Centre for Climate Change Economics and Policy

Grantham Research Institute on Climate Change and the Environment

Growth, climate and collaboration: towards agreement in Paris 2015

Nicholas Stern

Policy paper

December 2014

Centre for Climate Change Economics and Policy

Grantham Research Institute on Climate Change and the Environment

The Grantham Foundation for the Protection of the Environment

E·S·R·C Economic & Social Research Council

University of Leeds

LSE The London School of Economics and Political Science

The Centre for Climate Change Economics and Policy (CCCEP) was established in 2008 to advance public and private action on climate change through rigorous, innovative research. The Centre is hosted jointly by the University of Leeds and the London School of Economics and Political Science. It is funded by the UK Economic and Social Research Council and Munich Re. More information about the Centre for Climate Change Economics and Policy can be found at: http://www.cccep.ac.uk

The Grantham Research Institute on Climate Change and the Environment was established in 2008 at the London School of Economics and Political Science. The Institute brings together international expertise on economics, as well as finance, geography, the environment, international development and political economy to establish a world-leading centre for policy-relevant research, teaching and training in climate change and the environment. It is funded by the Grantham Foundation for the Protection of the Environment, which also funds the Grantham Institute for Climate Change at Imperial College London. More information about the Grantham Research Institute can be found at: http://www.lse.ac.uk/grantham/

Growth, Climate and Collaboration: Towards Agreement in Paris 2015

Nicholas Stern

Introduction[1]

International agreements are built on shared understanding. This paper and the lecture of 6 November at Sciences Po in Paris on which it is based, will characterise four key elements of the understandings on which a climate change agreement at the 21st Conference of the Parties (COP21) to the UN Framework Convention on Climate Change (UNFCCC) in Paris should be built. These elements are: the risks from unmanaged climate change are potentially immense and delay is dangerous; the path to a low-carbon economy can be highly attractive, embodying strong and high quality growth, investment and innovation in the context of rapid global structural transformation; the agreement should be based on a shared commitment to creating "equitable access to sustainable development"; the agreement should be structured to facilitate dynamic and collaborative interactions between parties.

The presentation, examination and discussion of these four statements is the main purpose of the paper and they form sections 1, 3, 4, 5. The science of climate change and the immense risks it identifies are the foundations of all that follows and that is where we begin in section 1. In section 2, I set out my assessment of how the world and the arguments have changed and developed in the eight years since the publication of the Stern Review online in October 2006 (book form, Stern, 2007, in January 2007).

The conclusion of the Stern Review that the costs of inaction greatly exceed the costs of action has strengthened still further. We have learned: that health risks from air pollution from burning hydrocarbons are deeply worrying; that technology has changed remarkably; much concerning what works on policy, including that vacillation damages incentives; and that political will has slowed or stalled in some places but become much stronger in others, particularly China. In consequence, I would now emphasise two perspectives on the economics of climate change still more strongly. First, we must see this as an issue of the management of immense risks so that narrow or marginal cost-benefit analysis has only a limited contribution in the analysis. Second, the low-carbon transition is an attractive, dynamic growth story and an attempt at maintaining a high-carbon path is deeply damaging and unsustainable.

[1] I am very grateful to Rodney Boyd, Fergus Green, Alina Averchenkova, Claude Henry, Jennifer Morgan and Laurence Tubiana for comments, guidance and support. This paper also benefitted from the discussion at the Sciences Po on 6 November 2014.

It was an honour to be invited to give the inaugural lecture in the series at Sciences Po in Paris, '*Make it Work*'. Sharing ideas, examining the evidence, learning from each other, finding creative ways to advance should be at the heart of policy discussion and action and of a strong and enduring international agreement. I am very grateful to Claude Henry and Laurence Tubiana for inviting me to give this lecture.

1. We have to understand clearly that the risks are immense

Human, economic and other activity results in emissions of greenhouse gases (GHGs), that are currently at higher levels than the planet can absorb. Thus concentrations of GHGs in the atmosphere rise. This results in less energy escaping – the greenhouse effect – and temperatures rise and the climate changes. The effects are in large measure via water, or its absence, in some shape or form: [2] extreme events, including hurricanes and storms, sea surges and sea-level rise, floods and inundations, desertification and so on. We cannot predict exactly where and when the effects will occur but the impacts could be widespread, long-lasting and immense. Essentially, if we continue as we are, we may drastically rewrite the relationship between humans and the planet, potentially, leading to the mass migration of perhaps hundreds of millions or billions of people. History tells us this could result in long and sustained conflict. These are the stakes we are playing for.

GHG concentrations have increased from around 285 ppm carbon dioxide equivalent (CO_2e)[3] in the mid-1800s to around 445 ppm CO_2e today. We are adding around 2.5 ppm CO_2e per year (and rising), up from 0.5 ppm per year in the first part of the 20th century. If the world continues to emit GHGs along a high-carbon path, following the old ways, concentrations of GHGs could rise to the region of 750 ppm CO_2e by around the end of the century. At these concentration levels, median temperature could increase over the next one or two centuries by about 4°C or more (increases in average global surface temperature relative to the second half of the

[2] See, for example, the World Bank 2012 report "Turn Down the Heat".
[3] Carbon dioxide (CO_2) is the main contributor to the greenhouse effect. It is also the easiest to measure, and has long lasting impacts. But it is not the only GHG. The six GHGs managed under the 1997 Kyoto Protocol are CO_2, methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). CO_2e is the expression of all these greenhouse gases in terms of the CO_2 that would generate the equivalent amount of warming potential as measured over a specific timescale (typically 100 years); ppm (parts per million) is the ratio of the number of GHG molecules to the total number of molecules of dry air.

nineteenth century, the usual benchmark), with substantial probabilities of well above 4°C.[4] The increase in concentrations of GHGs in the atmosphere to date has already corresponded to an average warming across the Earth's surface (combined land and ocean temperature) of around 0.8°C since the late 19th century,[5] and we are already seeing strong effects. We are already at the upper edge of temperatures seen during the Holocene period (the last 8,000 or 9,000 or so years)[6] during which our societies developed: grasses were cultivated to become cereals, thus requiring sedentary populations to tend and protect crops until harvest, and allowing both surplus and storage. This provided time and opportunity to develop villages and towns and much of the skills of civilization, culture, and ways of life as we know them. Yet we have seen only a small temperature increase relative to what we risk.

