



Centre for
Climate Change
Economics and Policy



Grantham Research Institute on
Climate Change and
the Environment

How we can respond and prosper: the new energy-industrial revolution

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Lionel Robbins Memorial Lecture Series

Lecture 2, 22 February 2012



Five Part Structure

- Part 1: What we need to do and scale of investment.
- Part 2: Dynamic change - policies for the transition.
- Part 3: The role of the private sector.
- Part 4: What are the sectoral issues?
- Part 5: How are countries moving?

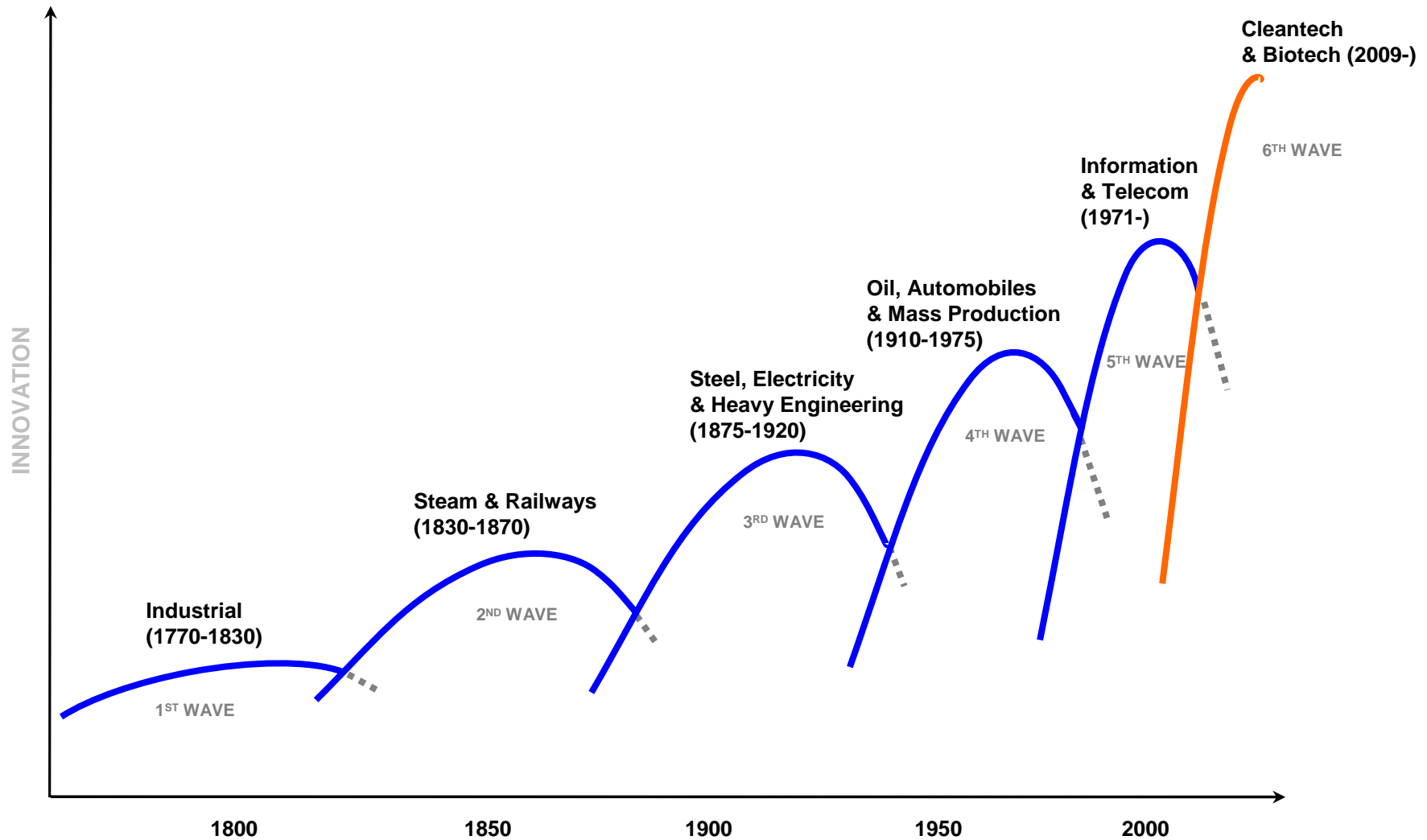
The new energy-industrial revolution (I)

