Lecture 3 – Keeping global warming well below 2°C: six priorities

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In Lecture 1, I set out an optimistic story about the technologies which can enable us to limit climate change while growing prosperity, but with an important distinction between three sectors of the economy: **[Exhibit 1]**

- Buildings, road transport and light industry, where electrification and power decarbonisation will enable us to eliminate at least 60% of emissions at negative eventual cost to consumers.
- Long distance transport and heavy industry, which together account for around 20% of emissions, where electrification is more difficult and in some case is impossible, and where decarbonisation will increase costs.
- And food and agriculture, accounting for another 20% of CO_2 equivalent emissions, and by far the most difficult sector because of the inherent inefficiencies of photosynthesis and animal protein production.

Overall, I hope I left those of you who were at Lecture 1 optimistic – enthused by the long-term potential for abundant clean energy for all.

In Lecture 2, however, I talked about political and economic challenges which could prevent us decarbonising fast enough to limit global warming to manageable levels **[Exhibit 2]**. I described three reasons why the transition to a zero-carbon economy is far from costless.

- First, the investments needed to build a zero-emissions economy, investment which must in some way be at the expense of somebody's current consumption.
- Second, the cost of going fast enough to keep global warming well below 2°C, and in particular the challenge of legacy assets.
- Third, distributional challenges, winners and losers, both within and between nations.

And I ended with a focus on China, which is simultaneously the biggest global emitter, the dominant developer of the technologies which enable us to reduce emissions, but also a huge threat to the competitiveness of European industry.

Given those challenges, I suspect I left those of you who attended Lecture 2 somewhat less optimistic than after Lecture 1, but I promised that Lecture 3 would lift you up again – setting out a still credible path to limit global warming to well below 2°C.

So that is what I will attempt this evening.

Keeping global warming well below 2°C

The challenge we face are summarised in **Exhibit 3.**

Both the IEA Stated Policy Scenario[1], and the BNEF Economic Transition Scenario[2] suggest that we are heading towards about 2.5-2.6°C of warming by end century. That is what will result, according to the IEA and BNEF, if companies and consumers take private least cost actions given the public policies to which governments say they are committed.

Shifting from that trajectory to one compatible with limiting warming to well below 2°C will require some combination of the actions shown in Exhibit 3:

- First, turbocharging clean electrification so that both power decarbonisation and electrification progress faster than the IEA and BNEF scenarios already assume.
- Second, decarbonising the hard to electrify sectors of the economy faster than those scenarios assume.
- Third, radically reducing methane and N_2O emissions in both fossil fuel production and agriculture.[3]
- Fourth, putting a stop to deforestation and other forms of land use change which result in emissions.
- Fifth, achieving a significant amount of carbon dioxide removals.

Two crucial questions are therefore:

- How large is the prospective reduction in future global temperature rise which can be achieved with each of those levers.
- And what policies and other actions are required to achieve them.

The Energy Transitions Commission has just commenced a major piece of work focused on providing a comprehensive answer to those two questions.

Tonight, I will not be comprehensive; instead, I will set out 6 priorities which we already know will be crucially important.

But starting with four comments on **how** we can win the argument for adequately forceful actions.

And with a clarification even before those comments. Throughout Lectures 1 and 2, I have drawn extensively on the excellent work of the Energy Transitions Commission which it has been my privilege to chair for the last 10 years. But some of the conclusions I will reach in this lecture are personal rather than an official ETC position.

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[1] IEA (2025), *World Energy Outlook, https://www.iea.org/reports/world-energy-outlook-2025*
[2] BNEF (2025), *New Energy Outlook 2025, https://www.bnef.com/insights/36179*
[3] One key issue I do not address in this lecture is the importance of reducing methane emissions from fossil fuel production and processing before end use application. The significant cost effective potential to reduce these is discussed in ETC (2023), *Fossil Fuels in Transition, Chapter 8* https://www.energy-transitions.org/publications/fossil-fuels-in-transition/

Winning the argument

To win the argument, we must combine optimism without puritanism, realistic recognition of transition costs, a willingness to make the climate case for accepting those costs, and pragmatic approach to the most difficult areas of decarbonisation.

Optimism not puritanism

Because as I described in Lecture 1, we have the potential to provide abundant clean energy at costs lower than those in today's fossil fuel-based system. Through clean electrification humanity can enjoy abundant energy at close to zero marginal cost, and with greatly reduced environmental impact – cleaner air in our cities, less pollution in our rivers and oceans, and dramatic reduction in the harm which climate change will otherwise impose.

And that means that limiting climate change does need not to entail a puritanical constraint on the use of energy-based services.

Personally, I do many things which limit my own climate change impact: I get around London by tube and electric bike: I eat red meat only around 4 times a month : I have a small electric car, and cannot comprehend why so many of my fellow citizens want to drive round a dense city in huge SUVs completely unsuited to our narrow streets. As much as possible, and certainly for journeys under a 1000km, I travel by train not plane. And none of these decisions in any way reduces my standard of living. Indeed, if you forced me to reverse any of them, I would consider myself significantly worse off.

And the more that other people share those preferences, the lower the cost of limiting climate change to a manageable level, and the better our local environments will be. I want to live in a London with still more bike lanes and pedestrianised spaces, and greenery: and I want to live in a world in where the pressures on biodiversity are significantly reduced.

But energy use is fundamental to human welfare, and rapidly rising demands for more cooling, more road transport, more air travel will be crucial to rising living standards in developing countries in particular. And the good news which I described in Lecture 1 is that by using technologies already available – primarily electric – we could deliver by mid-century 150% more cooling, 70% more road passenger km travelled and 150% more air travel, while reducing primary energy and final energy inputs.

We will not win the argument for an energy transition fast enough to limit global warming to well below 2°C, if we suggest that people in developing countries must constrain their growing demand for energy based services: and with the one possible exception of red meat consumption, we do not need to.

Realistic recognition of the costs

But optimism must be combined with realism, and as Lecture 2 described achieving a net zero economy will not be costless. We need to make transitional investments of about 1-1.5% of global GDP: the transition will create losers as well as winners: and in some sectors there

will be a green cost premium for many decades and perhaps forever. Cement and concrete will be more expensive in a zero-carbon future: so too will air travel.

We must not therefore tell people that the transition is costless, because they when they find out it is not, that will generate political opposition to the transition even if the costs are small and manageable. We have to anticipate and manage distributional effects.

And we have to make the climate change case for accepting some costs.

Making the climate change case

As I described in Lecture 1 the case for accepting costs to limit global warming is overwhelmingly strong. The cost of limiting global warming to well below 2°C is order of magnitude 1.5% of global GDP: the additional adverse cost of global warming reaching 3°C more like 10-25%.

But in many debates about climate change policy, the climate case for action is often deliberately downplayed. We cannot, it is often asserted, win the argument by warning people of the adverse consequences of rising temperatures for future generations; instead, we must convince people of the positive and self-interested case for embracing new technology and rapidly reducing fossil fuel use. So rather than doom and gloom about the climate, we should focus on:

- The green growth story, and the argument that the energy transition will deliver more jobs and prosperity.
- The potential for technological progress to reach tipping points beyond which green cost premia disappear.
- The self-interested case for companies and the financial institutions which invest in them, particularly in the fossil fuel sector, rapidly to adopt new clean technologies because otherwise they will be left with “stranded assets”.
- And the resulting likelihood that investment in clean technology will deliver superior returns than continued investment in fossil fuels.

But some of these arguments are partly right but overstated, others plain wrong, and none can replace the need to keep making the climate case for action.

- Yes, as I described in Lecture 1, the energy transition will create some new jobs, but small in number relative to overall work forces and to the employment challenge which AI will likely unleash.
- Yes, technological progress will reduce many costs below those of the fossil fuel-based system, but not in all sectors, and across the whole economy there are investment costs which will mean reduced consumption for some consumers.
- And fossil fuel companies and their financiers do not have a certain self interest in limiting fossil fuel investment, because the reduction in fossil fuel demand which will result in stranded assets is not certain but contingent on the strength of the policy commitment to achieve an energy transition. If that policy commitment is lacking – as it is today in the US – expanded investments in fossil fuel production may deliver strong shareholder returns for many years.

- And no, investment in clean technology does not certainly give a superior return over investment fossil fuels: from 2016-21, renewables investments beat fossil fuels: from 2021-26 fossil fuels have been the winner **[Exhibit 4].**

We have to return to the fundamental economics, set out clearly in the Stern Review of 2006.

Climate change is an **economic externality** – indeed the biggest and most dangerous externality humanity has ever faced. And we will only limit to an acceptable level if we make the case for accepting some current costs in return for a future huge benefit for humanity.

That may be difficult, and many are tempted to avoid a difficult challenge in the hope that it is not necessary.

But we should not fool ourselves. Unless most countries across the world – including the big developing countries - are convinced that there is a climate change case for accepting some cost to achieve a zero emissions economy, we have no chance of limiting global warming to well below 2°C.