We have not seen 3°C for perhaps around 3 million years and 4°C or more for perhaps tens of millions of years.[7] This is way outside the experience of *homo sapiens* (perhaps 250,000 years old).[8] The risks to lives and livelihoods could well be immense, with potential loss of life on a very large scale.

Delay is dangerous. There is a ratchet effect of GHG concentrations, where flows of GHGs from human activity are continually added to the existing stock of GHGs present in the atmosphere; carbon dioxide is long lasting. The influence of increased concentrations can last for many centuries. The building of high-carbon assets, for example, coal-fired power plants, can lock in high emissions for decades. If action is delayed then it can become very costly to get back on track, which would include substantial scrapping of high-carbon capital. Doing so, although it would be necessary to manage climate change, would be likely to run into intense reaction from those with vested interests in such capital.

A target to limit warming to 2°C above pre-industrial times was internationally agreed at Cancún. It was accepted by the scientific community as the temperature above which climate change should be seen as "dangerous," in part because of the uncontrolled cumulative effects, feedbacks, and tipping points that could occur. That limit, already significantly beyond our experience in the Holocene, still seems wise.

---

[4] See, for example, IEA (*World Energy Outlook 2012* and *World Energy Outlook 2013*); Stern (2013); Rogelj, Meinshausen, and Knutti (2012).
[5] See the National Oceanic and Atmospheric Administration (NOAA) Global Surface Temperature Anomalies, available at: www.ncdc.noaa.gov/cmb-faq/anomalies.php.
[6] See Marcott et al. (2013) or Alley (2004) for anomalies in last 8,000 or more years ago, NOAA (2014: www.ncdc.noaa.gov/cmb-faq/anomalies.php) for anomalies in last 100 years.
[7] See, for example, Zachos, Dickens, and Zeebe (2008).
[8] Stewart and Stringer (2012). See also http://www.worldmuseumofman.org/hum.php.

There are some who try to argue that they recognise the basic science but that we cannot go as fast as a 2°C target requires and that it should be relaxed. Such arguments usually, deliberately or otherwise, embody three assumptions: that the dangers of delay are modest; that learning processes are slow; and that policy can or should proceed gradually. In my view all three are mistaken. I have explained the dangers of delay above. The story of discovery, learning and growth is set out in section 3. The argument that policy can proceed gradually not only overlooks the dangers of delay but also risks giving mixed signals about the strength of policy commitment, creating additional uncertainty and reducing investment.[9]

The window to limit temperature increases to 2°C is still open, but is closing rapidly. Urgent and strong action in the next two decades, with global, deep and economy-wide progress this decade, is necessary if the risks of dangerous climate change are to be radically reduced. Indeed strong, clear policies are likely to lead to strong investment and innovation and rapid learning and discovery. Until now, the overall pace of emissions reductions has been dangerously slow. While current emissions reduction commitments represent a significant deviation from what might be described as business as usual, they are not on a sufficient scale to be consistent with the reduction in emissions required for managing climate change responsibly in the sense of a reasonable (say, 50-50) chance of limiting global temperature increases to 2°C. Nevertheless, in much of the world (but not all), there are signs that the pace could pick up. The challenge is to accelerate that process. An international agreement in Paris in 2015 would be a crucial factor.

2. Changes since the Stern Review

There have been a number of important areas of progress since I wrote *The Stern Review* in 2006.[10] It argued that the costs of inaction on climate change far exceed the costs of action. On policy it pointed to GHG emissions as the greatest market failure the world has seen. Both conclusions stand, indeed stand still more strongly. I would now strengthen still further the

[9] There are some who continue to suggest that the science is wrong. Their numbers are reducing but are still of some significance. They should go to their scientific societies, such as the US National Academy of Sciences or the UK Royal Society. They will find the arguments set out clearly by those with the skills and expertise to evaluate the evidence (see for example Royal Society/National Academy of Sciences (2014) Yet, if they have new evidence or serious scientific argument to show the received science is wrong, they should publish in the scientific journals right away. In any case, given the potential scale of risks and the dangers of delay, those who doubt the science must show that, notwithstanding two centuries of scientific study and evidence, they are very confident the risks are small. Few have the honesty to express their position in the form the argument for inaction requires.

[10] And in book form in 2007. See Stern (2007).

emphasis on, first, the importance of understanding the problem as the management of immense risks (thus going beyond narrow cost-benefit analysis) and, second, on the dynamics, discoveries and attractions for the low-carbon growth path. An attempt at an old-style high-carbon path would not be sustainable as a result of the very hostile environment it would create, with strong risks of undoing and reversing the advances in development over the last century.

Science

The science is still more worrying because emissions are higher than anticipated, some effects are coming through more quickly than foreseen, and factors omitted from many models, such as thawing permafrost and release of methane, look still more threatening. We have had the opportunity to take account of the very valuable fourth (2007) and fifth (2013/14) assessment reports of the IPCC,[11] both published since *The Stern Review*, with demonstration of the relentless building of evidence on the great risks of unmanaged climate change.

