LSE Works: Grantham Research Institute on Climate Change and the Environment

The Low-Carbon Industrial Revolution

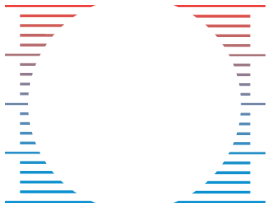
Professor Lord Stern of Brentford
Chairman, Grantham Research Institute on Climate Change and the Environment. Chairman, ESRC Centre for Climate Change Economics and Policy

Gerard Lyons
Chief Economist and Group Head of Global Research, Standard Chartered Bank

Professor Michael Jacobs
Visiting Professor, Grantham Research Institute on Climate Change and the Environment

Professor Judith Rees
Chair, LSE

LSE events



Centre for
Climate Change
Economics and Policy

Grantham Research Institute on
Climate Change and
the Environment

The low-carbon industrial revolution

Nicholas Stern

Chair of the Grantham Research Institute on
Climate Change and the Environment,
IG Patel Professor of Economics & Government,

London School of Economics and Political Science

LSE Works

17 March 2011

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

Living With Environmental Change

Munich RE

LSE THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

UNIVERSITY OF LEEDS

THE GRANTHAM FOUNDATION FOR THE PROTECTION OF THE ENVIRONMENT

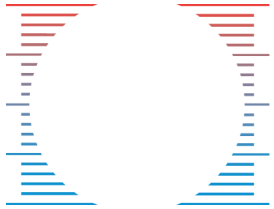
Four part structure

Part 1: Risk and magnitude of change

Part 2: The low-carbon industrial revolution: opportunity, creativity and innovation

Part 3: Policies for the transition to low-carbon growth

Part 4: The Grantham Research Institute and 'green growth'



Centre for
Climate Change
Economics and Policy

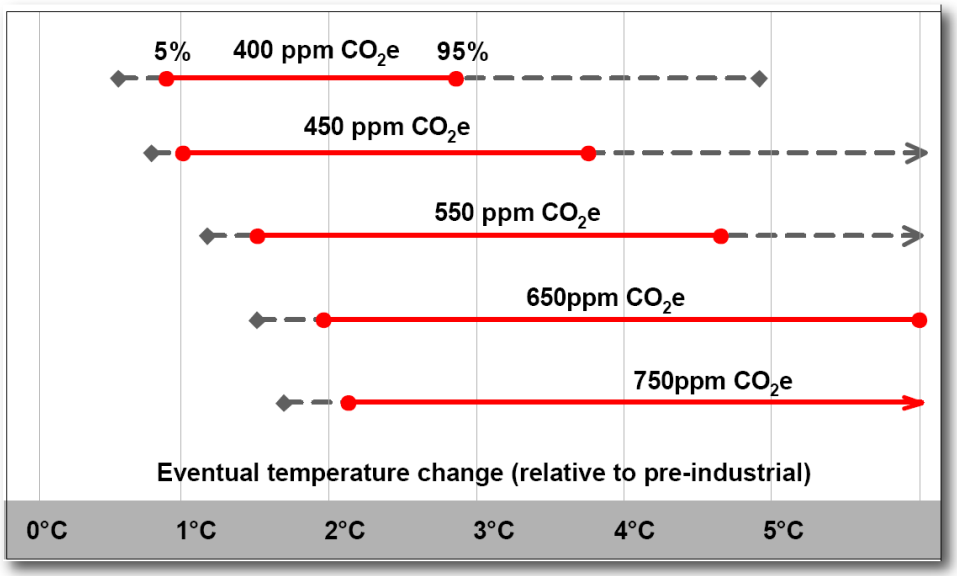
Grantham Research Institute on
Climate Change and
the Environment

The low-carbon industrial revolution

Part 1: Risk and magnitude of change

Risk on a global scale (I)

- Greenhouse gas concentrations or stocks have increased from around 285ppm in the 1800s to over 430ppm CO_2e today.
- We are adding at a rate of over 2.5ppm per year (likely to accelerate with little or weak action). BAU likely to take us over 750ppm by the end of the century.
- This level of concentration would result in a large probability, perhaps 50%, of an eventual temperature increase of more than 5˚C compared with the pre-industrial era. This would be enormously destructive.