Pragmatic approach to "last mile" decarbonisation

Fourth and finally, we must avoid imposing unnecessary costs through religious rather than pragmatic approaches to "last mile" decarbonisation. Three examples illustrate the point:

Power sector decarbonisation – a small role for unabated gas. The recent ETC report on Power Sector Transformation,[4] has shown that almost all countries could run power systems with very high levels of intermittent renewables, at costs below those of today's fossil fuel-based systems. But it also highlighted the higher costs likely to be faced in the high latitude wind belt areas, versus in the global sunbelt. These higher costs reflect the greater complexity and cost of balancing supply and demand on a seasonal versus diurnal timescale.

Our analysis also shows that costs will increase very significantly if we seek to achieve not just very low emissions (e.g. less than 30 g per kWh), but absolute zero emissions enabled either with hydrogen storage or by adding CCS to continuing gas generation.

Pragmatic policy should therefore be willing to allow a role for gas turbines running unabated basis for a very small number of hours per annum and generating a very small (e.g. <5%) share of total electricity, with the resulting emissions offset by CO_2 removals elsewhere in the economy. Strong and well enforced regulations to ensure the integrity of either nature based or engineered removals will be a crucial underpin to such a pragmatic approach.

Plastics end of life storage. The ETC's recent report on *Carbon in an electrified future* explored the continuing need for carbon molecules even in an economy where the vast majority of energy is derived from zero carbon sources.[5] For instance, carbon molecules will always be required to produce plastics. Plastic production and use can be made zero

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[4] ETC (2025), *Power Systems Transformation: Delivering Competitive, Resilient Electricity in High-Renewable Systems*, https://www.energy-transitions.org/publications/power-systems-transformation/

[5] ETC (2025) *Carbon in an electrified future* https://www.energy-transitions.org/publications/carbon-in-an-electrified-future

emissions through the use of bio feedstocks or through mechanical or chemical recycling, but these approaches are likely to entail significant cost premium.

A pragmatic approach should not therefore exclude the possibility that some plastics may continue to be made from fossil fuels, with the complete value chain made zero emissions not only by applying CCS to the production process but via end-of-life permanent storage in advanced, secure and high-quality landfill. Achieving a circular economy is highly desirable whenever possible, but should not become a religious edict which has to be achieved in 100% of cases whatever the cost.

Aviation emission reductions and removals. Aviation is at least for the foreseeable future one of the hard to electrify sectors. It can be decarbonised by using sustainable aviation fuels (SAF) in place of conventional jet fuel made from oil or gas.

But this will be an expensive solution and as I described in Lecture one, aviation is the one hard to electrify sector where the green cost premium will be significant even at the end consumer level. There is therefore a danger, as Michael Liebreich has argued, that if we enforce a complete shift to SAF via regulation whatever the cost, the resulting increase in consumer prices will help create political opposition to the whole energy transition. I agree.

This danger can however be avoided if we combine:

- Initial SAF mandates which incentivise the scale development of SAF technology through requiring a material but still small % of total fuel use to be SAF (e.g. the European Union requirement that SAF use should reach 20% of fuel use by 2035)[6]
- Accepting that if the green cost premium does not come down to an acceptable level (e.g. less than $200 per ton of CO2 abated) airlines should be able to use high-quality removals to achieve a significant proportion of net emissions reduction.

Pragmatic approaches to last mile decarbonisation could significantly reduce the cost of achieving net zero emissions: we must not make the best the enemy of the good.

Six priority actions and changes of approach

Three of my proposed priorities focus on specific levers within the framework shown on Exhibit 3, the other three focus on issues to do with international trade and cooperation which we need to resolve in order to deliver all of the actions required. My six priorities are:

- Turbocharging clean electrification as a strategic policy objective
- Driving decarbonisation of the hard to electrify sectors through carbon pricing or equivalent regulation
- Working effectively with China
- Fixing the food issue
- Focusing the climate finance debate
- And resetting global climate diplomacy

[6] https://climatecatalyst.org/learning-hub/sustainable-aviation-fuel-policy-in-the-eu/

1. Turbocharging clean electrification as a strategic objective

To begin with clean electrification. We don't know precisely the relative size of the wedges on Exhibit 3, but it's certain that clean electrification will be by far the largest – since it can eliminate at least the 60% of emissions which come from the building, road transport and light industry sectors of the economy.

And we should therefore make clean electrification a clear **strategic** priority.

The idea of a strategic technological priority contravenes a free market philosophy in which governments should not pick technology winners. And many free market economists – faced with the externality of climate change – hanker after a technology neutral policy in which government set a carbon price, and the market then determines the balance between alternative technology solutions – direct electrification, hydrogen, bio energy, or fossil fuels plus Carbon Capture and Storage (CCS).

But there is a very strong argument for defining clean electrification as a strategic priority at global and national levels. In particular as I described in Lecture 1: **[Exhibit 5]**

- There are fundamental reasons why electricity-based solutions which involve the manipulation of photons, electrons and ions, electric and magnetic fields are certain to see faster cost reductions than those which involve molecular chemistry or the biology of photosynthesis.
- And fundamental reasons too why economy of scale and learning curve effects will reduce costs faster in technologies such as solar photovoltaic (PV), batteries and electric motors which can be mass produced in a standardised form, than in technologies which require bespoke site by site engineering, such as carbon capture and storage **[Exhibit 6].**
- And further rapid technological progress and cost reduction will be driven by interactions between different elements of the electro tech stack which I described in Lecture 1 – with increasing deployment of solar and wind driving demand for storage batteries, which creates incentives for innovation in battery chemistry, which supports developments in robotics, which increases demand for smaller and more efficient electric motors and still lighter batteries **[Exhibit 7].**

It is these fundamental factors that mean that electricity-based solutions are bound to fall in cost relative to fossil fuels **[Exhibit 8].**

And as a result, this means that part of the first two clean electrification wedges shown on this slide may turn out to be costless **[Exhibit 9].**

Of course, if achieving these wedges were in part costless, it would imply that the BNEF Economic Transitions Scenario, which is designed as a least private cost scenario, is not really the least cost pathway available. But that does not imply that BNEF have got their numbers wrong. Rather, it reflects the fact that future costs are not exogenously given, but are endogenously determined by the pace of future technological deployment.[7]

[7] The strength of these effects has been extensively assessed for example in Rupert Way, Matthew C. Ives,

In Lecture 1, I showed both the dramatic fall which has occurred in solar PV installation costs over the last 15 years, and the extraordinary pace of solar PV installation growth, far outstripping successive IEA forecasts **[Exhibit 10].** But these are not independent phenomena; they are closely linked in a self-reinforcing loop.

The faster we install wind and solar, the faster the pace of cost decline, and the faster we drive electrification of road transport, residential heat and industrial heat, the faster those costs will fall.

That justifies making power decarbonisation and electrification global and national strategic objectives, with implications for both targets and policies.

Global and national targets

At the 28th Conference of the Parties (COP 28), 130 countries agreed global targets to triple renewables deployment by 2030 and to double the pace of energy efficiency improvements – an objective which can only be achieved by accelerated electrification.[8]

One possible initiative at COP 31 would be to add an indicative global target for electrification, measured by electricity as a share of final energy demand. The IEA's 2025 Net Zero scenario suggests that electrification of around 33% would be required to put the world on a path clearly compatible with limiting global warming to well below 2°C **[Exhibit 11].** The ETC's work this year will include an assessment of the case for agreeing a global electrification target at COP 31 and an appropriate level.

But while a global target can have a useful signalling effect, the crucial priority is for governments to set national clean electrification targets, and then to put in place the policies required to deliver them.

Public policies to deliver accelerated clean electrification

The strategic objective of clean electrification should be reflected in national targets and policies to drive both power decarbonisation and electrification, with the most important priorities and policies varying by country:

- In all countries, road transport electrification should be a major priority with targets for electric vehicle (EV) sales as a percentage of the total, emission reduction regulations which drive the shift to EVs, support for public charging infrastructure, and ideally dates beyond which the purchase of new internal combustion engine (ICE) passenger vehicles will be banned. Future bans have already been introduced by the European Union (in 2035) and several individual European countries, but partial bans have

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Penny Mealy, J. Doyne Farmer (2022) *Empirically grounded technology forecasts and the energy transition*, https://www.sciencedirect.com/science/article/pii/S254243512200410X

[8] COP 28 (2023), *Global Renewables and Energy Efficiency Pledge,* https://www.cop28.com/en/global-renewables-and-energy-efficiency-pledge

already been introduced by Ethiopia and Rwanda.[9] In the developing world in particular, electrification of two- and three-wheelers should be a particularly high priority, with huge potential to improve local air quality, as well as driving emissions reductions.

- In several developing countries which have limited domestic oil and gas resources – including in particular India – rapid electrification will also help deliver energy independence and reduced macroeconomic risk. Fossil fuels account for 31% of India's imports and fluctuations in the global price of oil and liquified natural gas (LNG) can generate inflationary effects which constrain Indian macroeconomic policy.[10] Rapid electrification of road transport to reduce oil imports, and actions which can reduce LNG imports, are therefore means to reduce economic risk.