- High-carbon growth will destroy itself as a result of the hostile environment it will create. It is not a medium-term option for growth for the world.
- Prudent risk management points to strong action (see Lecture 1, Part 3).
- For a 2 degree (50-50) path world emissions must come down from around 50 billion tonnes today to around 44 in 2020 to below 35 in 2030 and to well below 20 by 2050.
- If world emissions are to be cut by factor of close to 2.5 (2012-2050) and world output grows by a factor of 3 then emissions/output must be cut by a factor of 7 or 8.
- Will require strong action and major investment in all regions of world and in all economic sectors. Economy-wide, not just changing energy sources. Recasting of buildings, transportation, agriculture, manufacturing, communications, IT, ...
- Surely an industrial revolution.

The new energy-industrial revolution (II)

- History suggests major waves of technological innovation likely to bring two or three decades of dynamic, innovative and creative growth, and large and growing markets for the pioneers (see Perez, 2002 and 2010).
- Probably similar, or larger, growth effects, to railways, electricity, in earlier eras, and continuing ICT revolution.
- When achieved, low-carbon growth will be more energy-efficient, more energy secure, more equitable, safer, quieter, cleaner and more bio-diverse.
- Much more attractive than what has gone before with greater potential to improve world living standards and quality of life.
- Fortunate that will overlap with waves of technical change in ICT and biotech.
- Revolutions involve dislocation and disruption - beyond a comfortable interpretation of green growth.