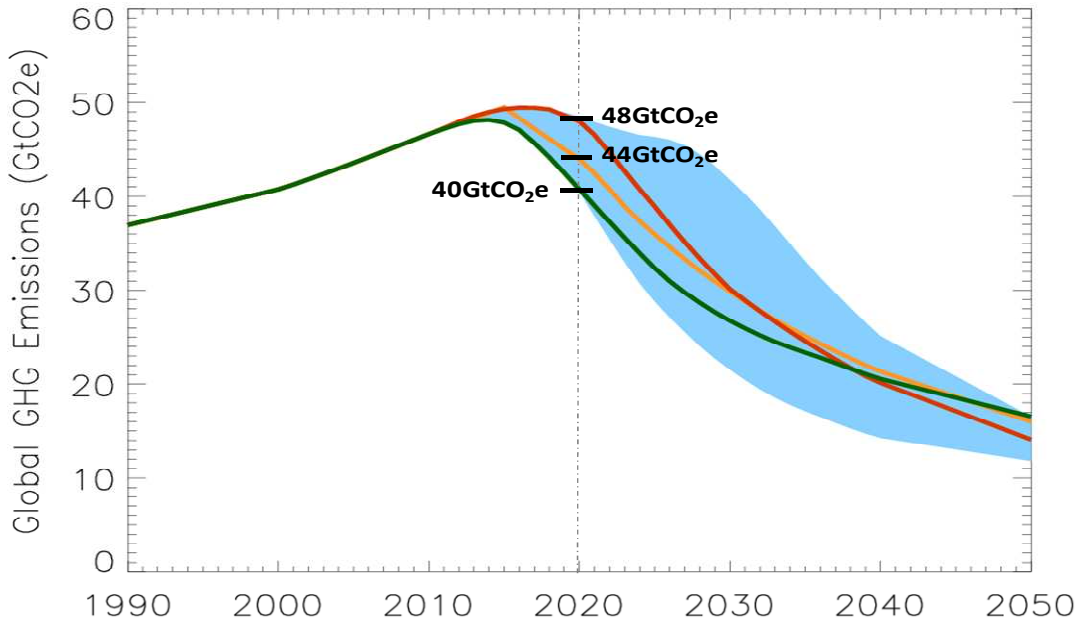


Probability distribution of possible temperature increases presented as 5-95% ranges. As a *rough* approximation, the distribution for 450ppm is centred around 2℃, for 550 around 3℃, for 650 around 4℃, and 750 around 5℃.

Risk on a global scale (II)

- Physical and human geography would be transformed with temperature increases of 5℃ or more. Deserts, coastlines, rive rs, rainfall patterns, the reasons we live where we do, would be redrawn.
- The planet has not seen such temperatures for 30 million years. Humans (as *homo sapiens)* have been around 200,000 years. Temperatures were around 5℃ lower than now during the last ice age 10 -12,000 years ago: population was concentrated in low latitudes.
- Potential cause of migration of hundreds of millions, perhaps billions, of people around the world: likelihood of severe and sustained conflict.
- Damages from climate change will accelerate as the world gets warmer. Impacts mostly via water in some way: storms, floods, inundations, droughts, desertification, sea level rise.
- Also nonlinearities and tipping points, e.g., collapse of Amazon forest or thawing of permafrost releasing methane.
- Such huge risks reinforce the importance of limiting the rise in temperature to 2℃ (or less). It would be a profound mistake to se e 2℃ as “too difficult”.
- Highly inequitable process.

The 2°C target: implications for emissions



Source: Bowen and Ranger (2009)

- Holding below 500ppm CO_2e, and reducing from there, is necessary to give a reasonable (say 50-50) chance of staying below 2℃. This requires bringing emissions down from 47Gt CO_2e today (reduced by economic slowdown – might have been 50) to below **20Gt CO_2e** (approx. 50% of 1990 levels) by 2050.
- A plausible emissions path is around **47Gt** CO_2e in 2010, **44Gt** in 2020, **under 35Gt** in 2030, and **under 20Gt** in 2050. Likely to have to go **'well under'.** Clearly necessary to 'peak' before 2020.

Centre for Climate Change Economics and Policy

*These results are based on the Hadley Centre climate model MAGICC. Thanks to Jason Lowe and Laila Gohar for running these trajectories through the model.
Gt ≡ gigatonnes ≡ billion tonnes

Grantham Research Institute on Climate Change and the Environment

Emissions: what our targets should be

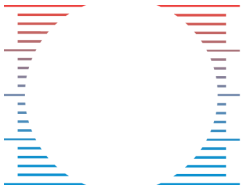
- Dangerous to ignore the arithmetic.
- As the global population will probably be around 8 billion in 2030 and 9 billion in 2050, these simple headline numbers mean that emissions have to average around 4 tonnes per person in 2030 and 2 tonnes per person in 2050.
- This 2050 figure is at least 80% below the EU's current emissions per person. US emissions are above 20 tonnes per person, China around 7.
- Cannot afford any delays: a delay of 10 years in initiating action would be likely to increase the 'starting concentration' from around 435ppm CO_2e to over 465ppm CO_2e, making holding below (and then decreasing from) 500ppm CO_2e much more costly or impossible.

China: key to achieving a 2°C target

- China has indicated a cut in emissions per unit of GDP (emissions intensity) of 40-45% 2005-2020:
  - The 12th plan - **17%** reduction (target 2011-2015);
  - The 13th plan - **17%** reduction (assumed 2016-2020);
  - To reach the 45% would require that the 11th plan had cut emissions intensity by **20%**.* Given that the energy intensity (energy/output) target looks to have been achieved in the 11th plan China seems on course for the 45%.
- Take 9 billion tonnes CO_2e approx., output 7% growth p.a. and a 31%** reduction in emissions intensity 2010-2020:

  → **12 billion** tonnes CO_2e in **2020**
  → **15 billion** tonnes CO_2e in **2030** (if add further 3 billion tonnes 2020-2030)
- *World* emissions budget for 2℃ path around 30-32 billion tonnes in 2030. China would be close to half of world target with 20% of population.
- World target would likely be out of reach unless China could peak at around 13-14 billion tonnes in early 2020s and return to around 9 billion tonnes p.a. by 2030.
- Implies cut in emissions intensity by around a factor of four by 2030, or 29%, on average, over each of the next four 5-year plans.***

* (0.83 x 0.83 x 0.8) = 0.55 (a 45% reduction)
**$(0.83)^2$ = 0.69 (a 31% reduction)
***$(0.71)^4$ = 0.25



Centre for
Climate Change
Economics and Policy

Grantham Research Institute on
Climate Change and
the Environment

The low-carbon industrial revolution

Part 2: The low-carbon industrial revolution: opportunity, creativity and innovation

The new energy-industrial revolution and low-carbon growth (I)

- High-carbon growth will kill itself as a result of the hostile environment it will create – hundreds of millions displaced. Likely consequences are extended, severe and global conflicts. It is not a credible medium-term option for growth.