- In China, India and several other major developing countries decarbonisation of the existing power system is a priority, and should ideally be reflected in explicit targets for rapid reduction in still high levels of carbon intensity – grams of CO_2 per kWh of electricity. Setting such targets will help drive accelerated deployment of renewables (and in some cases nuclear) but achieving them will also require clear plans for reducing generation from existing coal plants, whether through retiring them before the end of useful life, or by running them on an increasingly flexible basis to complement wind and solar generation.

- In Sub-Saharan Africa outside of South Africa, by contrast, current electricity systems are so small that the challenge is not primarily one of decarbonisation, but achieving rapid growth of electricity use to support prosperity growth, while also ensuring that almost all new supply is zero-carbon.[11] Explicit targets to increase the percentage of the population who have electricity access (whether from the grid or via decentralised solar plus battery installations) are important. Restraints on future purchases of diesel generation sets should also be considered, with battery storage an increasingly competitive option.

- In some developed high-latitude countries, policies need to address the challenges created by large residential heating needs and wind-dominated power systems:
  - Rapid residential heat electrification will often require subsidies to support heat pump installation and improved building insulation in low-income households, addressing the distributional issues considered in Lecture 2.

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[9] Ethiopia has banned the import of internal combustion engine passenger cars in January 2024, and has subsequently extended the coverage, e.g. to cover semi -finished kits for assembly in country. Clean Technica (2025), *Ethiopia Updates ICE Vehicle Import Ban To Include Imports of SKD & CKD Kits*, https://cleantechnica.com/2025/06/21/ethiopia-updates-ice-vehicle-import-ban-to-include-imports-of-skd-ckd-kits/. Rwanda has banned the registration of new ICE motorcycles in Kigali. The New Times (2024), *Rwanda to halt registration of petrol motor-cycles in 2025, https://www.newtimes.co.rw/article/21528/news/rwanda/rwanda-to-halt-registration-of-petrol-motor-cycles-in-2025*

[10] Ministry of Commerce and Industry (2025), *A quick view of India's trade scenario,* https://www.dgciskol.gov.in/writereaddata/Downloads/20250819155439A%20Quick%20View%20of%20Indias%20Trade%20Scenario.pdf

[11] Energy Transitions Commission (2023), *A Path Across the Rift: Informing African Energy Transitions by Unearthing Critical Questions and Data Needs*, https://www.energy-transitions.org/publications/african-energy-transitions/

- And in some of these countries (in particular those which lack large low-cost hydro resources), clear strategies for electricity pricing are also essential. In these countries, as I discussed in Lecture 2, the total system cost for round-the-clock electricity will be significantly higher than in the global sunbelt, and those countries which have large gas distribution networks also face the challenge of building much larger electricity supply and transmission systems, while still needing to run the gas grid until the final customers go electric.
- In these countries it may be essential to take some of the costs of the transition onto the government budget, or investment onto public development bank balance sheets, to avoid a perverse loop in which transitional costs result in high electricity prices, which slows the pace of electrification required to amortise the investments being made.[12]

Several of these policies will require accepting some transition cost, incurred either by consumers or the taxpayer. But accepting these transitional costs will accelerate the development of electrified economies which once in place will deliver energy services at lower cost than a fossil-based energy system.

Committing to clean electrification as a strategic objective should also entail the development of industrial strategies, in both developed and developing countries which focus on the electro technologies of the future and which identify the role that different countries can play in the supply of those technologies, given their starting points and natural resource endowments. Since successful strategies will need to respond effectively to China's current technological and cost leadership, I discuss these under my third priority.

2. Carbon pricing and regulation in the hard to electrify sectors

Beyond the clearly electrifiable sectors, the costs of decarbonisation rise **[Exhibit 12].** And while in the heavy industry and long-distance transport we know the technologies which can get us to net-zero, there will be "green cost premia" – i.e. higher costs for producing steel, fertiliser, or concrete in a zero-carbon fashion - certainly for several decades and in some cases forever.

As a result, some experts, and I hope it is correct here to include Michael Liebreich, argue that we should deemphasise action in these sectors to avoid imposing costs on consumers which might provoke a political response which derails other more affordable elements of the energy transition.[13]

But I disagree for two reasons:

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[12] For example, the UK government will from April 2026 assume 75% of the cost of the Renewable Obligation scheme, which subsidised the first costly generation of UK solar and wind deployment.
[13] Michael Liebreich (2025), *Liebreich: The Pragmatic Climate Reset – Part I*, https://about.bnef.com/insights/clean-energy/liebreich-the-pragmatic-climate-reset-part-i/; Michael Liebreich (2025), *Liebreich: The Pragmatic Climate Reset – Part II: A Provocation,* https://about.bnef.com/insights/clean-energy/liebreich-the-pragmatic-climate-reset-part-ii-a-provocation/

- First, because action to reduce this 20% of emissions will be essential if we are to keep global warming to well below 2°C. **Exhibit 13** compares BNEF's projection of emissions from the hard to electrify sectors with those which the IEA estimates would occur in a scenario reaching net zero by mid-century. Up to 2050, the difference in cumulative emissions could be 260 Gt versus 130 Gt, but in the Economic Transition Scenario there will also be emissions well into the late 21st century, perhaps equivalent to another 200 Gt if decarbonisation eventually occurs on a straight line between say 2050 and 2090. Treating the hard to electrify sectors as too expensive to abate could therefore result in additional cumulative emissions of 330 Gt this century which would result in additional global warming approaching 0.2°C, enough to make a target of well below 2°C unattainable, however much we accelerate clean electrification.

- The second reason for taking action in these sectors is illustrated by **Exhibit 14** which I also used in Lecture 2. It shows that while the green cost premia are likely to be large at the level of intermediate products sold from business to business – +75% on the price of iron, +45% on the price of steel – by the time we get to the products that consumers actually buy – a car, a home, a loaf of bread – the cost premia are so small that they would not be noticed if introduced gradually over say a 25 year period.

That is why there is little evidence that these sectors are in fact politically hard to abate. Populist parties frequently post scare stories about the ineffectiveness and costs of heat pumps, or about EVs stranded when they run out of power; but I have never seen them warning voters of the threats to their wallets from a potential carbon pricing on international shipping. And in that, they are completely rational:

- Installing heat pumps imposes major switching costs on households, both administrative and financial: and the payback varies with household cost of capital and the specific nature of the property.
- By contrast imposing a global carbon price on international shipping does not require any household to do anything: and will change the price of a pair of jeans made in Bangladesh and bought in London by so little that no one will notice.

In terms of their impact on consumer living standards, the hard to electrify sectors are much easier than residential heat.[14] We should therefore commit to decarbonising them.

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[14] The one exception to the rule that the decarbonisation of hard to electrify sectors has a minimal impact on consumer prices is aviation, where consumers directly buy the service itself (a passenger flight ticket) rather than end products in which the decarbonised intermediate product is embedded (a car made out of green steel). If in 2050, sustainable aviation fuel still cost 100% more than conventional fuel, and if fuel accounts for 25% of total airline operating cost, a fuel mandate which required 100% of fuel to be sustainable could add 25% to the cost which would apply in 2050 if we continued to use fossil fuels. It is important to note, however, that this 2050 price of aviation ticket might still be below todays in real terms, if fuel efficiency improved by 25%, and the incentive to achieve energy efficiency improvements would rise if fuel prices increased as a result of regulation or carbon pricing. The maximum consumer price impact could also be mitigated if airlines were allowed the option of offsetting some emissions via high-quality removals, rather than having to achieve complete decarbonisation within sector whatever the cost.

That will require public policies to overcome the green cost premia. In principle those premia could also be overcome if buyers of the relevant product or service were willing voluntarily to pay a higher price for green steel, green shipping and the other products and services. At COP 26 in Glasgow a First Movers' Coalition of over 90 companies therefore committed to use their purchasing power to speed the decarbonisation of the hard to electrify sectors.[15]

This has helped create some useful demand. But analysis by the Mission Possible Partnership (MPP), which tracks the development of decarbonisation projects in all of the hard to electrify sectors, illustrates the limitations of this approach.

Voluntary commitments can help support pilot and demonstration plant development and provide a small contribution to overcoming green cost premia in commercial scale plants. But without strong public policy support, there is insufficient certainty of high-volume demand for more expensive decarbonised products and services to support large scale development. The MPP's project tracker identifies 857 "announced" projects which would entail gross investment of $1.84 trillion, but only 82 projects actually in operation, with 62 more having passed final investment decision (FID) **[Exhibit 15].**[16] Many of the announced projects will not proceed to FID without an expectation of public policies which overcome the green cost premia.

We face an economic externality which voluntary actions alone cannot overcome without strong public policy support.

The two main potential policies are carbon pricing and regulations which mandate a specific market share of low carbon technologies.[17] The European Union has led the way in the introduction of carbon pricing via the Emissions Trading Scheme, and that system is now generating current and expected carbon prices sufficient to make decarbonisation increasingly economic in the hard to electrify sectors.