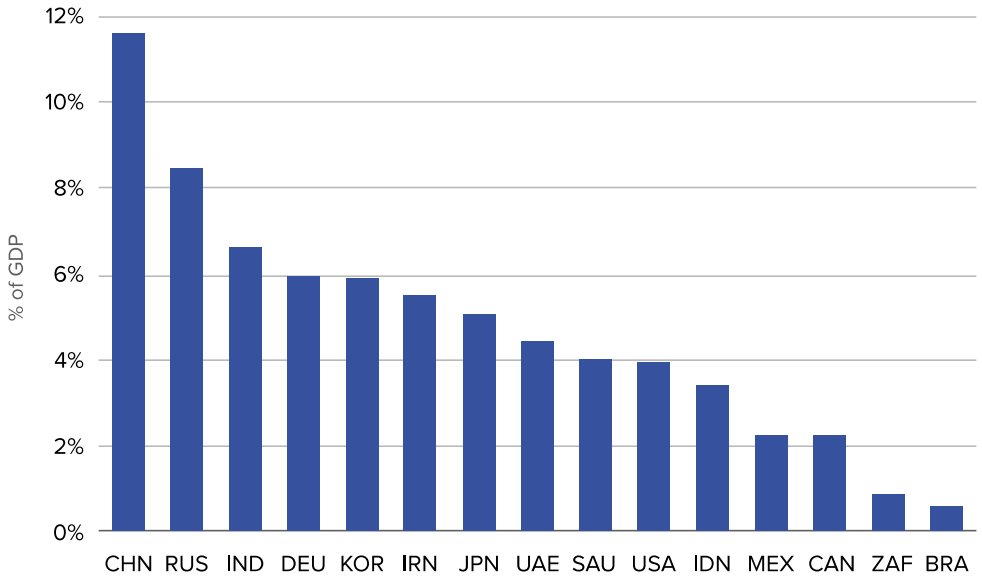
Health and costs

The health consequences of burning fossil fuels are coming through very strongly. Satellite data in the last few years have shown how pervasive are particulates from using hydrocarbons and the World Health Organisation (WHO) has shown the scale of potential mortality consequences. New analysis on the basis of these data suggests that the pollution costs of coal- and diesel-based energy (the main source of particulates) may already be 5% of GDP in many countries: the costs of mortality from particulate matter PM 2.5 alone, have been estimated at more than 10% of GDP per year for China and 6% for Germany, for example.[12] The low-carbon transition is likely to be a cost-effective way of tackling them.

[11] See http://www.ipcc.ch/report/ar5/.

[12] See Hamilton (2014), where health damage from air pollution averaged above 4% of GDP in the 15 largest CO_2 emitters in 2010.

Figure 1: Value of the premature deaths from PM2.5 air pollution as a percentage of GDP. Note: PM2.5 are particulate matter measuring 2.5 micrometres/microns in diameter or less (PM2.5) which can penetrate deep into lungs and bloodstreams unfiltered. Source: Hamilton (2014: footnote 12).



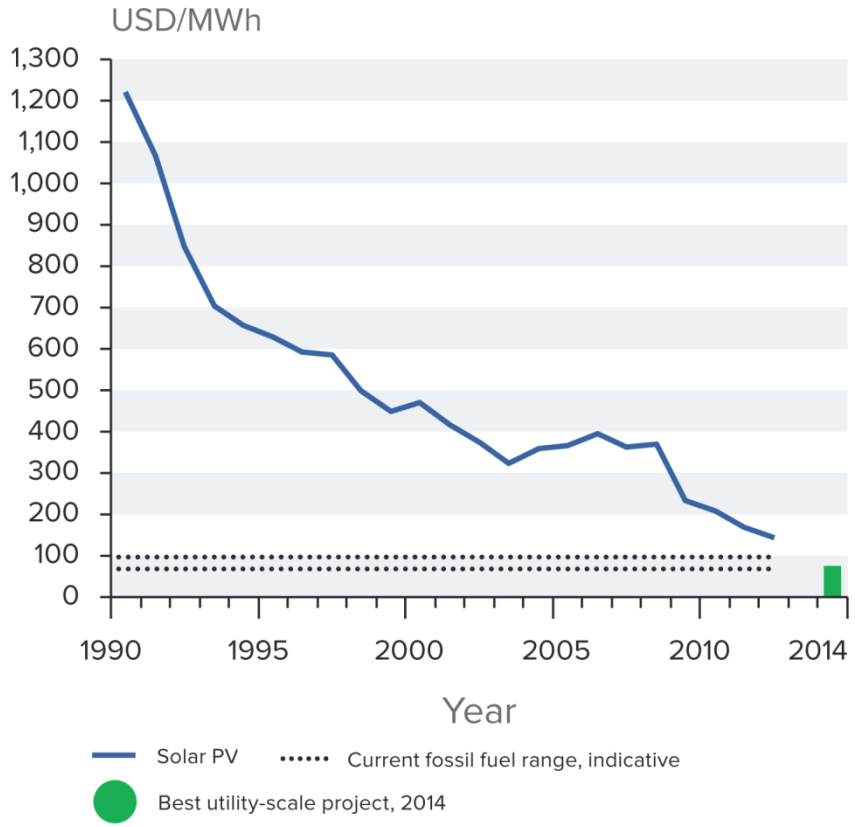
Action to reduce emissions can have health benefits beyond the very important reduction of particulates. Better city planning, public transport, walking and cycling infrastructure and urban green spaces provide more healthy lifestyles. They can also reduce congestion and urban air pollution, and improve mobility and the efficiency of travel, thus saving time and creating a more appealing urban environment.

Technology

Technology has moved far faster than would have been anticipated. Examples include solar, wind, building and insulating materials, techniques for managing energy and increasing efficiency, including information technology, electric, hybrid and hydrogen vehicles, LED and other lighting, energy storage, and so on. For example, in solar photovoltaic (PV) particularly, prices of delivered energy are now 80-90% less than 2007 (see Figure 2). Al Gore suggests that the technology is competitive with delivered grid electricity in 79 countries.[13] The International Energy Agency has also shown very widespread competitiveness.[14]

[13] Gore, A. (2014).
[14] IEA (2014).

Figure 2: Solar PV cost of energy compared with current reference case of fossil fuel generation.[15]



We are seeing strong advance in battery storage technologies which could help balance the variable nature of renewable energy generation. The first large-scale 5 MW battery storage installation occurred this year in Berlin.[16] Most major multinational car producers are now developing electric vehicles as battery storage and infrastructure become increasingly commercial. In part this has been helped by industry leader, Tesla Motors, which plans to mainstream the technology and produce some 500,000 vehicles per year by 2020. This is in addition to releasing all their electric vehicle patents to the public: the CEO and founder, Elon Musk argued that all car companies would "benefit from a common, rapidly-evolving technology platform".[17] These changes have transformed cost comparisons with conventional alternatives, unlocked investment opportunities, and unleashed further waves of innovation and discovery. Strong progress is being made in storage in other ways, including via molten salt.

[15] GCEC (2014).
[16] Berlin-based grid and storage company, Younicos AG, recently installed Europe's first and largest battery power plant. The 5 MW lithium-ion unit benefits from a 20 year performance guarantee from the technology provider that addresses the perception that the technology is risky. See http://www.younicos.com/en.
[17] Musk (2014).

I now see the story of alternative low-carbon paths as still more exciting and full of opportunity, given the coming together of phenomenal technical progress and the structural transformations of the world economy, discussed below. Thus I would place still more emphasis on a Schumpeterian interpretation of learning, rapid technological change and radical change in structure. This embodies a still more dynamic and structural approach to growth and development than in *The Stern Review*.