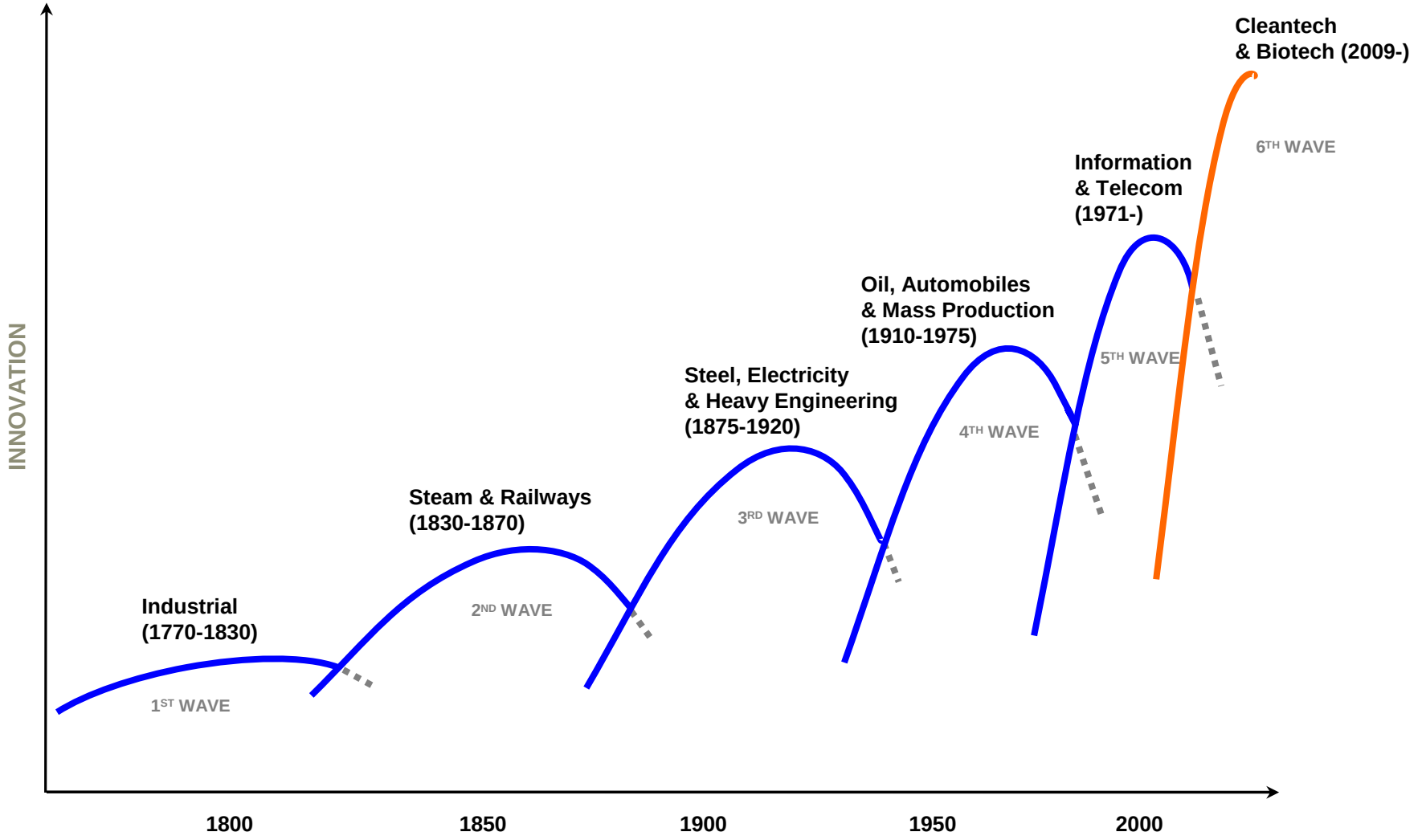
- Will require strong action in all regions of world and in all economic sectors.

- If world emissions are to be cut by factor of close to 2.5 (nearly 50 billion tonnes in 2010 to below 20 in 2050) and world output grows by a factor of 3 then emissions/output must be cut by a factor of 7 or 8. Surely an industrial revolution by any definition.

The new energy-industrial revolution and low-carbon growth (II)

- New industrial revolution and the transition to low-carbon growth constitute a very attractive path.
- Likely to bring two or three decades of dynamic, innovative and creative growth, and large and growing markets for the pioneers.
- Probably similar, or larger, growth effects, to railways, electricity, IT in earlier eras.
- When achieved, low-carbon growth will be more energy-efficient, more energy secure, more equitable, safer, quieter, cleaner and more bio-diverse. Far more attractive than what has gone before. Far greater potential to improve China's living standards and quality of life.