But if a serious carbon price is imposed in only one country – e.g. in the European Union but not in Turkey, India or China - we will not see real decarbonisation but only a shift in industry location to countries with low or non-existent carbon prices.

In response to this international competitiveness challenge, the EU has therefore introduced the carbon border adjustment mechanism (CBAM), and it should be robust and unapologetic in doing so. CBAMs are not protectionist, but simply a means to maintain the relative competitive position which would exist if there were no domestic carbon price and no CBAM. They in no way contravene the principle of common but differentiated responsibilities: and

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[15] World Economic Forum (2022), *First Movers Coalition Commit $12 Billion to Commercialize Zero Carbon Tech, Cut Emissions*, https://www.weforum.org/press/2022/11/first-movers-coalition-commit-12-billion-to-commercialize-zero-carbon-tech-cut-emissions/

[16] Mission Possible Partnership (2025), *Tracker Insights: November 2025*, https://www.missionpossiblepartnership.org/tracker-insights/nov-25/

[17] Carbon pricing has the merit of creating incentives for decarbonization which are neutral as between alternative technology solutions; this can be valuable where there are multiple alternative technologies to achieve partial or complete decarbonization, as for instance iron making. Quantitative regulation such as the EU's mandate for a rising share of aviation fuel to come from sustainable sources, has the merit of creating a certain market for new production facilities, but leaves the cost impact on consumers uncertain.

they are the only way by which developed countries can take responsibility for "consumption-based emissions" i.e. for emissions embedded in the goods they import.[18,19]

But if we are to limit global warming to well below 2°C we need to decarbonise heavy industry and long-distance transport, not just in Europe but across the world.

Exhibit 16 shows that 52% of iron and steel related emissions come from China and 15% from India: 51% of cement emissions from China and 7% from India, and while the Chinese figures will decline as the Chinese construction sector contracts, the shares in India and other developing countries will grow rapidly.

The good news is it in both China and India we are seeing technological developments and investments which are reducing the costs of heavy industry decarbonisation. In both for instance the cost of green hydrogen is now far below the level seen in Europe, and it is possible that in the long run, and in particular in the global sunbelt where renewable cost will be cheapest, that the green hydrogen cost may get so low that hydrogen based iron production will be competitive with blast furnaces using coking coal.

And Chinese iron and steel companies are developing hydrogen direct iron reduction (H2 DRI) technology for iron production, for instance here at the China Iron and Steel Research Institute's demonstration plant in Linyi in Shandong province **[Exhibit 17].**

Chinese and Indian companies are also at the cutting-edge of developments in green ammonia production, this slide shows Envision's green ammonia plant in Inner Mongolia **[Exhibit 18].**

But analysis still suggests that even in the lowest cost locations, there will be a significant green cost premium in iron production for several decades; while if in cement production the only way to reach net zero is to add CCS, that by definition adds cost. Similarly in petrochemical production, I can see no way that the green cost premium will disappear within the next two to three decades.

Which means that decarbonisation of heavy industry in China, India and other developing countries will not occur without serious carbon pricing or equivalent regulation.

Among my six top priorities is therefore the spread of adequately high carbon pricing in the hard to electrify sectors, though not necessarily in other sectors, from Europe to China and all major developing countries.

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[18] See ETC (2025), G*lobal trade in the energy transition, Chapter 2* https://www.energy-transitions.org/publications/global-trade-in-the-energy-transition/ for analysis of the fundamental economics and ethics of carbon border adjustments.

[19] The explicit stated objective the CBAM is not to raise tariff revenue, but to incentivise other countries to introduce equivalent carbon prices in the heavy industry sectors, which would remove any carbon tariff liability on exports to Europe. One way in which the European Union and UK could signal the non-protectionist intent of the CBAM is to commit to use any tariff revenues which do arise to providing climate finance support for low-income countries.

China already has in place a carbon trading market, which now covers 60% of all emissions after extension to the steel, cement and aluminium industries during 2025.[20] But the system is currently based on emissions intensity standards rather than an absolute emissions cap: it grants free allowances for emissions below the intensity standard: and it generates carbon prices of only about $8 to $10 per tonne, far below the levels required to drive significant decarbonisation in the hard to electrify sectors.

The intention is to tighten the system gradually over time, with carbon prices gradually rising towards more adequate levels. The faster this occurs, the greater the chances that the world will limit global warming to well below 2°C, both because of the Chinese emission reductions which will result, and because the imperative to reduce emissions will drive the development of relevant technologies, reducing the green cost premia to the maximum extent possible.

The European CBAM should be used as a means to encourage adequate carbon pricing in the hard to electrify sectors in China and other developing countries.

At present the official position of the Chinese and Indian governments is that Europe's CBAM is protectionist and unacceptable. But get away from official circles and talk to many business and policy experts in these countries, and there is increasing agreement that a serious domestic carbon price will be required. As a senior Chinese Policy makers said in a recent meeting I attended, "*if Europe goes ahead with a CBAM, we should widen our carbon pricing coverage and increase the carbon price, so that we still have access to the European market"*.

The faster that attitude spreads, the better our chance of limiting global warming to well below 2°C.[21]

At COP 31, orchestrating an open and fact-based discussion about how to achieve decarbonisation of the hard to electrify sectors should therefore be a top priority.

3. Working effectively with China

My third priority is working effectively with China.

In Lecture 2, I said that two stories are told about China and climate change:

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[20] Down to Earth (2025), *China's carbon market expands to heavy industries, sets global pace*, https://www.downtoearth.org.in/climate-change/chinas-carbon-market-expands-to-heavy-industries-sets-global-pace

[21] The conclusion of the recent EU-India trade deal usefully included de facto acceptance that the CBAM would apply to Indian exporters to the EU, plus the establishment of technical dialogue to smooth verification and compliance processes. New Indian Express (2026), *EU, India agree on technical dialogue to ease market access under CBAM rules*, https://www.newindianexpress.com/business/2026/jan/27/eu-india-agree-on-technical-dialogue-to-ease-market-access-under-cbam-rules

- First, that China is by far the biggest greenhouse gas emitter, with emissions per capita now well above European and UK levels, and with emission reduction targets which are incompatible with limiting global warming to well below 2°C **[Exhibit 19].**
- Second, that China's technological leadership and the cost reductions which it has delivered make it possible for the world to decarbonise faster and cheaper than we dared hope 15 or 10 or even five years ago.

Both stories are true.

The first implies that China must develop strategies for faster emissions reduction – in heavy industry and coal power generation in particular – and I will come back later to the issue of fair shares of emission reduction between nations.

But my focus now is on the opportunities and challenges created by China's extraordinary leadership in all the technologies needed to build a deeply electrified economy.

In almost all of those key technologies, China has a dominant share and one that has increased over the last three years **[Exhibit 20].** And while lower labour cost, initially lower environmental standards, and direct subsidies played an important role in the early stages of China's rising competitive strength, they are no longer the significant drivers. Instead, China's technological leadership and cost-competitiveness now reflects excellent scientific and engineering capability, strategic commitment to the electric future, economy of scale and learning curve effects and the resultant development of cost-effective supply chains in every part of the electro tech stack.

China has made a big bet that the future is electric – and it's a winning bet **[Exhibit 21].**

And in a world of perfect peace, cooperation, and widespread rising prosperity, what China has done would be welcomed with open arms. In many countries indeed that will be the straightforward response – Africa sits on an enormous opportunity for cheap solar and battery deployment which it should grasp using Chinese solar panels and batteries.

But in some countries China's technological leadership is also seen as a threat, and nowhere more so than in Europe, which faces what I called in Lecture 2 **[Exhibit 22]** a perfect storm of threats to international competitiveness,

- In heavy industry, and despite the introduction of the CBAM, Europe's long-term competitiveness is threatened by the structural cost advantage of the global sunbelt; simultaneously its auto industry, wind turbine manufacturers and battery ambitions are threatened by China's technological leadership and hyper competitiveness.
- Russia's invasion of Ukraine provoked an energy price shock, forced a rapid reconfiguration of gas supply, and has required increases in defence expenditure which will compete with energy transition requirements for fiscal resources.
- Trump's tariffs have directly impacted many European manufacturers, while some Chinese exporters excluded from the US have increasingly turned to European markets.

Faced with these multiple threats, there is a danger that European and UK commitments to a rapid energy transition will weaken. Across Europe right wing populist parties argue for the repeal of net zero targets, and so to now does the UK Conservative party. Chancellor Merz of Germany has argued that current commitments to progressive tightening of the EU ETS

emissions cap may need to be revised or postponed.[22] Politicians and industry lobbyist are arguing for a delay to the 2035 EU ban on internal combustion engine vehicle sales.

These pressures have implications for the feasibility of increased developed country climate finance commitments, or increased emission reduction commitments, which I will discuss under my fifth and sixth priorities.

But they also have implications for how Europe and the UK should respond to China's technological leadership and cost competitiveness in the key clean technologies. Faced with that competition, the European Union is now considering a set of "buy European" policies to protect "strategic sectors" of European industry:[23] but these policies could increase the cost of the energy transition to consumers and intensify political opposition to strong emission reductions targets.