Waves of innovation

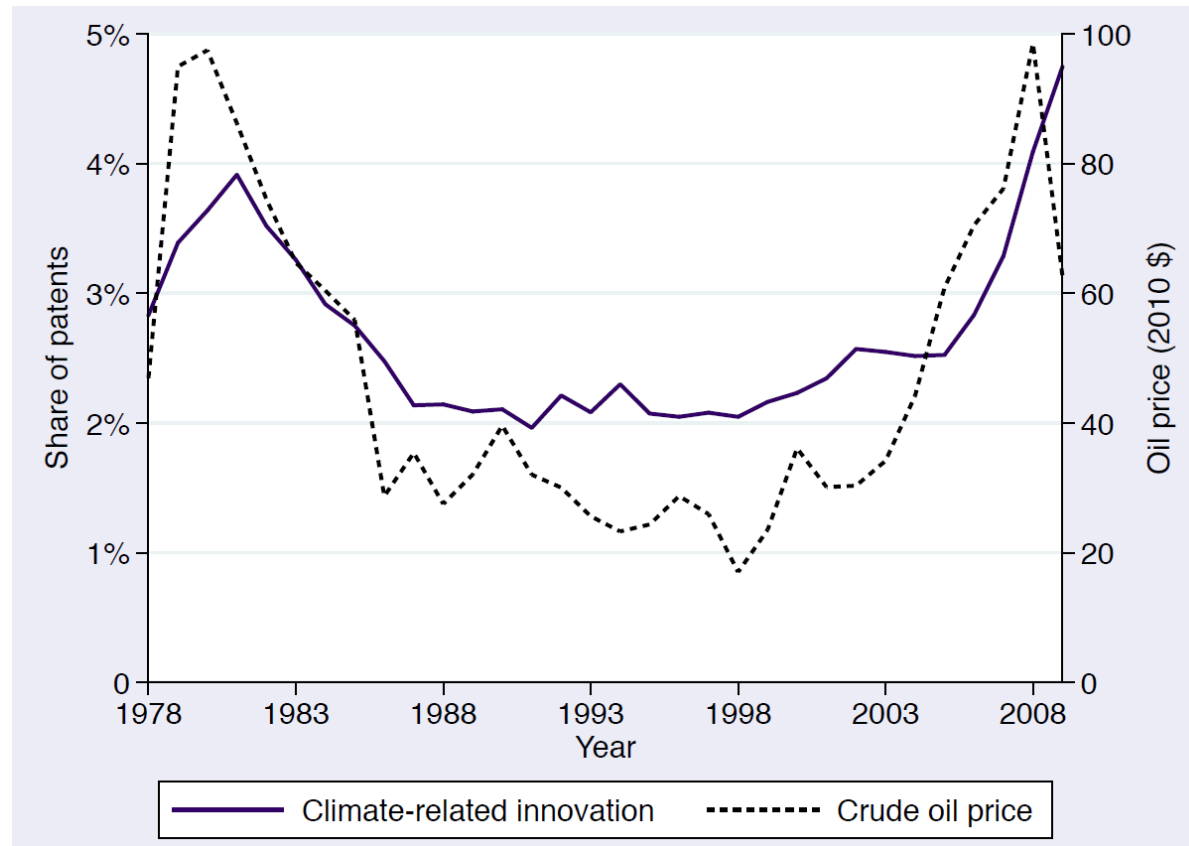


The new energy-industrial revolution (III)

- A perspective which embraces a Schumpeterian understanding of 'endogenous growth' and creative destruction will be central to making policy for the transition; new firms and methods drive out old.
- Endogeneity of technological progress: learning from experience; trial and error; direct investment in R&D.
- Already great breadth and increasing depth to this nascent low-carbon technological revolution.
- This is the start of a period of strong innovation and there will be (already are) exciting developments and 'breakthroughs' along the way from the speculative (e.g. synthetic algae, high-capacity nano-batteries, CO₂ to solids), to known technologies being implemented now (e.g. solar). Energy efficiency central: much innovation here, including ICT and new materials.
- But will not happen without **policy**: will have to overcome market failures and foster discovery and innovation à la Hayek/Schumpeter.

The new energy-industrial revolution (IV)

- Low-carbon “innovation” as share of total patents - dramatic rise 2005-2009. EU-ETS and oil price rise from 2005: strong incentives drive innovation.



Adaptation, mitigation and development

- The world must also be prepared to adapt to the climate change to which we are already committed from past and future emissions (as argued in Lecture 1): adaptation is development in a more hostile climate.
- There should be close intertwining of adaptation, mitigation and development – indeed it is a mistake to separate them rigidly in terms of organisation and implementation.
- For example, much of irrigation and water management should combine the three, similarly buildings, city management, power, and so on. Innovation should keep this centre stage.
- Similarly low-till agriculture, using degraded land, managing forests.
- The stronger the emissions reduction, the less the necessary scale of adaptation.

The scale of investments/costs (I)

- Expenditure involved in making the transition to a low-carbon economy must be analysed as an *investment*, rather than only a net cost (many co-benefits outside climate change). Most is not a direct cost to the public purse, largely private (Romani, et al., 2011).
- This is about the *dynamics* of innovation and learning and creation of benefits beyond narrow GDP; *not simply static* shift to higher input-output/coefficients and lower growth.
- Important to understand what the scale and nature of investment and full, dynamic economic costs, benefits and risks (including those of alternative paths) of the transition to low-carbon growth are likely to be. Inevitably some uncertainty as learning and discovery are central.
- *Bad policy* could raise costs.

The scale of investments/costs (II)

- Many models fail to adequately reflect crucial parts of the policy problem: the value of emission reductions; the potential for efficiencies in energy and other areas to cut costs; the scope for learning and innovation; and the value of energy security, safety, biodiversity, etc.
- They also fail to model the complex dynamics associated with inertia and path-dependency. Thus they essentially *assume* (not deduce) low-carbon detrimental to growth. Weak economics.
- Stern Review (2007) - incremental global investment required to move to a low-carbon economy is in the range of 1-2% of GDP per year. Lower figure was for target of stabilising below 550ppm CO₂e.
- For 450ppm IEA (2011a) suggest incremental world investments in energy sector around US\$ 1 trillion p.a. to 2030, around 2% of current world GDP. Total investment for 450ppm more like 2+%. Could even be 3+% but would still look like wise investment. Will discover and learn along the way.
- 2% of GDP in extra investment represents around a 10% increase in investment.