Waves of innovation



Centre for Climate Change Economics and Policy

Source: Based on Perez (2002) drawing on a diagram by Merrill Lynch (schematic not precise quantitative vertical axis).

Grantham Research Institute on Climate Change and the Environment

Green growth: what it might look like

More visible now:

- Energy efficiency across the board – half of what we need to do on energy.
- Agriculture:
  - Techniques for low-till agriculture can reduce emissions from tilling, save energy, save water, and provide climate resilience;
  - Avoiding flooding paddy fields reduces methane and saves water.
- Buildings:
  - Architects/engineers coming up with many ideas for energy efficiency and local power generation.
- Renewables and power.
- Natural gas has the potential to play a transition role on the path to a low-carbon future due to new discoveries and improved extraction technologies (Brown et al., 2009): substituting natural gas for coal in electricity generation can reduce emissions by around a half.

Green growth: where are we now?

- Firms are taking a long-run view:
  - Car manufacturers, e.g., General Motors developing hybrid/electric vehicles (even Ferrari);
  - Banks and financial institutions, e.g., HSBC/Deutsche/Crédit Agricole climate research and products;
  - Retail: Walmart, Tesco, Marks and Spencer…;
  - Many large long-term funds managing trillions of dollars seeking opportunities;
  - Firms are seeking and finding opportunities, e.g., DuPont finding $2bn p.a. in energy efficiency savings;
  - Firms are subjecting themselves to scrutiny and adopting tough targets, e.g., Carbon Disclosure Project.

Low-carbon growth: innovation and opportunity

- This is the start of a period of vigorous innovation and there will be (already are) exciting developments and 'breakthroughs' along the way.

- Recent innovations include:

  – solar cells printed on aluminium film using nanotechnology;

  – high-capacity batteries made with titanium dioxide coated carbon nanotubes;

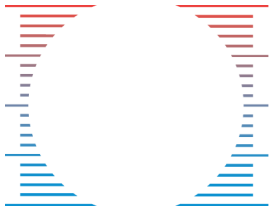
  – bacteria that produce biofuels or soak up CO_2 from the atmosphere;

  – carbon capture and storage (CCS) with storage in cement.

- A strong, globally-coordinated policy framework would help to facilitate high levels of innovation and growth.

Centre for
Climate Change
Economics and Policy

Grantham Research Institute on
Climate Change and
the Environment



Centre for
Climate Change
Economics and Policy

Grantham Research Institute on
Climate Change and
the Environment

The low-carbon industrial revolution

Part 3: Policies for the transition to low-carbon growth

Public policy for the transition

- Low-carbon growth is the only option in the battle for higher living standards: abandoning growth but maintaining current technologies will not reduce emissions.

- The central challenge is how to organise the transition; will involve both complex and dynamic processes and difficult questions on how best to promote structural change.

- The transition must be supported by transparent, long-term and credible public policies, and public investment that create a positive environment for innovation and change.

- A perspective which embraces a Schumpeterian understanding of ‘endogenous growth’ and creative destruction will be central to the transition; new firms and methods drive out old. But will not happen without policy.

The role of public policy: market failure (I)

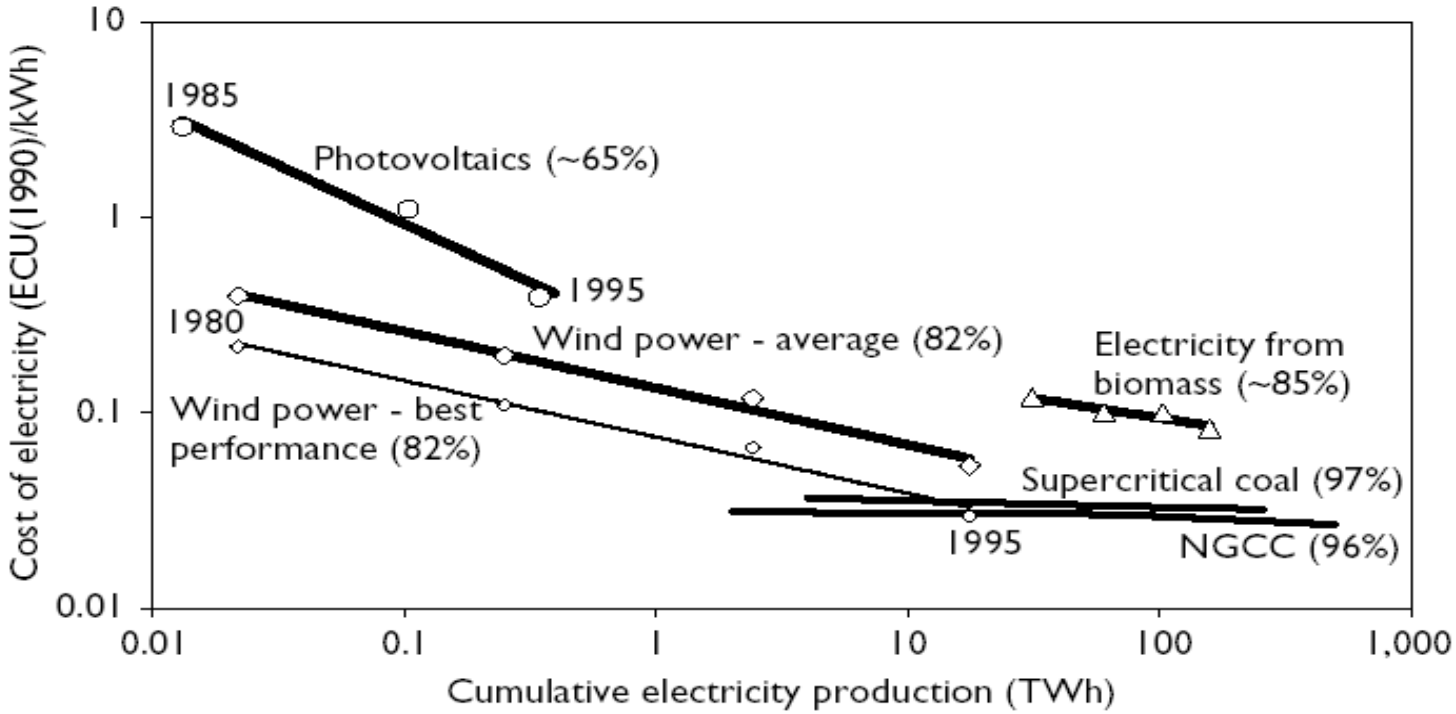
- Policy must correct the biggest market failure the world has seen - failure to price greenhouse gas emissions - and will also involve at least five further externalities of great relevance:
  - ***Greenhouse gases*:** emissions severely damage consumption and productive prospects of others;
  - ***Learning*:** R&D and demonstration/deployment bring learning and exploitation of economies of scale and scope;
  - ***Risk*:** weakness in capital markets, particularly in relation to major risks and long term (policy and technology risk are particularly relevant);
  - ***Networks*:** enabling access to, e.g., transport systems, electricity grids (smart and low transmission costs), communication networks, to broaden options, reduce transactions costs, facilitate smarter decisions;
  - ***Information*:** understanding the GHG properties of what we buy, consume, use, and what options are available;
  - ***Co-benefits*:** a low-carbon future will be quieter, safer, cleaner, more biodiverse and more energy secure.