Simply put **[Exhibit 23],** if Europe wants cheap wind power supply, it should buy Chinese wind turbines: if it wants more jobs in Europe, it should insist on some domestic manufactured supply. If it wants to get faster to the point where EVs are cheaper to buy up front than ICE vehicles, it should allow Chinese car companies like BYD unrestricted market access. If it wants to protect employment at European auto companies, it may need to impose tariffs [24].

How then can Europe and other countries manage that trade-off? In the ETC's report on *Global trade in the Energy transition*, we suggested five principles **[Exhibit 24].**

- First, that we should aim for diversified supply chains not complete autarky: the EU's Net Zero Industrial Act proposed that Europe should aim for at least 40% of overall clean technology supply to be domestic by 2040 and should consider the need for a strategic response in sectors where the import share exceeds 50%.[25] Those seem sensible overall guidelines if applied flexibly in response to different sectoral conditions.[26]

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[22] S&P Global (2026), *European carbon prices slide as Germany's Merz says EU ETS may need revamping*, https://www.spglobal.com/energy/en/news-research/latest-news/energy-transition/021226-european-carbon-prices-slide-as-germanys-merz-says-eu-ets-may-need-revamping

[23] The Guardian (2026), *EU leaders agree to move ahead with 'Buy European' policy*, https://www.theguardian.com/world/2026/feb/12/eu-leaders-clash-buy-european-belgium-summit

[24] Countervailing tariffs ranging from 17% on BYD EVs to 35.3% on SAIC were imposed by the EU in December 2024. European Commission (2024), *EU Commission imposes countervailing duties on imports of battery electric vehicles (BEVs) from China*, https://trade.ec.europa.eu/access-to-markets/en/news/eu-commission-imposes-countervailing-duties-imports-battery-electric-vehicles-bevs-china

[25]The European Commission overview of the Act states that "The aim is that the Union's overall strategic net-zero technologies manufacturing capacity approaches or reaches at least 40% of annual deployment needs by 2030". The Act also defines that manufacturing projects should be counted as "strategic "where they increase EU capacity in sectors where imports currently account for more than 50% of demand". European Commission (2024), *Net-Zero Industry Act*, https://commission.europa.eu/topics/competitiveness/green-deal-industrial-plan/net-zero-industry-act_en , European Commission (2025), *Communication from the Commission providing updated information to determine the shares of the European Union supply of final products and their main specific components originating in different third countries under Regulation (EU) 2024/1735 on establishing a framework of measures for strengthening Europe's net-zero technology manufacturing ecosystem (Net-Zero Industry Act)*, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ%3AC_202503236&

[26] See also ETC (2023), *Better, Faster, Cleaner: Securing clean energy technology supply chains*, https://www.energy-transitions.org/publications/better-faster-cleaner-supply-chains/

- Second, we should vary policy by sector to reflect different starting points and the inherent characteristics of the relevant supply chain. Europe now has no employment at risk in solar PV manufacturing, which in any case is a highly automated process employing very few people. And Europe could spend huge subsidies attempting to re-create domestic solar PV manufacturing companies and still end up uncompetitive with China. But Europe has significant employment at risk in the automotive sector. And in auto manufacturing being physically close to market enables faster response to customer demands; and the logical place to locate battery factories is right next door to automotive manufacturing plants. So, well designed policies should be able to preserve a vibrant European electric vehicle and battery manufacturing base.

- Third, Europe should use tariffs in a fact based and World Trade Organisation (WTO) compliant fashion, focusing on those circumstances where there is evidence of current subsidy.[27]

- Fourth, and perhaps most controversial, Europe and the UK should focus primarily on the location of employment and value added rather than ownership. Part of building a vibrant European automotive and battery industry should therefore be to welcome inward investment from Chinese EV and battery companies, while making any financial support for that investment contingent on local value-added commitments and other mechanisms to ensure technology transfer. That is strategy which China used very effectively when it was behind technologically in the 1990s; it should be part of Europe's strategy today.

- Fifth and finally, we need to think straight about different dimensions of "security":

    - The term "security" is sometimes used in an economic sense, but often in a confused fashion. I have, for instance, heard people say that relying on Chinese solar panels is exactly like relying on Russian gas before February 2022. In fact, it is exactly <u>not</u> like that. If you import gas through a pipeline and end up in deep conflict with the exporter, you will be cold the next day; if you import solar panels from a country which subsequently refuses to supply you, you still have all the panels you've bought in the past, producing electricity at close to zero marginal cost for the next several decades. Renewable energy systems are inherently more economically secure than fossil fuel ones.

    - But "security" can also refer to intelligence and cyber security related issues, to concerns that if Europe's electricity grids are built with Chinese smart hardware and software, they might be vulnerable to future manipulation. Here again, we need to start by distinguishing different technologies – solar panels and battery cells are dumb hardware, central grid control software is a highly strategic asset.

[27] The EU EV tariffs introduced in December 2024 did broadly comply with WTO principles and entailed a differentiated tariff rate % for different manufactures, based on assessment of the extent of current subsidies in each specific case.

Europe's industrial strategy must therefore integrate legitimate rather than paranoid security concerns with a realistic assessment of where within the electro tech stack Europe could still have a significant competitive advantage.

Further work is needed to turn these general principles into specific policies but one of the most convincing analyses I have seen is Tatiana Mitrova and Anna-Sophie Corbeau's paper on "The EU in a Petrostates and Electrostates World".[28] This argues that both potential competitive advantage and security concerns should lead to a European focus on everything to do with grid control hardware and software, smart building control systems, and the business models and software that enable flexible demand response, underpinned by strong regulation of cyber security standards.

But whatever the precise answers, Europe and the UK must devise clean industrial strategies which engage effectively with China and minimise the cost of the energy transition while building a vibrant industrial base in sectors where Europe/UK can be competitive.

Similarly, in developing countries, it is vital to design an effective response to China's clean tech leadership, with the available options and appropriate approach varying with specific national conditions.

India as an alternative clean technology industrial power

India's population of 1.4bn creates the market potential for it to achieve the economies of scale seen in China, provided it makes the strategic commitment to clean electrification described in Section 1 above. In principle it could become an alternative low-cost supplier of solar panels, batteries, and wind turbines, not only for its own use, but also for other countries. It is already developing a solar PV manufacturing base, with policies which combine tariff protection against Chinese imports with targeted subsidies under the Production Linked Incentive regime. [29]

But successful development depends on striking a careful balance between domestic protection and continued trade and investment flows with China. In solar PV supply, initial tariff protection and subsidies were focused on building PV module manufacturing with the solar cells still imported from China. The intention looking forward is to gradually extend domestic production up the supply chain, to cells, wafers, ingots and eventually polysilicon. But India's solar module and cell manufacturing plants typically use Chinese manufacturing equipment, and close relationships with the Chinese suppliers are required for effective plant commissioning. In other sectors too, such as batteries, electrolysers, and wind turbines, maintaining adequately open trade relationships with China will be vital to the successful development of an Indian clean industrial base.

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[28] National Interest (2025), *The EU in a Petrostates and Electrostates World*, https://nationalinterest.org/blog/energy-world/the-eu-in-a-petrostates-and-electrostates-world

[29] Government of India, Press Information Bureau (2025), *PLI Scheme: Powering India's Industrial Renaissance, A Transformational Push for Manufacturing, Employment, and Global Competitiveness*, https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=155082&ModuleId=3&reg=3&lang=2

Other developing countries – the role of Chinese inward investment

Other developing countries to different degrees lack India's massive potential market size, but in some cases have other strategic advantages. Indonesia combines a very large market with significant mineral resources, for instance in nickel, which could give it an advantage in the development of domestic battery manufacture. But seizing that opportunity fast is likely to require a significant role for Chinese companies with relevant expertise. In smaller countries at earlier stages of economic development, opportunities may be more limited, but there could still be opportunities to create local value added and employment in, for instance, two-wheeler EV assembly, via joint ventures with Chinese, Indian or other country investors.

4. Fixing the food issue

I've called my fourth priority "Fixing the food issue" but I will openly admit that this is the one where I am least confident that I have a convincing answer **[Exhibit 25].**

- 60% of emissions can be eliminated by clean electrification.
- 20% of emissions lie in the hard to electrify sectors, but we have the technologies, and the costs to consumers are small.
- But the last 20% of CO_2 equivalent emissions are really difficult to reduce, because they derive from the huge inefficiency of the biology of photosynthesis and animal protein production [30], and none of the policy responses proposed so far are making progress. Major commitments were made at COP 26 in Glasgow to end deforestation – but deforestation continues. Several countries say they will rely on carbon dioxide removals to offset methane emissions from animal herds – but the volume of carbon removals today is a minute fraction of what we need.

