal government is no longer committed to achieving this, but instead committed to “drill baby, drill” for new oil and gas supplies.

## Communication, policy and geopolitical priorities?

So given both the technology potential, and political barriers, how do we still maximise the possibility of staying below and ideally significantly below 2°C.

Of the many things that are important I’d like to end by highlighting five priorities.

**First,** we need to **win the argument** that climate change is a huge problem and that, while we will have to face some costs to mitigate it, these are very, very small compared with the harm which climate change will do to human welfare across the world.

Which may seem an odd thing to say because of course we have to win the argument. But in the years following the Paris COP21, there was sometimes a tendency to shy away from the fundamental climate change imperative to reduce emissions and to instead suggest.

- That the economic case for the energy transition was compelling in itself, even if we did not care about climate change.
- And that companies and financial institutions should set net zero targets in their own self-interest because otherwise they would be left with stranded assets which would harm shareholder value.

But we have to return to the fundamental economics here. We face a massive global long-term externality, and private incentives alone will never solve an economic externality – you need public policies, carbon prices, initial technology subsidies, and regulation, without which it will never make sense for the private sector to invest fast enough in the zero carbon technologies now available.

We have to win the argument that long-term collective interest and a moral responsibility for future generations demands action today. We have to make the connection between these weather events (Slide 20), and the need to invest to build a zero carbon economy as fast as possible.

That will not be easy in a world where social media, exploited by opportunistic politicians and vested interest, generates misinformation, doubt and confusion. But unless we win the fundamental argument, I fear we will not achieve the transition fast enough to prevent catastrophic levels of climate change, well above +2°C.

**Second**, where there are costs to achieving the transition, we need to recognise them in advance and actively manage the distributional consequences.

In 2018, President Macron's government introduced very significant increases in petrol and diesel taxes, justifying them in part as a means to encourage transition towards more efficient ICEs or electric vehicles. But that was before they were EVs available with range sufficient to meet the requirements of rural rather than city dwellers, and the economic impact for ICE vehicle owners was much higher for people living in the countryside and small towns, who have longer trips to work and shopping, than in Paris.  The result was the *gilets jaunes* protests, one of the first examples in Europe of populist opposition not to immigration or to austerity but to climate change related policies.

We have to get smarter in future.

And we need to recognise that in an era of increased inequality (in both income and wealth) it will be very difficult to persuade people in the bottom half of the income distribution, even in rich countries, to accept a significant cost penalty to achieve zero emissions – so the burden has to be picked up primarily by the top half.

At the very top end that means taxing private jets and first class travel much more aggressively: at a mass affluent level, it means taxing business class travel and large SUVs far more aggressively;  and across the broad mass of the income distribution it could mean, for instance, increasing gas prices for middle and higher income families living in larger homes, and using the money to pay for subsidies to help lower income households install heat pumps.

**Third**, we should seize the opportunity created by the fact that in distributional terms, decarbonisation of the so called hard to abate sectors is not a major problem. In the UK the transition from gas boilers to heat problems will create difficult distributional issues which require careful management: In Germany opposition to that transition is already an AfD campaigning point. But a global carbon tax on shipping, or a high domestic carbon price plus an effective border carbon adjustment for steel and cement, has a minimal impact on consumer prices, spread between different households in a fashion roughly in line with their income.

So, we should strongly support proposals, such as put forward by President Ruto of Kenya, for a global carbon tax on the shipping sector; we should try to win the argument for carbon taxes across the world on heavy industrial production: and we should be unapologetic in imposing carbon border adjustments on any country which does not yet accept that argument.

And in UK aviation, we should exploit the fact that we already have significant taxes on flights to convert those taxes into an effective carbon price. If we took the already existing Air Passenger Duty and committed to raise it gradually over time, but with discounts proportional to the share of Sustainable Aviation Fuel used, we would strongly reinforce incentives, immediate and forward looking, for the development of SAF.

**Fourth,** we must place a very strong emphasis on mobilising capital flows at a reasonable cost of capital to lower middle and low income countries, exploiting to the maximum the fact that development banks, through their leverage, can create spending power far greater than the equity investments which government shareholders put in.