The role of public policy : market failure (II)

- Policy for the market failures. Different failures point to different instruments:
  - ***Greenhouse gases:*** carbon taxes / cap-and-trade / regulation. A combination of all three likely to be needed for different circumstances;
  - ***RD&D:*** Assistance with R&D, tax breaks, feed-in tariffs for deployment;
  - ***Imperfections in risk/capital markets:*** risk sharing/reduction through guarantees, equity, feed-in tariffs, floors on carbon prices, green investment banks;
  - ***Networks:*** rules governing electricity grids, building regulations, mandatory efficiency standards, community based 'street-by-street' schemes;
  - ***Information:*** labelling and information requirements on cars, domestic appliance, products more generally, awareness of options;
  - ***Co-benefits:*** regulation of dirty and more dangerous technologies, valuing biodiversity.

Promoting technological innovation (I)

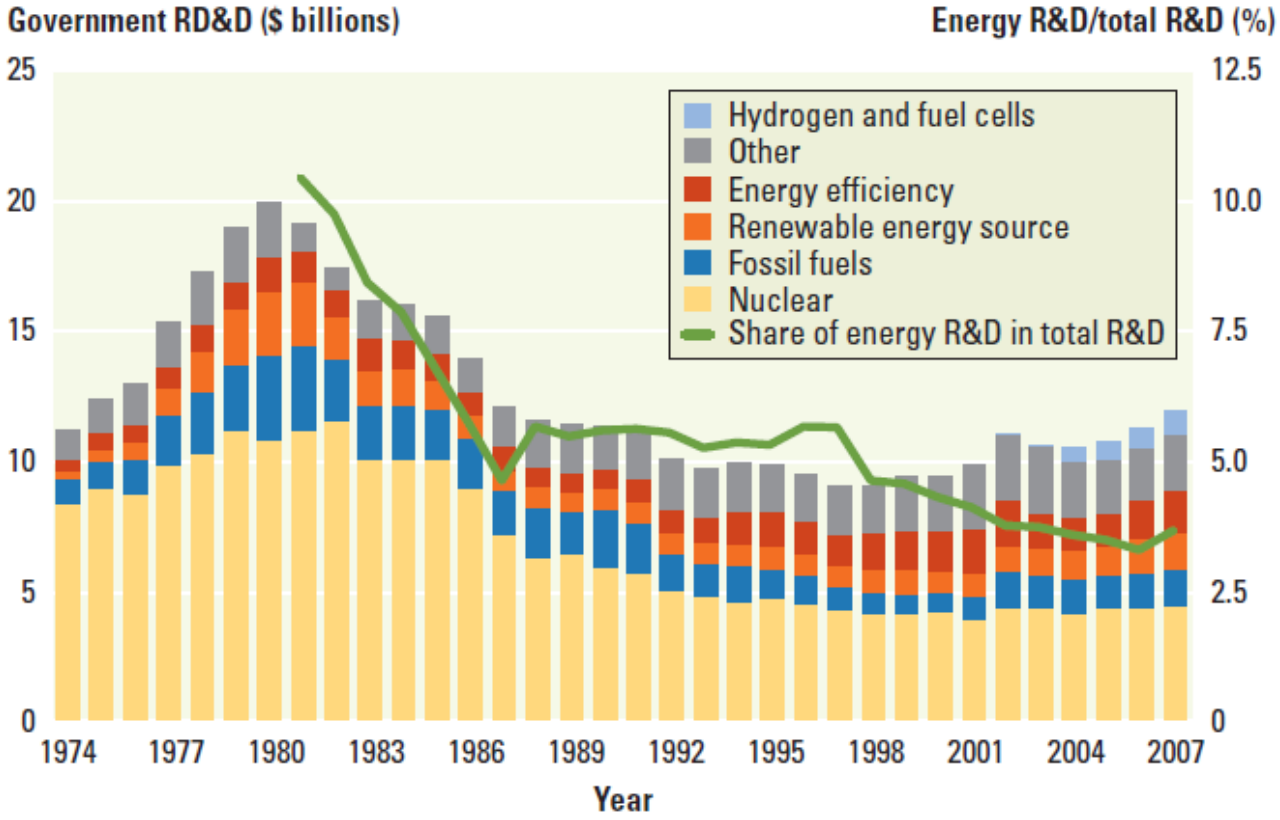
Electric Technologies in EU, 1980-1995



- Cost of electricity and electricity produced from selected electric technologies installed in the European Union 1980-1995. Numbers in parentheses are estimates of progress ratios.

Source: IEA (2000)

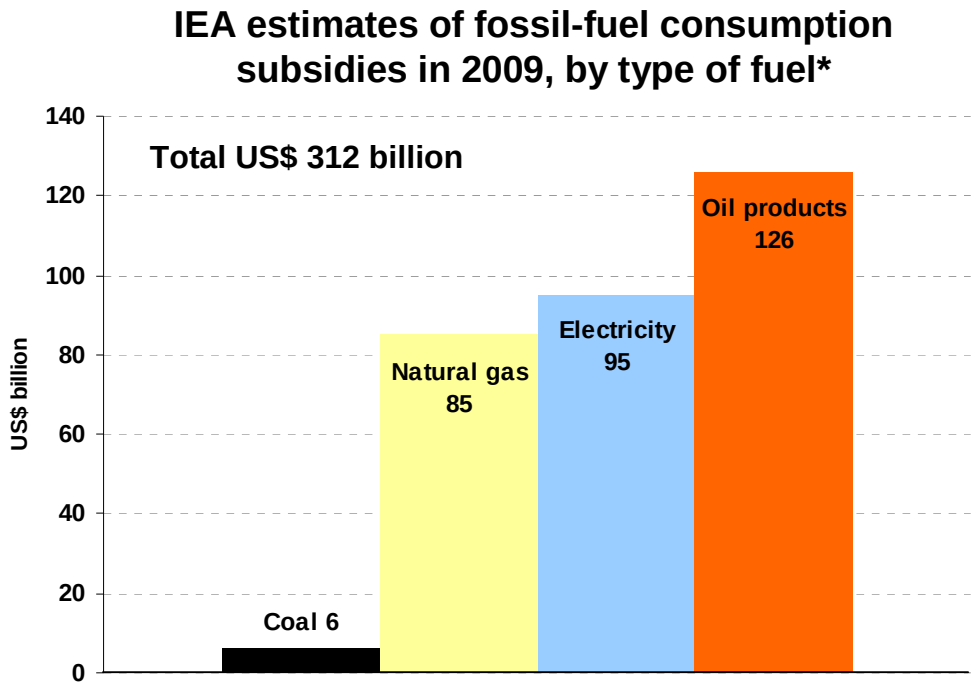
Promoting technological innovation (II)



Sources: IEA 2008a; IEA, http://www.iea.org/Textbase/stats/rd.asp (accessed April 2, 2009); Organisation for Economic Co-operation and Development (OECD), http://www.oecd.org/statsportal (accessed April 2, 2009).