There are no easy answers. But sometimes recognising that reality is the first step towards sensible answers. Global discussions of the agricultural sector's role in climate change – at COPs and elsewhere – should therefore start by recognising clearly the scale of the challenge and the fact that it primarily arises from red meat consumption. They must then progress to realistic assessment of the potential for 4 categories of possible solution:

- First, consumer behaviour change. In Lecture 1, I argued that in all the electrifiable sectors, the technologies available to us are so powerful and will be so cheap, that we can rapidly grow human consumption of energy-based services and products while dramatically reducing emissions. As a result, ETC projections of attainable reductions in emissions in the energy, building, industry and transport sectors rely only minimally on assumed changes in consumer behaviour.[31] But the one exception may need to be

[30] The importance of food related emissions could be even higher than this 20% suggests. The global warming impact of methane depends on the time period considered, and in the figures shown on Exhibit 1 I have used a 100-year period for expressing methane emissions in CO2 equivalent terms. But given the importance of preventing short term increases in temperature which take the climate beyond some of the "tipping points" considered in Lecture 1, there could be strong argument for focusing on a shorter period e.g. 20 years. Considered on a 20-year basis, food related emissions could account for over 25% of the total.

[31] Exhibit 21 in Lecture 1 showed a breakdown of the levers which could reduce final energy demand in 2050 by 51% below a business-as-usual level, with the vast majority achieved via electrification and equipment

less red meat consumption. Any such change will have to be almost entirely voluntary, but the more that people are aware that this is the most difficult decarbonisation challenge, the more they may be willing to change.

- Second, non-radical technological and efficiency improvement solutions, accelerated by policy incentives. Even while continuing to consume unchanged foods, in particular animal red meat, there are multiple technologies which could significantly reduce emissions. Numerous options are being investigated to reduce methane emissions from animal enteric fermentation through animal diet changes or via vaccination-based approaches. Potential emissions reductions are estimated in the 10% to 50% range, but with important implementation challenges still to be overcome.[32] There are also many opportunities to apply nitrogen fertilizer more effectively, reducing the resulting N_2O and CO_2 as well as reducing nitrogen run-off pollution in rivers, lakes and oceans. The priority now is to accelerate technological innovation and deployment via policy incentives:
  - Some of these options may become costless overtime, but many will entail some additional cost even in the long-term, or require upfront investment.
  - As a result, deployment will not occur as rapidly as needed without policy support equivalent to the carbon pricing and regulation which is needed in the hard to electrify sectors.
  - Measurement challenges make it more difficult to apply methane pricing to animal production than CO_2 pricing to steel production or shipping, but potentially effective approaches are still possible, e.g. broad-based methane taxes applied per heard of cattle/sheep but with discounts for proven use of effective methane reduction diets.

- Third, the radical technologies of synthetic protein production which I described in Lecture 1. As I argued then, it is highly likely that in the long run, synthetic protein production will beat animal protein on nutritional quality and cost and fully meet expectations on taste. With knowledge and low-cost energy, the potential for innovation is limitless: and while knowledge accumulation is being accelerated by artificial intelligence (AI), clean electrification is the route to abundant cheap zero carbon energy.

  The pace of development is however unclear. Government support for the development of synthetic protein and other "novel foods" is therefore a crucial priority. This requires both regulatory frameworks which facilitate market access while ensuring food safety, and targeted financial support. Singapore, which has set a target of sourcing 30% of its food domestically by 2030, is a leader in both regulation and technology: China is increasingly committed to developing a major role in novel food

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efficiency improvements. It showed 11% out of the 51% deriving from "demand reduction", but of this, 2/3rds derives from operational efficiency improvements in for instance logistics and air traffic control. Only 4% out of the 51% is assumed to result from changes in consumer behaviour such as modal shifts from cars to public transport or bicycle.

[32] Ijoear (2025), *Methane Reduction Strategies in Ruminant Systems: From Feed Additives to Genetic Selection*, https://ijoear.com/methane-reduction-strategies-in-ruminant-systems

production: Europe and other countries should adopt policies which increase the potential for domestic technology development and deployment

- And fourth, carbon dioxide removals to offset remaining agricultural emissions. Whatever the progress on the first three categories of solution, it is highly likely that getting food related emissions close to zero early enough to limit global warming to well below 2°C will require a significant role for carbon dioxide removals. These could be either nature based (e.g. reforestation or peat land restoration) or engineered (e.g. direct air carbon capture and storage [DACCS]. As a result, several countries with large cattle or sheep herds – including New Zealand, Ireland, and Brazil – have strategies for achieving net zero which are either vague or assume a large role for CO_2 removals. But as I described in Lecture 1, CO_2 removals are not developing at anything like the pace required. While the ETC estimated in 2021 that the world would need 5 Gt of removals per annum by 2030 to limit global warming to 1.5°C, total removals in 2024 were about 48 million tons.
  To accelerate progress towards credible global and national strategies for the use of carbon removals it is essential to:
  - Focus global debates about the use of carbon credit purchases on the need for actual carbon removals rather than "offsets" relative to business-as-usual levels.[33]

  - Press nations which have large food related emissions to set out strategies for their reduction which are as specific and quantified as those to reduce emissions from the energy, building industry and transport sectors of the economy.

Overall, we will not fix the food issue unless we approach it as we do the other sectors of the economy: quantifying clearly the scale of the challenge; identifying the range of solutions; assessing which of those can be costless; and where there are unavoidable costs defining the policy levers required to speed technology development or to overcome the externality of permanent green cost premia.

5. Focusing climate finance

I have called my fifth priority "Focusing climate finance" and in Lecture 2 I described some of the financial flows covered by that very broad term and the challenges that stand in the way of those flows occurring.

I described:

- The investments we need to build a zero carbon economy across the world – potentially reaching $4.5 trillion per annum by the 2040s, and the fact that so far investment growth has been concentrated in developed countries and China, and to a lesser extent India, with very little growth in many other developing countries.

[33] See Group of Thirty (2025), *Carbon Pricing and Markets: Enabling Efficient Emission Reductions*, https://group30.org/publications/detail/5482

- I talked about the challenge of high costs of capital in many low-income countries which can impede their ability to seize the huge opportunity created by for instance cheap solar panels and batteries.
- And I highlighted the significant payments needed to pay for the rundown of existing coal generation, potentially reaching $25-40 billion per annum for a decade or more in developing countries outside China.

And beyond these mitigation related climate finance flows, there are requirements for adaptation finance, and a debate about compensation for loss and damage.

Climate finance is therefore a very wide ranging and complex issue, and one on which many excellent reports have been produced – including those from the International High Level Action Group on Climate Finance, co-chaired by Nick Stern.[34]

And in 2024, the UNFCC and the COP 29 Presidency were charged with gaining agreement to a *New Collective Quantified Goal* [NCQG] on climate finance to be approved at COP 29 in Baku.

The resulting agreement is shown in **Exhibit 26,** combining:

- Paragraph 7 which says that all countries will work together to scale up finance for climate action in developing countries to $1.3 trillion per annum in 2035, with that potentially coming from *all private and public sources.*
- While paragraph 8 sets a goal of $300 billion per year by 2035 in finance for developing countries for climate action from such a wide variety of sources, that it might just as well have said all public and private sources as it did in Paragraph 7.

So that these two paragraphs say essentially the same thing, but one refers to $1.3 trillion per annum and the other to $300 billion.

Sometimes when an emperor is walking around naked, it is important for someone to point out that fact. And the sad fact is that this agreement is a total mush and muddle, which could mean almost anything and therefore almost nothing, and from which almost no useful action has followed or will ever follow.

The fundamental problem is a failure to clearly distinguish:

- Quite different categories of required climate finance,
- Quite different categories of developing country.

[34] Key reports include 4 reports from the Independent high Level Expert Group on Climate Finance chaired by Amar Bhattcharya, Vera Songwe and Professor Lord Nicholas Stern: LSE Grantham Institute / IHLEG (2025), *Delivering an integrated climate finance agenda in support of the Baku to Belém Roadmap to 1.3T*, https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2025/11/IHLEG-on-Climate-Finance-4th-Report-Delivering-an-integrated-climate-finance-agenda.pdf , and the report by the G20 Independent Expert Group, chaired by NK Singh and Lawrence Summers: Center for Global Development (2023), *Strengthening Multilateral Development Banks: The Triple Agenda*, https://www.cgdev.org/publication/strengthening-multilateral-development-banks-triple-agenda

… a failure to be realistic about what developed countries will do to help different categories of developing country.[35]

Mobilising finance for investments

The big numbers, in the trillions, relate to investments which need to be made in new clean technology assets. Some of these would not be economic without appropriate regulation or carbon pricing, but they are still investments in revenue generating assets. As a result:

- Very little of this investment will be financed by grants or concessional finance from developed countries, with any such finance extended only to the lowest income countries.
- But a significant share of this can be mobilised by development banks, whether national or multinational (MDBs), which through the alchemy of bank balance sheets, can create large investable funds at reasonable cost of capital by leveraging the equity contributions of both developed and developing country members.
- And a significant share could take the form of international flows of private finance, in some cases leveraged by MDB activities.