Politics

Assessments of changes in the politics of climate change since 2006 depend on where you look. In some respects, the international discussion is more mature, with an improved sharing of assessments and principles for international action. I focus briefly and particularly on China, the USA and Europe, which together account for around half of global emissions.

Of particular and profound importance is the change during this time in the policies and plans of China, by far the world's largest emitter. It overtook the US to become the number one emitter around the time *The Stern Review* was published. China with its dependence on water from the Himalayas, intense water scarcity in many parts of the country, and dense population on coasts is very worried about climate change. It recognises that others focus on what happens in China and is understandably concerned about water, air pollution, and energy security. At the same time China is becoming ever stronger in developing affordable sustainable and renewable energy technologies.

The joint announcement on climate change (a few days after the Sciences Po lecture was delivered) from US-China (12 November 2014) demonstrates real leadership in the run up to the Paris climate conference next year. China has said that it will make peak emissions by around 2030, and earlier if possible, and the USA has committed to 26–28% reductions on 2005 levels of emissions by 2025. Both will work to exceed targets. With strong commitment, progress and discovery may well be more rapid than currently anticipated. We should note that all of USA, China and Europe look likely to achieve their 2020 Copenhagen-Cancún commitments.

As I said in my press release commenting on that announcement:[18] "[China and the US] have together recognised the global importance of the need to avoid the risks of dangerous climate change, and the many benefits of the transition to low-carbon economic growth and

[18] See http://www.lse.ac.uk/GranthamInstitute/news/comment-by-nicholas-stern-on-china-united-states-joint-announcement-on-climate-change/.

development. This very significant and valuable joint announcement should add further momentum towards an international agreement on climate change, which is due to be finalised in Paris in December 2015."

At its meeting of the European Council of 23/24 October, the Prime Ministers and Presidents of the EU reaffirmed their commitment to domestic action on emissions with a target of 40% reductions 1990-2030 and 27% of energy from renewables by then. There has been some wavering in Europe over the last few years, in part as a result of the economic crisis. Also the radical reduction in solar and wind energy costs made some feed-in tariffs look generous (a problem of success, of course). At the same time, some countries, particularly Germany, have turned away from nuclear. Notwithstanding some wavering, Europe remains committed to action.

Looking back, I think historians may see missed opportunities for further action because of distractions from the economic crisis, slow-down and recession. We should be investing when interest rates are low and many resources remain unemployed. However, rates are still low—and there are many unemployed resources. The opportunities for action continue. A slow-down is the time to invest in the growth story of the future.

There is a long way to go before a strong international agreement can be established. Of course, time does not stand still while international discussions take place. There has been real progress in a number of countries beyond the three geographical areas discussed. Yet national commitments across the world still fall a long way short of the goal of cutting GHG emissions sufficiently to give a reasonable chance of avoiding a rise in average temperature of more than 2°C above its pre-industrial level. Progress could be greatly accelerated by a strong international agreement.

3. An alternative growth path is not only possible but attractive

Many still seem to be talking and acting as if change is too difficult and costly and as if delay is not a problem. Yet we can now see that the transition to a low-carbon economy can be highly attractive, embodying strong and high quality growth, driven by strong investment and innovation. When placed in the context of profound global structural transformation (in urbanisation, energy systems and land use, see below) and when health, energy security, eco-system and other co-benefits are taken into account, the bulk of investments will show positive

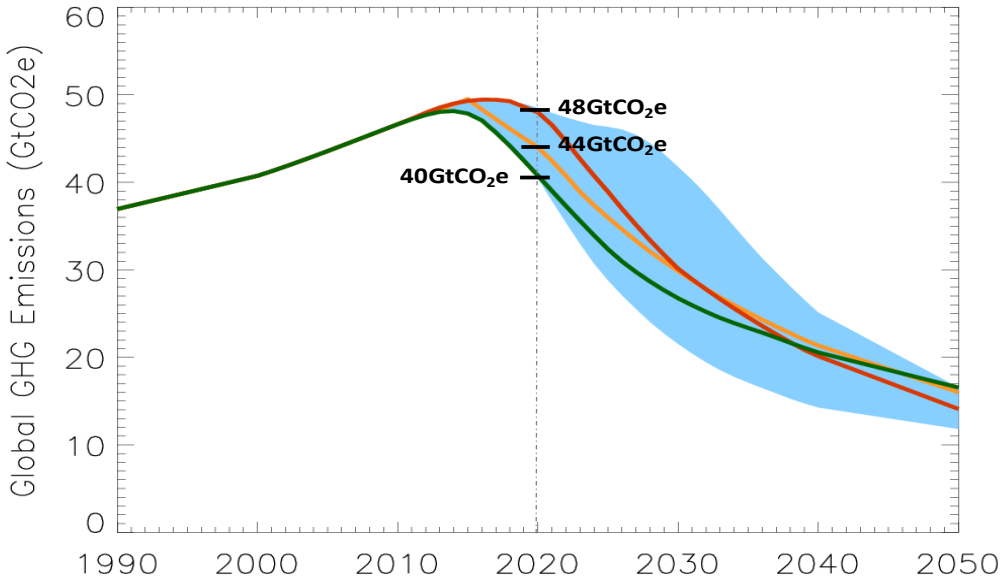
returns to the country making them before taking account of the fundamental climate benefits. The combination of the transition to the low-carbon economy and the structural transformations in train thus represent a great opportunity. These were the basic conclusions of the report by the Global Commission on the Economy and Climate (GCEC)[19], chaired by President Felipe Calderon (former President of Mexico) and co-chaired by myself. The Commission was around one-third business leaders, one-third former PMs, Presidents, and finance ministers; a group experienced in real economic decisions.

Let us first look at the pace and scale of change necessary in the transition to the low-carbon economy. Staying below 2°C with reasonable probability requires an emissions path with the peaking of global emissions, declining from approximately 50 billion tonnes of GHGs (CO_2 equivalents – CO_2e) today to approximately 35–40 $GtCO_2e$ by 2030, less than 20Gt by 2050, and net-zero or negative emissions within the second half of this century. The weaker the action now the stronger it would need to be later. For example, with strong assumptions about the ability to go to zero or negative emissions in the second half of the century, the 35 $GtCO_2e$ in 2030 might be raised to around 42 $GtCO_2e$.[20] Negative emissions would require, for example, strong expansion of forests and regarding of degraded land, carbon capture and storage from the use of bio-fuels (created appropriately), or chemical or other extraction of GHGs from the atmosphere.