Note: RD&D calculated at 2007 prices and exchange rates. Values on left axis are for RD&D (that is, including demonstration in addition to research and development), as is typical in the energy sector. However because totals of cross-sectoral R&D alone are available, the right axis only includes R&D.

Promoting technological innovation (III): support for consumption/production of fossil-fuels far bigger than for energy R&D



*IEA estimates are based on the price-gap method with a sample size of 37 counties, which the IEA state represent 95% of global subsidised fossil-fuel consumption. All but 2 of the 37 countries are non-OECD.

- Total production subsidies could be in the order of US$ 100 billion p.a., although there are no current analyses of production subsidies that systemically examine a wide range of countries.

Centre for Climate Change Economics and Policy

Source: IEA (2010); IEA, OPEC, and The World Bank (2010).

Grantham Research Institute on Climate Change and the Environment

The role of public policy: research for better design (I)

- The design of policy is key – good analytical work in policy will help drive the transition.

- Fischer (2008) finds R&D subsidies are effective only if there is a price on carbon and spillover effects are significant. R&D subsidies on their own are ineffective. A carbon price is required to provide the incentive to adopt new technologies.

- Popp (2006) finds combining carbon taxes and R&D subsidies leads to the best outcomes.

- A number of studies find a portfolio of different policies, some broad and some targeted, facilitate innovation and lower costs of emissions reductions relative to any single instrument (e.g., Otto and Reilly, 2008; Fischer, 2008; Fischer and Newell, 2008; Acemoglu, 2009).