The key actions required to mobilise finance for investment in a wide range of developing countries are therefore to:

- Increase the capacity of the MDBs to lend at reasonable rates and to operate in ways (e.g. through guarantees) which maximise the mobilisation of private finance.
- Increase the proportion of MDB lending which is focused on climate related investment.
- Put in place the domestic regulations and carbon pricing measures which make investment in clean technology economic for both MDB and private investors.

In addition, it is important to be clear about the major role that China will and must play in climate finance to support investment in developing countries. In the COP 29 text shown on Exhibit 25 that is covered by the vague words of paragraph 9. In the language of COPs, China is a developing country, and financial flows from China to say Southeast Asia or Africa, count as “south-south” cooperation, and are presented as marginal add-ons to the core flow of money from developed to developing countries.

But as I argued in Lecture 2, it is inevitable that China will play not a marginal role but a massive role and probably a bigger role than Europe in financing the energy transition in developing countries, both because it runs a large current account surplus which reflects excess domestic savings, and because China is the dominant provider of clean technology equipment and already provides large-scale finance support for the purchase and installation of that equipment.

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[35] See ETC (2024), *NDCs, NCQG, and Financing the Transition: Unlocking Flows for a Net-Zero Future*, https://www.energy-transitions.org/publications/ndcs-and-financing-the-transition/

Grant and concessional finance focused on specific priorities or lowest income countries

As for Paragraph 8 of the Baku agreement, the precise meaning of the $300 billion figure is unclear. The concept behind having a separate lower figure is that, separate from investment in middle- and lower-income developing countries, there is a need for grant or concessional finance to address two priorities:

- Support for the lowest income countries which could not sustainably take on new debt finance at market rates. This finance could be to support investment in clean economic development, but could also support adaptation investments by the most vulnerable countries.
- Actions which must be achieved in order to limit global warming to acceptable levels, but which will not occur unless someone is willing to pay – in particular for instance to achieve the early retirement or rundown of generation from existing coal assets.

The crucial question is how much of such finance is needed and how much can reasonably be provided by those developed nations (sadly now excluding the US) which are still committed to addressing the causes and consequences of climate change:

- At COP 21 in Paris, developed countries reaffirmed a commitment to jointly mobilise $100 billion per year by 2020 to help developing countries with mitigation and adaptation. But this apparent promise was made vague by the fact that it could include not only public but also private commitments, over which governments have no clear control. Whether the promise was subsequently met is unclear and contested.
- The Baku agreement increased this apparent promise to $300 billion per annum but again left it vague where the money would come from. As a result, it will be equally difficult to gauge how much of this promise is ever fulfilled.

The key priority is therefore to cease making vague and undeliverable promises, and to instead make commitments which are clear and credible. Debates on global finance at future COPs should therefore aim to achieve:

- Specific commitments of grants or concessional finance to support mitigation or adaptation investment in the lowest income and most vulnerable countries.
- Credible combinations of public and private finance from higher income countries (including some still formally defined as developing under the United Nations Framework Convention on Climate Change (UNFCCC) framework) to achieve the early rundown of existing coal generation in developed countries outside China.
- With the total public finance commitments from the responsible developed countries bound to be far less than the $300 billion headline figure included in paragraph 8 of the Baku agreement.

Credible commitments to deliver $10s of billions of annual publicly funded grant and concessional finance would be more valuable than apparent commitments to much larger figures from a vague combination of sources.

Changing the way climate finance is debated

Overall therefore, effective action on climate finance requires a change in the way in which global debates have until now been conducted:

- Past debates at COPs have been processes in which major developing countries such as India insist on a very large headline figure with little definition of what the figure covers, while developed countries appear to agree significant commitments expressed in such vague terms that it is impossible subsequently to work out whether they have actually been delivered.
- Future COPs should focus on agreeing the specific actions which can unleash both:
    - The very large financing flows required to seize the investment opportunity across all developing countries.
    - And the much smaller finance flows which must be provided on a grant and concessional basis to achieve specific objectives or to support the lowest income and most vulnerable countries.

Resetting global climate diplomacy

Greater clarity and honesty on the climate finance debate must however sit within a wider reset of international climate diplomacy.

From the beginning of international climate negotiations in the 1990s there has been an assumption that developed countries must lead the way in emission reductions, both in their own countries, and via the technological and financial assistance they give to developing countries.

And an assumption that commitments to emission reduction by developing countries are to a significant degree dependent on the scale of such assistance.

This is formalised in some developing country Nationally Determined Contributions (NDCs) which are explicitly "contingent" on various forms of future support.[36] But more generally it is reflected in the tone of many COP discussions, in which the willingness of major developing countries such as India to support stretching global or national emission reduction targets has been seen as dependent on whether developed countries come up with a big "Climate finance" offer. At COP 26 in Glasgow for instance, the Indian spokesman made it clear that "g*lobal action on climate change is contingent on the delivery of timely and adequate finance".*[37]

This philosophy reflects three key facts or assumptions:

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[36] For an assessment of the nature and adequacy of country NDCs, see ETC (2024) *Credible Contributions : Bolder plans for higher climate ambition in the next round of NDCs* https://www.energy-transitions.org/publications/credible-contributions-bolder-plans-for-ndcs/

[37] Scroll (2021), *Developed countries must provide finance to help combat climate change: India at COP26 summit*, https://scroll.in/latest/1010140/developed-countries-must-provide-finance-to-help-combat-climate-change-india-at-cop26-summit

- First, that developed countries have higher emissions per capita both current and historic, and therefore a greater responsibility to reduce fast.
- Second, that developed economies have great technological capacity to reduce emissions at low cost.
- Third, that because developing countries need simultaneously to decarbonise and to grow energy supply to support prosperity growth, they face a more difficult and expensive energy transition challenge than the developed countries.

But each of these assumptions is challenged by developments which have occurred over the last three decades **[Exhibit 27].**

In 1990, developed countries accounted for 58% of global emissions, and developing 42%: today those proportions are 28% and 72%. But within the developed country share, 11% of global emissions come from the US, whose President believes that climate change is a hoax and which has withdrawn from the UNFCCC, and 5% comes from Russia, which though nominally committed to the COP process, in practice has no interest in reducing its own emissions, or in helping developing countries achieve emissions reductions.

Only 12% of emissions now come from what we might call the "responsible developed nations" who are seriously committed to limiting global warming.

And looking forward, these countries will become still less important.

Exhibit 28 shows the cumulative CO_2 emissions which will come from different groups of countries if they meet both their NDC reduction commitments and their stated net zero targets. It shows that the EU and UK, plus Japan, Korea, Canada and Australia, would account for 57 Gt out of a global total of about 790 Gt, i.e. about 7%. While China could have cumulative emissions of 260 Gt, India over 100 Gt, and with large emission wedges arising from multiple countries in the Middle East, Eurasia and Southeast Asia.

What the group of "responsible developed countries" does to reduce emissions is now far less important than what China, India and other major developing countries do.

Meanwhile the assumption that developed countries as conventionally defined have superior technological capability is outdated by the rise of China. The idea that there is a major technological transfer issue in clean technology is in any case overstated: unlike in pharmaceuticals, intellectual property rights and licensing fees are not a major impediment to the cost-effective installation of clean technologies in less developed countries. But if there is a technological transfer issue, it is China which leads in almost all the technologies which need to be transferred.

Third and finally, the idea that developing countries face a more expensive decarbonisation challenge is contradicted by the comparison of renewable power auction results shown on **Exhibit 29.** It indicates a strike price for the UK's Allocation Round 7 (AR7) offshore wind auction 2.5 times the strike price in a recent renewables auction in India:

- But the UK price is indexed to inflation, while the Indian result is fixed nominal and will fall by 50% in real terms over the term of a 20-year contract.
- And the UK contract is for delivering power whenever the wind blows, with no supplier responsibility to provide balancing services: while the Indian contract is to supply power for 75% of all hours, rising to 85% in three years' time, and with the developer

therefore needing to invest in a combination of wind, solar and storage to deliver that promise.
- On a truly equivalent basis, the UK price is more like four times the Indian price than the 2.5 multiple which the strike price comparison suggests.

This strongly reinforces the conclusion of the ETC's 2025 report on Power Sector Transformation which projected that total system generation costs in renewable dominated power systems will be much lower in the global sunbelt than in the high latitude windbelt, with implications not only for costs face by household electricity consumers, but also for electricity costs in energy intensive heavy industry.[38]

It is going to be much cheaper to build zero carbon electricity systems in many developing countries than to decarbonise existing fossil fuel dependent systems in developed ones: mitigation costs are going to be lower in the sunbelt than the windbelt.

And that has profound implications for debates about the fair distribution of emissions between countries.

I recently showed Exhibit 28 to a Chinese colleague and ETC member, and I suggested that it implied that China must tighten its emission reduction target to become compatible with a well below 2°C limit. In response, and after first suggesting that we should look at whether the figures for India aren't too low, he said "*but of course we could still achieve well below 2°C if the EU and UK delivered negative emissions"*.

And the argument is often made that because of developed countries' historic emissions, their fair share of future emissions should be negative. But the time has come for blunt talking – any idea that developed countries are going to make a significant unilateral contribution to achieving a well below 2°C limit by paying for large scale negative emissions is neither practical politics nor good welfare economics.