Figure 3 illustrates a range of feasible paths we could follow that are consistent with at least a 50–50 chance of holding temperature increase to 2°C. The message is the same in all: for that objective the emissions trend needs to change rapidly.

[19] Chaired by Felipe Calderón (President of Mexico until late 2012) and co-chaired by myself. See GCEC (2014).
[20] That is the approximate "target" emissions used by the Global Commission on the Economy and Climate, drawing on the IPCC report (2014), but it does make strong assumptions about zero or negative emissions towards the end of the century (GCEC, 2014).

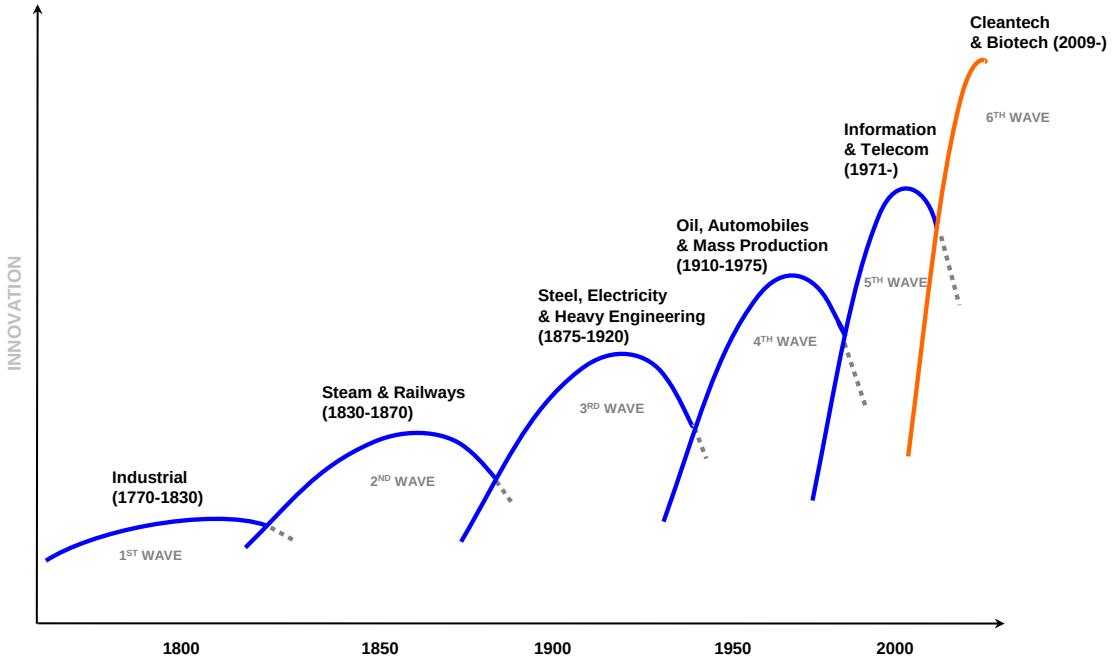
Figure 3: Paths for global annual emissions that lead to a reasonable chance of a temperature rise of no more than 2°C. Note: the shaded area represents the range of emissions paths that are consistent with a commonly-regarded (50–50) chance of the 2°C goal, and the three lines show specific paths within this range.[21]



If we were to assume approximately 3% global growth per year until 2050, emissions per unit of output must fall by a factor 7 or 8 in that time (a factor of 2.5 for absolute emissions reductions multiplied by a factor of around 3 for the growth of the economy). The scale of change associated with this pathway would essentially imply a new energy-industrial revolution, involving a wave of innovation, discovery, creativity and investment. The investment, innovation and growth could be similar to those of the railways or electricity in earlier waves of technological change (see Figure 4). Past examples of such waves have been associated with two or three decades or more of strong investment, innovation and growth. With rising resource efficiency, clean and smart infrastructure, and strong innovation, the transition to the low-carbon economy promises to deliver a period of very attractive and robust growth: cleaner, quieter, safer, more energy-secure, more bio-diverse, more inclusive, and with more liveable cities and stronger communities.

[21] Results are based on Hadley Centre climate model IMAGICC. Source: based on Bowen and Ranger (2009).

Figure 4: Waves of innovation.[22]



To get there, the GCEC report focuses on the crucial first part of the transition, specifically investment over the next 15-20 years, and sets it in the context of the great structural transformation in train in urbanisation, energy systems and land use. The report identifies and analyses key areas which are core to the processes of the low-carbon transition and the structural transformation: the design of new cities and renovation of existing ones to support the rapid and widespread urbanisation that is in train; radical changes in the ways we produce and consume energy including the construction and refurbishment of energy systems; and how we manage our natural resources including our land and forests.

This timeframe is crucial because if the next two decades are managed well, a strong platform could be created and driving forces unleashed for discovery and emissions reductions over the coming decades. If the opportunity is not taken, the challenge of holding to 2°C will be much more difficult and costly. We would lock-in high-carbon capital and infrastructure. The proposals outlined in the GCEC report focus on the three key areas described and on resource efficiency, infrastructure and innovation as drivers of change in all three areas. They do not constitute a rigid plan but a path of growth and discovery which give a strong and sustainable future of continued growth and poverty reduction.

[22] Source: DONG Energy (2009); diagram based on Merrill Lynch (2008), drawing on a report by Perez (2002).

Over the next two decades or so the world output will likely approximately double, there will be a surge of population into the cities, world population will rise from 7 billion to more than 8 billion, and the future of the world's forests and land areas will be profoundly shaped as population and incomes rise. The rapid shift of economic activity from developed countries to emerging and developing countries will also continue. In 1985 the developed-country proportion of world output was around two-thirds and it is now less than half (at purchasing power parity). Twenty-five years or so from now it will likely be around one-third. These changes constitute the fundamental transformation that provides a crucial context and opportunity for the transition to low-carbon growth.

We are at a fork in the road. Two remarkable processes are occurring simultaneously over the next two decades: profound structural transformation of the world's economies, and the transition to the low-carbon economy. If the former is managed well over the next two decades, in relation to congestion, efficiency, pollution and care of our land and natural resources, then we will do much of what is necessary for the latter and we will create sound foundations for the low-carbon transition which must proceed strongly throughout this century. That these two periods coincide presents both opportunity and time for decision: an opportunity we can use or lose.