The role of public policy: research for better design (II)

- Policy to ensure technology diffusion is also key. Research using patent data finds that capacity building, removing trade barriers and strong intellectual property rights regimes encourage international technological diffusion (Dechezleprêtre et al., 2009).

- The direction and rate of technical progress and the stages in the innovation process around low-carbon technologies can be influenced through good policy (Jamasb and Köhler, 2007).

- Policy design must also consider constraints and general equilibrium feedbacks throughout the economy (Dreze and Stern, 1990).

- Crucial to consider how policy instruments will interact and change over time. For example, some renewable targets or policies may focus efforts on technologies that are not necessarily the most cost competitive; this may result in slower development of other technologies with great future potential.

The role of public policy: moving to scale

- Good policy must enable scale of action:
  - International standards;
  - Common procurement policies by cities;
  - Infrastructure, e.g., electric charging points, hydrogen stations, public transport;
  - Smart grids crucial: capable of cheap long-distance transmission and accommodating different kinds of generation and use.
- Good policy must also be: flexible (we will learn); targeted at the appropriate level (community, regional, national or global); encourage collaboration; risk sharing; and beyond simplistic economics. Must combine flexibility and predictability.

The role of public policy: "shaping the debate"

- Strong debate in China and many other countries over low-carbon growth, what it may look like, and the opportunities it might bring.
- Important in the debate to show that low-carbon growth is an attractive alternative, indeed the only growth-option.
- Power of the example:
  - British Telecom saved £1.5bn between 2002 and 2006 from reducing energy costs;
  - Marks & Spencer plans to be carbon neutral by 2012 (plans to use food waste to generate power);
  - Walmart (CEO Lee Scott 2008) told 1,000 suppliers in China that high environmental and energy saving standards would be required: supply chains are crucial. And it is 'zero waste' and '100% renewable energy'.

The role of public policy: behaviour

- Promoting a shared understanding of responsible behaviour – beyond sticks and carrots.

- For example, alcohol and driving. In 1966 in the UK laws were introduced limiting the permitted levels of alcohol in the blood while driving. From many there was uproar and the shouts were of limitations of freedom.

- It seems strange to reflect on these attitudes now. Public discussion, education, experience, and evidence changed attitudes and the notion of what is responsible.

- There are, of course, penalties for the offences of drink-driving, these are the economists' sticks and carrots, but they have not been the whole story of public policy.

- Related public discussions around what is responsible are already taking place on climate change.

The role of public policy: promoting change (I)

- Industrial revolutions involve dislocation – candle makers and whaling disrupted by electricity.
- There will be vested interests that oppose change.
- There will be those who sow doubt in science: smoking/health; HIV/AIDS. (Refer David Michaels (2008) “Doubt is their product” and Naomi Oreskes and Erik M. Conway (2010) “Merchants of doubt”). Techniques include: suggestion that a few flawed papers in many thousands undermines overall case, that uncertainty over impacts implies that sensible assumption is that risks are very small, confusion of fluctuations and trend, misuse of short-term or local fluctuations….
- Dislocation must be managed.
- Responsible public debate (and responsible journalism) can deepen understanding.

The role of public policy: promoting change (II)

- Given the huge risks of delaying action and the scale of necessary changes we need to develop theories on how to foster rapid and radical change.

- During my time (1993-1999) as Chief Economist of the European Bank for Reconstruction and Development (EBRD) the mandate was to foster the transition to a market economy (including criteria associated with democracy and environment).

- Developed useful indicators of the "transition impact" of projects based, inter alia, on:

  – the potential power of the example;
  – the ability to scale up;
  – the enabling role of infrastructure;
  – the training in more market-based approaches including pricing, information, logistics, procurement, etc.;
  – aspects of finance which might provide for innovation and leverage;
  – small and medium enterprises; etc…

Summary

- Low-carbon growth is feasible and attractive. It is the only alternative to high-carbon growth. The debate can and must take place on all levels: national governments, firms, local communities. Should be integrated with other macro and international challenges of this decade.
- Public policy must be designed in the context of a collection of crucial market failures.
- Different failures require different policy instruments.
- Moving to scale is key: standards, infrastructure, national and global policy action, etc.
- Research on better policy design will help drive the transition.
- Broader perspectives on policy in terms of how to foster radical change.
- Dislocation.
- The debate can move forward through the power of example and engagement of communities.

Centre for
Climate Change
Economics and Policy

Grantham Research Institute on
Climate Change and
the Environment

The low-carbon industrial revolution

Part 4: The Grantham Research Institute and 'green growth'

Green growth: Nick Stern activities

- Highlights of recent lectures, papers and other activities on green growth, in collaboration with colleagues at the Grantham Research Institute (Grantham):
  - College de France lectures and colloquium 2010;
  - China Development Forum 2010 and 2011 (this coming Sunday in Beijing) and two separate policy papers on China's transition to a low-carbon economy;
  - Shanghai Expo November 2010, including a policy paper on low-carbon growth in China;
  - Bangalore Climate Change Initiative (for Karnataka) launched October 2010.
  - Sir Douglas Robb lectures – University of Auckland, NZ;
  - G20 Low-Carbon Business Summit in Seoul, Korea;
  - UN High-Level Advisory Group on Climate Change Financing;
  - International negotiations: Copenhagen and Cancun.
  - Interventions during Australian federal government formation September 2010.