This does not preclude the possibility that later in this century all countries might jointly agree to share the cost of the large carbon removals which will be needed if the world is to return to a +1.5°C temperature after the mid-century overshoot which is now inevitable.

But if during the next 5 or 10 years any European government came come back from a COP having promised to pay for negative emissions sufficient to move the dial on future global warming, that would be a wonderful gift for the right wing populists parties now committed to abandoning national net zero targets.[39]

But it would also be incompatible with a rigorous definition of economic equity.

Emissions, whether historic or present, are not valuable to countries per se, but because they allow countries to use cheaper fossil fuel energy rather than more expensive alternatives. But if the alternatives are cheaper, there is no value in emissions. Any attempt to determine fair emission shares by counting emissions per se, rather than the emissions multiplied by the

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[38] ETC (2025), *Power Systems Transformation: Delivering Competitive, Resilient Electricity in High-Renewable Systems*, https://www.energy-transitions.org/publications/power-systems-transformation/
[39] BBC (2025), *Tories pledge to scrap landmark climate legislation,* https://www.bbc.co.uk/news/articles/czrp2k3m3deo

different costs required to reduce them in different places and different dates, is intellectually flawed. Annex A sets out a simple example to illustrate this point and the implications for robust theories of equitable shares of cumulative emissions past and present.

Debates about fair shares must therefore focus on today's emissions and cumulative emissions looking forward. And the key decisions which will determine whether we limit global warming to well below 2°C are going to be made in Beijing, Delhi and other major developing countries, not in Brussels or London.

Those countries will have to decide whether to tighten their emission reductions targets, not in return for a financing offer from the developed world, but because they recognise that global warming poses a severe threat to their people's welfare, which they are determined to avoid by cutting their own emissions and urging others to do likewise.

In Lecture 1 I presented analysis from a recent BCG / Cambridge University study which argued that the costs of inaction on climate change (i.e. the additional costs which humanity will face if it allows global warming to reach 3°C rather than 2°C), will reach about 11-24% of cumulative global GDP this century, versus required mitigation investments of 1-2%. The analysis also suggests that many countries in the global sunbelt, which will enjoy lower mitigation costs than the high latitude windbelt, face higher costs of inaction **[Exhibit 30].**

That still leaves it essential for the responsible developed nations to cut emissions fast:

- We should reduce our emissions faster than the developing countries, achieving the ~90% reductions by 2040 and net zero by 2050 to which the EU and UK have both committed.
- We should stick to our 2035 ICE passenger vehicle sales bans because that will help drive further progress of EV technology.
- We should achieve almost complete decarbonisation of our electricity systems by the mid-2030s, not only because that is essential to drive rapid emissions reductions, but because it will provide powerful demonstration of the feasibility of running power systems with high levels of intermittent renewables.
- We should play a major role in supporting development banks across the world and oppose any US attempts to limit their ability to finance development which uses Chinese equipment, since any such limits immorally impose unnecessarily high costs on developing countries.
- We should lead on carbon pricing in all the hard to electrify sectors and convince other countries to do the same.
- And we should continue to provide direct grant and concessional finance support to the lowest income countries.

But all of that will only be successful in limiting global warming to well below 2°C if China, India and the other major developing countries are also committed to the actions needed to achieve that objective.

In summary

So at the end of three lectures, let me go back to where I began.

Humanity could not have achieved the transformation in living standards which has occurred over the last 200 years, without a 30 times increase in energy use **[Exhibit 31].**

But today 80% of our energy comes in fossil fuel form, and that is driving a rise in global temperatures which have already reached 1.5°C above pre-industrial levels **[Exhibit 32].** That warming is already producing catastrophic weather events across the world, with huge losses resulting, both economic and of people's lives **[Exhibit 33].**

This will get worse with every 0.1°C of further warming and dramatically so if we allow global warming to rise above 2°C.

But as of today, on the basis of the stated policies to which countries are committed, we are heading to around 2.5°C of warming by the end of this century **[Exhibit 34].**

That would be a catastrophe for humanity and we must prevent it.

We have the technologies to do that while delivering abundant energy to support rising prosperity across the world.

There are transitional costs to be faced but they are very small compared with the damage which unconstrained climate change will wreak.

And there is still a feasible pathway to limit global warming to well below 2°C.

I hope I have convinced you.

Annex A: Climate Justice and Historic Emissions

To limit global warming to acceptable levels requires global greenhouse gas emissions to fall to net zero across all countries: but current emissions per capita and income levels per capita very greatly, both between and within countries. The Rio Declaration on Environment and Development (1992) therefore established the principle of "*common but differentiated responsibilities*" to reduce emissions. This implies that all countries should have plans to eventually reach net zero emissions, but that the pathway from today's level to a future zero point should vary to reflect countries' emissions per capita and income levels.

It is intuitively obvious that the application of this principle should at least reflect emission and income levels (and should ideally apply both between and within countries). Richer countries/people with higher emissions should reduce their emissions at a faster pace than poor countries/people.

In addition it is often asserted that any fair distribution of the remaining "carbon budget" (i.e. the cumulative future GHG emissions which can still be emitted while staying within a defined temperature target) should include countries "historic emissions" since these past emissions have contributed to climate change, and have used up the carbon budget which would otherwise be available to other countries.

Since today's developed economies have been primarily responsible for these historic commissions, this can imply that a fair allocation of future carbon budget should entail developed countries committing to negative emissions, to allow developing countries more "carbon space". At the extreme, the principle proposed could be that the fair allocation of emissions should entail an equal per capita cumulative level of emissions combining both historic and future.

But any theory of climate justice which refers solely to the quantity of emissions, and which ignores the varying cost of reducing emissions is profoundly flawed. Fundamental ethical principles can often be best identified by considering a stylised hypothetical case. Imagine the following such case:

- The world is comprised of two islands, which have in the past developed quite separately, with no inter country trade or investment flows, or technology transfer.

- Island A began an industrial revolution over a century ago, initially relying on fossil fuels technologies since those were the only ones available which could enable industrial and economic development. It has emitted 1000 Gt of emissions over its history, but 30 years ago it became worried by about climate change and has developed and deployed zero carbon technologies. In the early stages of this transition, the clean technologies were far more expensive than the fossil fuel technologies, and had to be heavily subsidised, but they have now achieved cost priority or better when applied on a greenfield basis. Current emissions are now 10 Gt per annum, deriving entirely from legacy assets in heavy industry, but these will fall to zero within 10 years: future cumulative emissions from now to the net zero point will be 50 Gt.

- Island B has until now been an entirely non-industrialised country, with subsistence farmers using no modern energy supplies, and with traditional use of biomass offset by new biomass growth. Cumulative historic net emissions have been zero. Island lan B now plans to industrialise and grow prosperity using the clean technologies which have been developed by Island B.

- The cumulative historic and future carbon budget compatible with limiting global warming to an acceptable level is 1050 Gt.

Given these assumed conditions, what is Island B's fair share of total global cumulative emissions from the start of the first industrial revolution to the point of global net zero?

The answer is zero emissions. Because Island B can now build a prosperous economy, dramatically increasing its energy use, but with zero emissions.

The essential insight here is that countries do not derive welfare from emissions per se: nobody gets an increase in standard of living because CO2 and other GHGs are rising up to the atmosphere. Emissions are only valuable if they reduce the cost of energy in conditions where clean technologies are more expensive than fossil fuel technologies. For Island A to achieve net zero emissions 30 years ago (when solar PV panels and lithium ion batteries cost over 20 times as much as today) would have entailed a significant reduction in standard of living; insisting that Island B now avoids any phase of fossil fuel based growth, impose no cost, and therefore no negative impact on human welfare.

It is therefore impossible to develop a coherent theory of climate justice solely by reference to the quantity of emissions historic and future. Any coherent theory has to be based on the fair distribution of the **costs** of delivering energy-based services without emissions.

Of course, this case is highly stylised, and real-world conditions are far more complex. Clean technology costs are now below those for fossil fuels in many applications and locations, but there are still green cost premia in some sectors. If Island B needed cement to build an economy, doing so with zero emissions would impose some cost even if solar plus batteries are now a cheaper way to produce round the clock electricity than gas turbines.

And none of this denies that current income levels are an important determinant of the fair pace of emission reductions. It still leaves a strong theoretical case for the saying that richer people (whatever country they live in) should reduce emissions faster than poorer people, and in some cases, that rapid reductions in rich individual or country emissions should create space for rising transitional emissions from poorer people or countries if avoiding those emissions would impose a cost.

But it does illustrate that any theory of fair emissions allocations which refers solely to emission quantities and not to costs of reductions is theoretically flawed; and that this flaw is hugely important when considering historic emissions given enormous differences in the cost of emissions reduction at different points in time.

Any proposal that a globally agreed temperature objectives should be achieved by demanding large negative emissions from developed countries, solely by reference to the past quantity of historic emissions, is therefore not only a political non-starter, but theoretically unjustified.