4. The agreement should be based on a shared commitment to creating "equitable access to sustainable development"[23]

Tackling climate change, overcoming poverty, and promoting growth and development all require collaboration amongst peoples and nations. They require action over the short, medium and long term. Sustaining the collaboration and commitment will in turn require some understanding and belief that all, or at least most, countries and groups are playing their part and that the strategies, actions and outcomes are designed and carried through in a manner and spirit that is equitable.

In thinking about the meaning of tackling climate change equitably, we must confront both the inequity of the past, and the reality of the present and future.

[23] This section is based on a chapter in my forthcoming book: *Why are We Waiting?* MIT Press (2015) — the Lionel Robbins Lectures.

Climate change is a deeply inequitable phenomenon. It is inequitable in its origin: developed countries, with around 1/7 of the global population, have been responsible for around half of global emissions since 1850. And it is inequitable in its impacts: poor people tend to be hit earliest and hardest by the impacts of climate change, and have fewer resources to deploy for adaptation. These facts are surely morally significant, and, in my view, place a responsibility on rich countries to play a leading role in reducing emissions. But they are also politically significant, since responses to climate change that are not perceived to be equitable are unlikely to be accepted, in particular, by developing countries.

We must also confront the reality of the present and the likely future: that developing countries are now responsible for the majority of current emissions (though their emissions per capita are still on average only about one third to one half of those of rich countries[24]) and they will be responsible for the big majority of future emissions. Emissions from all sources must come down if we are to avoid the grave risks of climate change associated with much higher temperatures.

Given all of these facts, how should the world collaborate in its approach to the task of reducing emissions, both generally, and specifically in the context of developing a new agreement in Paris 2015? What would constitute an equitable response?

In the past, a failure to understand the scale and nature of the necessary response to climate change, and the process of dynamic learning which must be at its heart, has distorted the ethical, economic and political discussion. In particular, a narrow formulation of the basic production processes, which models a transition to lower-carbon activities as simply switching to technologies with higher costs, leads to a framing of the discussion in terms of a permanent sacrifice of living standards to protect the environment. It thus pushes the ethical questions toward "Who bears the incremental cost?" and can lead to a presentation of the issues as being largely about "burden-sharing". But we know in economics that confining equity discussions only to the division of a pie can miss fundamental issues about the growth of the pie and dimensions beyond those captured in the "pie".

The challenge of managing climate change is absolutely not equivalent to dividing up a given pie. As I have argued, to tackle climate change wisely is to provide not only radical reduction in

[24] IPCC (2014, Chapter 1, Figure 1.4) shows that low income and lower-middle income countries' per capita emissions were around one-third of high income countries' in 2010; upper-middle income countries' per capita emissions were around half of high income countries'. China's emissions per capita are likely already similar to EU levels.

climate risks but also an attractive transition to low-carbon growth. It is the route that allows us to tackle the two defining challenges of this century: overcoming world poverty and managing climate change. We have to both see these as the defining challenges and recognise that the transition to lower-carbon growth allows us to rise to both challenges. An attempt at the high-carbon route will eventually fail on both.

The ethical issues must still be centre-stage but they look very different and much less vexing if we carry the understanding of the nature of the objectives and of the problem into the analysis: on the one hand, this is about externality, market failure, and inefficiency on a massive scale, and, on the other, the response is about discovery and co-benefits in terms of a more inclusive, secure, safe, clean, and biodiverse way of consuming and producing. There will be initiatives to be launched, investments to be made, and costs to be borne, and the questions of who does what and when matter greatly. But to focus relentlessly and narrowly on the notion of burden-sharing risks distorting and undermining both understanding and agreement. At the same time, an understanding both of the origins of the problems of climate change, their potential impacts and the challenge of world poverty requires ethics and equity at centre-stage.

We have seen that there is a way, different from burden-sharing, of understanding the transition which is both more accurate and more positive. This focuses first on the dynamic nature of the low-carbon transition and its coincidence with a wider set of structural transformations occurring in the global economy, and second on the co-benefits of new and cleaner technologies over and above those associated with reduced emissions — both of which are discussed above. Understanding the transition in this way shows strongly that much of what is necessary on the low-carbon front is also very good for growth, development and poverty reduction. If the great structural transformations are managed well, then much of what is necessary for the low-carbon transition can be achieved. Clearly this is not a zero-sum game. The processes of structural transformation and low-carbon transition will go much better with collaboration on the basis of these understandings, and if all are involved, to the benefit of all.

The dynamic nature of the low-carbon transition, and the fact that costs, benefits and their distribution depend strongly on the paths followed and what is learned along the way, makes it very difficult, and perhaps misleading, to assign a specific “net cost” to reducing emissions in a given country at a given time. This reality does not do away with the need for ethics and it does not do away with the importance of keeping a close eye on costs and waste in economic activity, but it does influence how the equity discussion should be framed: the focus should be on how

growth, poverty reduction and the necessary energy-industrial revolution can be fostered in an equitable and sustainable way. Thus the approach is dynamic and potentially collaborative.

We must now begin the process of turning this overall perspective, with its greater accuracy in portrayal of the problems and its potential advantages in finding agreement, into practical propositions.

A promising way forward is to embrace the twin ideas of (i) rich countries embarking on a dynamic and attractive transition to the low-carbon economy in their own economies, involving strong and early emissions cuts, and strong examples, and (ii) supporting developing countries, with finance, technology and know-how, to undergo a transition, along a sustainable development pathway of their (the developing countries') choosing, shaped by their own characteristics and endowments. In other words, it is to give life to the idea of "equitable access to sustainable development" (EASD) proposed by India and adopted in the UNFCCC agreement at COP16 in Cancún in December 2010.

This is not the place to set out the specifics in detail. Much is contained in the recommendations of the GCEC report *Better Growth, Better Climate*. I take the ideas further in my forthcoming book, *Why are We Waiting?*, which is based on my Lionel Robbins Lectures and will be published by MIT Press in Spring 2015.