Green growth: other activities (I)

- Low-carbon workshop on promoting green growth in January 2011 (organised jointly by Alex Bowen and the ESRC-supported centre CAGE at Warwick University).

- OECD 26th Round Table on Sustainable Development in Paris in December 2010 and the Green Growth Strategy Workshop in February 2011. Contributed feedback to the OECD on its draft synthesis report for ministers on green growth.

- Contributed a chapter assessing the effectiveness of UK climate-change policies for the 2011 Economic Survey of the United Kingdom (released yesterday).

- EBRD-Grantham study of the challenges to the 'transition' economies of moving to low-carbon growth paths.

- Alex Bowen has also spoken on green growth themes at the Asian Development Bank Institute and UK DECC.

Green growth: other activities (II)

- Alex Bowen and Nicola Ranger, in collaboration with the UK Met Office, published a major new policy brief in August 2010 on emissions pathways necessary to avoid more than 1.5℃ warming.

- A team from Grantham led by Simon Dietz collaborated with the investment consultants Mercer in a major new study on the implications of climate change for the strategic asset allocation of institutional investors. Involved pension and wealth funds, as well as the IFC, the Carbon Trust and Vivid Economics.

- Policy and Communications: at the forefront in making the case for action on climate change and green growth. Numerous interventions in newspapers, blogs and on television and radio.

- Grantham staff have worked with GLOBE on a joint study of climate change legislation in 16 major economies. The joint report was reviewed by parliamentarians at their Tianjin Forum in November 2010 and will be launched this month.

Green growth: future research

- Areas of future research:
  - evidence from economic history about past waves of innovation and the sources of growth more generally;
  - the interaction of business cycles, macroeconomic policies and long-run 'green' growth;
  - integrated assessment models to investigate the impact of policies to mitigate climate change on the rate and composition of growth;
  - the relationship between 'green' growth and job opportunities;
  - how adapting to climate change will affect growth in the longer run;
  - empirical studies of the impact of climate-change policies on environmental outcomes and productivity growth;
  - empirical studies of the impact of innovation policies on investment and productivity growth;
  - implications of the above analysis for the design of policy instruments.

Conclusions

- Two defining challenges of 21st century: managing climate change and overcoming world poverty. If fail on one, fail on the other.
- The risks of climate change are growing larger and more worrying.
- The UK and the EU's example will be crucial in influencing the world's transition to a low-carbon economy and thus how successful the world will be in managing the huge risks of climate change.
- New energy-industrial revolution and the transition to low-carbon growth constitute a very attractive path.
- The coming decade will likely establish the leaders in the new industrial revolution and they will demonstrate to the world the potential of the industrial revolution. China's 12th plan of great significance.
- A range of policies will be required that address both the fundamental market failure and the range of other barriers to the transition and which focus on fostering change.
- This is a new and exciting area of research and public policy. Much scope and potential for future research and influence. Grantham is establishing solid foundations.

References

- Acemoglu, D. et al., 2009, *The Environment and Directed Technological Change*, MIT, Harvard, NBER working paper.

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

- Brown, S., A. Krupnick, and M. Walls, 2009, *Natural Gas: A Bridge to a Low-Carbon Future?* Resources For The Future, December, Issue Brief 09-11.

- Dechezleprêtre, A., Glachant, M., and Y. Ménière, 2009, *What drives the international transfer of climate change mitigation technologies? Empirical evidence from patent data*, Centre for Climate Change Economics and Policy Working Paper No. 16 Grantham Research Institute on Climate Change and the Environment, Working Paper No. 14.

- Dreze, J., and N. Stern, 1990, *Policy reform, shadow prices and market prices*. Journal of Public Economics 42, 1-45.

- Fischer, C., 2008, *Emissions pricing, spillovers, and public investment in environmentally friendly technologies*, Energy Economics 30, 487-502.

- Fischer, C., and R. Newell, 2008, *Environmental and technology policies for climate mitigation*, Journal of Environmental Economics and Management 55, 142-162.

References

- HSBC, 2011, *Decarbonising China's growth: What China's green goals mean for heavy industry in the 12th Five-Year Plan*, HSBC Global Research, March.
- IEA, 2000, *Experience curves for energy technology policy.*
- IEA, 2010, *World Energy Outlook 2010*.
- IEA, OPEC, and The World Bank, 2010c, *Analysis of the Scope of Energy Subsidies and Suggestions for the G-20 Initiative*. Available at: http://www.g20.org/exp_04.aspx
- Jamasb, T. and J. Köhler, 2007, *Learning curves for energy technology: a critical assessment*, Cambridge.
- Michales, D., 2008, *Doubt is their product,* Oxford University Press.
- Oreskes, N., and E.M. Conway, 2010, *Merchants of doubt*, Bloomsbury Press.
- Otto, V., and J., Reilly, 2008, *Directed technical change and the adoption of CO2 abatement technology: The case of CO2 capture and storage*, Energy Economics 30, 2879-2898.
- Perez, C., 2002, *Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages,* Edward Elgar, UK.
- Popp, D., 2006, *R&D subsidies and climate policy: Is there a 'free lunch'?* Climate Change 77, 311-341.
- Stern, N., 2007, *The Stern Review: The Economics of Climate Change*, Cambridge University Press.

Centre for
Climate Change
Economics and Policy

Grantham Research Institute on
Climate Change and
the Environment