The scale of investments/costs (III)

- This investment will create and embody the discovery at the heart of the industrial revolution it drives. And provide further “co-benefits” beyond the fundamental reduction of the risks of climate change.
- Other estimates consistent with Stern Review, e.g.: den Elzen et al. (2007); Knopf, et al. (2009); Edenhofer et al. (2009).
- Uncertainty around these estimates, but could be lower than 2% of GDP with energy and resource efficiency gains (see work on efficiency by McKinsey 2011 and also WEF 2012), technological change, greater energy security. Other co-benefits are also potentially substantial and could deliver material benefits in the short run.
- Realising these overall benefits from investments and managing costs will depend on how we manage market failures and how we work together as a community.
- To remind: bad policy could raise costs.

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Policy – market failure (I)

- Dynamic public policy analysis required to deal with the issues of fostering a transition on this scale. Much market failure analysis à la Pigou is comparative statics, but nevertheless basic to policy.
- When we emit GHGs we damage the prospects of others. Unless appropriate policy is in place we do not bear the costs of the damage.
- GHGs are the biggest externality the world has seen: all are involved; the potential effects are global and very large.
- Correcting the GHG externality will involve carbon taxes / cap-and-trade / regulation. A combination of all three likely to be needed.
- Important additional market failures are relevant: public policy must be examined in the context of a *collection* of market failures.

Policy – market failure (II)

- Policy for the **market failures**. Different failures point to different instruments, but the collection is mutually reinforcing:
 - **Greenhouse gases**: carbon taxes / cap-and-trade / regulation;
 - **R,D&D** (research, development and deployment): tax breaks, feed-in tariffs (FIT) for deployment;
 - **Imperfection in risk/capital markets**: risk sharing/reduction through guarantees, equity, feed-in tariffs, floors on carbon prices, **green investment banks**. FIT straddles first 3 imperfections;
 - **Networks**: electricity grids, public transport, broadband, community-based insulation schemes. Government frameworks needed;
 - **Information**: labelling and information requirements on cars, domestic appliance, products more generally. Awareness of options;
 - **Co-benefits**: valuing ecosystems and biodiversity, valuing energy security, regulation of dirty and more dangerous technologies.
- Should not see these in terms only of static re-allocations or corrections: policy concerns the dynamics of change and learning. Fostering a transition.
- Will not rehearse detailed arguments on policies relevant to above 6 failures. Instead will look at four issues underplayed by economists: values; standards; institutions; community.