Technological progress and cost reductions have, over the last 10 years, revolutionised the potential for poor countries, for instance in sub-Saharan Africa, to leap over the fossil fuel stage of development and to drive economic development via clean electrification. Multiple reports have described the reforms to the development banks policies and focus required to help achieve this revolution.[8] [9]We need to turn that analysis into action.

**Fifth** and crucially, we need to ensure as much international cooperation and momentum as possible within the COP process even with the US no longer there, and within that multilateral context develop in particular a collaborative, constructive but also where necessary robustly honest relationship with China.

Two stories are told about China and climate change.

- One is that it is the biggest polluter in the world, now emitting about 12 Gt of energy related $CO_2$ out of a global total of 37Gt, and with per capita emissions higher than in the UK, is still building new coal power plants and only committed to peak emissions "by 2030".
- The other is that China is the major driver of clean technology, deploying solar and wind as fast as the rest of the world put together, far ahead of the world in the electrification of surface transport and industry, and able to supply the whole world with the solar panels, batteries and EVs at prices which can enable rapid energy transition at low cost.

Both stories are true, and our relationship with China must therefore combine three aspects:

- First, being clear that China must accept the responsibility which comes with its greatly increased prosperity, and emissions: it cannot go on in international climate negotiation claiming the status of a developing nation; it must be a contributor to global climate finance quite as much as the developed world, and it must set a more aggressive emission reductions target.
    - China's current commitment is to peak its emissions by 2030 and to get to net zero greenhouse gas emissions by 2060. (Slide 21) Suppose that in terms of $CO_2$ that means China will continue to emit at 12GT per annum to 2030, and then reduce on a straight line to zero by 2060: that would result in cumulative

[8] https://www.cgdev.org/publication/strengthening-multilateral-development-banks-triple-agenda

[9] https://www.lse.ac.uk/granthaminstitute/publication/raising-ambition-and-accelerating-delivery-of-climate-finance/

$CO_2$ emissions – the area under the curve – of 240 Gt; that compares with the 4.5Gt which the UK will emit between 2025 – 2050 under our climate change act commitments, which, even if multiplied by 22 to allow for China's far greater population, would be about 100GT vs China's potential 240Gt of emissions.

  - There are many indications that China can and probably will achieve a significantly earlier peak and faster rate of reduction that this slide suggests; but **committing** to a faster pace would a hugely positive effect on global climate negotiations: and without that commitment, it will be increasingly difficult for people like myself and others in this room to win the political argument for rapid emission reductions in the UK and Europe.

- But conversely, we should openly applaud the Chinese for their extraordinarily positive contribution to the development of clean technology, which contrary to myth (Slide 22) does not now primarily reflect lower environmental standards, or bad labour standards, but brilliant entrepreneurship, technological leadership, economies of scale and learning curve effects. Which means that:
  - if we want to have affordable EVs for the mass market soon, we cannot exclude imported Chinese vehicles.
  - And if we want to build domestic supply chains in Europe, in say batteries and low cost EVs, we should combine any tariff protection with a welcome to brilliant Chinese companies to invest here, creating domestic employment and value added, and helping us, via the technology transfer which inward investment achieves, to become also a driver of clean technology development.
- And we should work together on the fourth priority I mentioned, mobilising capital flows and to support clean technology investment in developing countries.

So, five priorities at least, none easy, and all requiring political imagination and leadership to deliver.

But the good news to which I return in conclusion is that the technology trends are in our favour, and to a far, far greater extent than I anticipated when I was first chair of the UK CCC in 2008.

One of the most important things we must therefore do in making the case for strong action to reduce our emissions, is to tell the story about the amazing technological improvements which have been achieved, and the further progress that it is possible.

This technological development is so rapid, and the fundamental advantages of electrification so great, that even with highly imperfect policies we will probably get to close to a net zero carbon economy sometime in the late 21st century, and will almost certainly avoid the truly catastrophic levels of global warming – say above +3°C – which still seemed possible before the Paris climate conference.

And I have not the slightest doubt that with strong policies and reasonable international cooperation, we could achieve that zero carbon global economy by 2060 and at minimal or even negative cost to living standards.

And if we did that, we could still limit global warming to perhaps +1.7°C limit and avoid the extremely severe harm to human welfare which will otherwise result.

However difficult the politics, we must achieve this.