Making the idea of EASD, which is already in the Cancún agreement, central and more substantive, could provide the basis to bring people and countries together, to achieve the fundamental goals of development and climate change mitigation and adaptation. If we, as a world, can do this well, we would be doing the right thing morally, and we would bring people together in a much more collaborative way than simply arguing over the distribution of a fixed "burden" of cutting emissions. It is interesting to relate this concept to "Common but Differentiated Responsibilities" (CBDR). In my view EASD includes CBDR as a narrow particular, and rather static, case. It extends it powerfully in a dynamic direction. The language and concepts of EASD with the words and ideas of equity, sustainable, and development carry dynamism and collaboration. The language and concepts of CBDR, with "but" and "differentiated" look more static and divisive. And as such are likely to lead to more modest ambitions. Let me be clear, I am advocating broadening and deepening ideas of equity to fit better with the dynamism of the issue at hand; and in that sense enhancing the ideas and values behind CBDR. At the same time, surely "ambitious, dynamic and collaborative" is to be preferred to "modest, static and divisive".

5. The agreement should be structured to facilitate dynamic and collaborative interactions between parties[25]

International agreements on climate change should be structured so as to facilitate the kind of collaboration needed to achieve mutual confidence and equitable access to sustainable development. They should be dynamic in the sense that countries' ambitions for emissions reductions can be encouraged by, and captured in, international processes and in ways that promote increased ambition over time.

The UNFCCC negotiations leading up to Paris have been organised on the basis that each country or region will determine their own contribution to the global climate mitigation effort. Countries have been encouraged to submit their "Intended Nationally Determined Contributions" (INDC) by the end of the first quarter of 2015, so that countries can examine and reflect on what others are doing and proposing. This more decentralised approach to mitigation is predicated on an understanding that different countries have different motivations and capacities for reducing emissions, and different means of achieving those emissions reductions. The idea is that, as the technology, economics, and politics of mitigation become more favourable over time, countries will be able to increase their ambition.[26]

This more decentralised approach seems likely to lead to more ambitious commitments from many key countries. A number of large emitting countries are likely to moderate their ambition or participation in international agreements where they perceive the potential for sanctions or reputational damage if they fail to meet them. Conversely, they may be more likely to pledge more ambitious commitments in the absence of perceived sanctions or damage. This argument may well apply to both the US and China, which jointly announced their contributions at the conclusion of the APEC summit in Beijing on November 12th, 2014. China announced that their emissions would peak by around 2030 and the USA that their emissions would be reduced by 26-28%, comparing 2025 with 2005. Were such pledges to be internationally "legally binding" and subject to centralised enforcement measures, China would have likely been reluctant to name a peaking year for its emissions. The US would effectively be unable to participate in an international agreement where the emissions targets themselves constituted a legally binding

[25] This section is based on Stern (2014).
[26] For a developed country expression of this position, see: Government of United States (2014); Stern, T. (2014).

obligation under international law, since the Senate would have to approve ratification by a two-thirds majority, which is most unlikely in the foreseeable future. The leaders of the countries of the European Union decided at the European Council of 23/24 October 2014, to reduce emissions by 40%, 1990-2030 on the basis of domestic action.

Some may fear that commitments that are not internationally legally binding may lack credibility. That, in my view, is a serious mistake. The sanctions available under the Kyoto Protocol, for example, were notionally legally binding but were simply not credible and failed to guarantee domestic implementation of commitments. Canada's penalty for failing to achieve its target was to do more in the second commitment period. However, Canada simply withdrew from the Protocol and avoided that sanction altogether. Institutional and legal measures at the domestic level, which are actually capable of being implemented and enforced, are a better guide to the credibility of a country's international commitment. China uses its planning structures to implement policy. Its five-year plans have legal force and its leaders are judged by their ability to deliver on them. The EU has its own legal structures which, though unwieldy at times, are credible. And the US is pursuing its emissions goals through regulation with legal force in large measure through the Environmental Protection Agency (although we should recognise that there are also strong actions at the state and city levels). We should recognise that all of the USA, China and the EU are on track to meet their 2020 targets agreed at COP16 in Cancún, in Mexico, 2010, even though these are not internationally legally binding.

A new international climate agreement could foster a stronger focus on domestic structures for implementation by requiring countries to explain how their proposed contributions will be implemented and achieved, to commit to implement them in domestic law, and to indicate which of their domestic commitments will be subject to monitoring, reporting and verification (MRV) at the international level. The new agreement could also contain strong, centralised institutions and rules for MRV. In light of the greater focus on the domestic implementation of international commitments, it will become increasingly important for international MRV institutions to capture information about not only countries' emissions, but also about their policies, measures and institutions to reduce those emissions, which would be based standards and processes that have been built over many years through the UNFCCC. Moreover, the new agreement could contain a review and revision mechanism to encourage countries to increase the ambition of their commitment at regular intervals (e.g. every five years).[27] These MRV institutions and the regular review mechanism are of particular importance because it seems

[27] GCEC (2014); Morgan et al. (2014).

likely that initial INDCs put forward in 2015 for the period to 2030 are likely to fall substantially short of what is necessary for a path consistent with a reasonable chance of holding to 2°C.

Thus, it is possible to have a "hybrid" international framework that mixes binding and non-binding, centralised and decentralised elements, so that the substance of parties' contributions is a matter for their individual determination. However, there could be dynamic processes to enable ambition to scale-up over time and mechanisms that bring countries together to better understand one another's contributions, capacities and needs. And, while this discussion has focused on mitigation, the embodiment of EASD in any new agreement would require that the agreement contain methods to promote increasingly ambitious efforts toward adaptation, and also flows of support from developed to developing countries, including finance and technology.[28]

There is a crucial question concerning the potential pace of emissions reductions which might be embodied in the discussion in section 4, on EASD, and, in this section, on the Paris agreement. The processes described for building an understanding of, and action on, EASD and constructing a Paris agreement which recognises a likely substantial gap between the emissions reductions necessary for 2°C and what is intended by countries, might seem inconsistent with the necessary global early peaking of emissions and the subsequent rapid reduction.

The first part of the response to this question is that unless we recognise both the equity issues, I have argued EASD as a possible route, and the political realities of how decisions are built domestically and internationally, then we will not have agreement. That would be the slowest and most dangerous of outcomes. A second part is that if we do move forward on the basis described we can embark on two decades of strong innovation, collaboration and discovery which could lay the foundations for rapid acceleration thereafter. The third part is that we must keep in mind throughout the agreement and in the next two decades of innovation and discovery, the magnitude of the risks and the requirement for acceleration of emissions reductions so that the processes can create the acceleration that will be necessary. It seems much wiser to go down a route which yields some chance of success than one which yields no chance.

[28] See Morgan et al. (2014) for a discussion of how a new international agreement could facilitate the mutual interaction between three interdependent "cycles of continuous improvement" in mitigation, adaptation, and support.

Conclusion – potential for a strong agreement

I am optimistic about what the world could do if decision-making were to be wise, collaborative and committed. We do, or should, understand that the risks are immense. We can see the scale of reductions necessary to give a reasonable chance of holding temperature increases to 2°C. We can now recognise the growth potential of the transition to the low-carbon economy, particularly in the context of the great structural transformations that are taking place in the world economy. And we understand the economic policies that can set us on that road, including carbon pricing and regulation, support for innovation, and fostering long-term finance.

Will we have the wisdom to do this? Will we have the commitment and resolve? Will we be able to collaborate in the right spirit? I hope so, but we cannot be sure. The road to Paris must be trod constructively and creatively. We are already seeing promising signs such as the joint announcement by the US and China in Beijing in November 2014 and the decision of the European Council a few weeks before. Together these cover around 50% of world emissions. These decisions are important and substantive steps in a sensible direction and suggest seriousness about a strong agreement in Paris in 2015. Taken together, they do not yet constitute the world being "on track" for a 2°C path, but all involved are discussing the possibility of raising ambition on emissions reductions.

The current structures for an agreement being formulated by those involved in, and who are advising, the discussions and negotiations on the road to Paris make sense. The approach of making processes binding internationally and numerical targets for emissions reductions binding domestically is pragmatic and sensible.

If we share an understanding of the four propositions set out above in the introduction, which were the subject matter of this lecture, then I think we could have the foundation of an agreement. If we proceed as I have tried to describe in a way that sees discussions and the agreement itself as ambitious, dynamic and collaborative, then we have a real chance of a strong agreement in Paris.

Once again, I am very honoured to have been asked to give the inaugural lecture in the series *Make it Work*. I have confidence in the skills, talents and judgement of those who have been charged with the great responsibility of guiding the journey to Paris 2015 and building the agreement. That journey is in good hands.

References

Alley, R.B. 2004. "GISP2 Ice Core Temperature and Accumulation Data". World Data Center for Paleoclimatology Data Contribution Series. National Oceanic and Atmospheric Administration (NOAA)/NGDC Paleoclimatology Program, Boulder CO, USA.

Bowen, A., and N. Ranger. 2009. "Mitigating Climate Change through Reductions in Greenhouse Gas Emissions: The Science and Economics of Future Paths for Global Annual Emissions." Policy brief, Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment, December.

DONG Energy. 2009. "Rethinking Energy." Presentation at Ascent Business Leadership Forum 2009, 22 October.

GCEC [Global Commission on the Economy and Climate]. 2014. "Better Growth Better Climate: The New Climate Economy Report (Global Report)." Washington, D.C.: New Climate Economy. Available at: http://newclimateeconomy.report/.

Gore, A. 2014. "The Turning Point: New Hope for the Climate." Rolling Stone Magazine. Available at: http://www.rollingstone.com/politics/news/the-turning-point-new-hope-for-the-climate-20140618.

Government of United States. 2014. "US Submission — September 2014". Submission to UNFCCC/ADP. Available at: http://unfccc.int/files/bodies/awg/application/pdf/us_submission_fall_2014_final.pdf.

Hamilton, K. 2014. "Calculating PM 2.5 Damages for Top Emitters: A Technical Note." Global Commission on the Economy and Climate (New Climate Economy) background note. http://newclimateeconomy.net.

International Energy Agency (IEA). 2014. "Technology Roadmap Solar Photovoltaic Energy." IEA/OECD Paris.

IPCC [Intergovernmental Panel on Climate Change]. 2014. "Fifth Assessment Report: Working Group III (Mitigation of Climate Change)." Geneva: UNEP/WMO. Available at http://www.ipcc.ch/report/ar5/.

Marcott, S. A., J. D. Shakun, P. U. Clark, and A. C. Mix. 2013. "A Reconstruction of Regional and Global Temperature for the Past 11,300 Years." Science 339: 1198–1201.

Merrill Lynch. 2008. "The Sixth Revolution: The Coming of Cleantech Clean Technology." Industry Overview. Online at: www.responsible-investor.com/images/uploads/resources/research/21228316156Merril_Lynch-_the_coming_of_clean_tech.pdf.

Morgan, J., Y. Dagnet, and D. Tirpak. 2014. "Elements and Ideas for the 2015 Paris Agreement". ACT 2015 and World Resources Institute Working Paper (forthcoming).

Musk, E. 2014. "All Our Patent Are Belong To You" [press release 12 June 2014]. Available at: http://www.teslamotors.com/blog/all-our-patent-are-belong-you.

Perez, C. 2002. "Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages." Cheltenham, UK: Edward Elgar.

Rogelj, J., M. Meinshausen, and R. Knutti. 2012. "Global Warming under Old and New Scenarios Using IPCC Climate Sensitivity Range Estimates." Nature Climate Change 2: 248–253.

Royal Society/National Academy of Science. 2014. "Climate Change: Evidence & Causes." The Royal Society and the US National Academy of Science. Available at: https://royalsociety.org/~/media/Royal_Society_Content/policy/projects/climate-evidence-causes/climate-change-evidence-causes.pdf.

Stern, N. 2007. "The Economics of Climate Change: The Stern Review." Cambridge: Cambridge University Press.

Stern, N. 2013. "The Structure of Economic Modeling of the Potential Impacts of Climate Change: Grafting Gross Underestimation of Risk onto Already Narrow Science Models." Journal of Economic Literature 51: 838–859.

Stern, N. 2014. "Ethics, Equity and the Economics of Climate Change Paper 2: Economics and Politics." Economics and Philosophy 30 (03). DOI: http://dx.doi.org/10.1017/S0266267114000303.

Stern, T. 2014. "Seizing the Opportunity for Progress on Climate". Remarks by Todd D. Stern, U.S. Special Envoy for Climate Change. Yale University, New Haven, CT.

Stewart, J. R., and C. B. Stringer. 2012. "Human Evolution Out of Africa: The Role of Refugia and Climate Change." Science 335: 1317–1321.

Zachos, J. C., G. R. Dickens, and R. E. Zeebe. 2008. "An Early Cenozoic Perspective on Greenhouse Warming and Carbon-Cycle Dynamics." Nature 451: 279–283.