The role of values

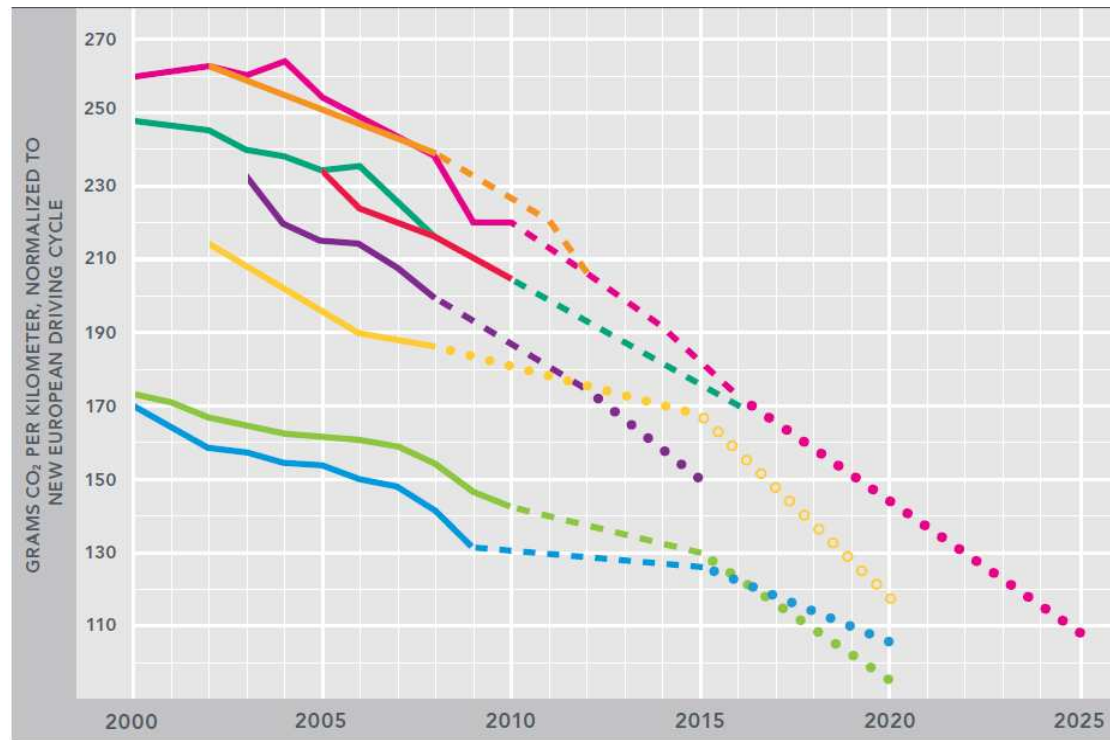
- Good policy is not just incentives/information in relation to market failures, vital though they are.
- How do we understand responsibility and values?
 - Thinking through consequences helps understand values.
 - Public interaction helps us clarify and perhaps change what we think.
- Setting our own notions of responsibility, not just gaming the systems. We are more than the narrowly interested, fully informed, instantly calculating, relentlessly maximising individual with totally clear objectives of first year economic theory.
- Public reasoning and standards of behaviour are part of policy (see also policy on tobacco, alcohol, drugs, health in general, noise, recycling, litter...).

The role of standards (I)

- For example, mandatory efficiency or emissions standards, building regulations, could straddle several of these market failures (GHGs, risk, learning and scale, co-benefits...).
- Well-designed physical standards can *provide clarity, promote scale and reduce uncertainty*, e.g. energy efficiency and car emissions standards (King Report, 2008). Recall unleaded petrol.
- India could eliminate blackouts by 2014 and increase the value of national output by around 50% by 2017 through strong energy efficiency standards (Climate Works, 2011a).
- Standards must be designed carefully, e.g. mandatory biofuel targets could see undesirable land-use change (King Report, 2008).
- Should also consider incentives to exceed the standard and how to phase in or support the meeting of standards.

The role of standards (II)

Historical CO₂ Emissions Performance and Current/Proposed Standards – New Vehicles



Source:
ClimateWorks
(2011b)



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The role of institutions in dynamic change (I)

- Imperfections in risk and capital markets imply a role for public institutions, such as a Green Investment Bank (GIB).
- A GIB is different to existing private financial institutions in a number of key ways:
 - reduces policy risk: governments less likely to chop and change policy if a public long-term investment bank involved;
 - develops banking and sectoral skills in new and important areas;
 - has special convening powers and strong networks to put together different coalitions and sources of finance;
 - has a capital structure which allows it to take a long-term view.
- Will help show what works and what doesn't – the ***power of example*** will be crucial in fostering the transition. See also EIT/KIC.

The role of institutions in dynamic change (II)

- Can learn much from the experience of the European Bank for Reconstruction and Development (EBRD), whose mandate was the promotion of a transition to an open market economy in the countries of central and eastern Europe and the former Soviet Union and has been extended to Turkey and some of North Africa.
- Its operations were guided by three principles: (i) sound banking; (ii) additionality; (iii) transition impact. The last could be replaced with low-carbon or green-impact in context of GIB.
- Imperfect markets/market failures and strengths of EBRD make intersection of (i) and (ii) not empty. Similarly for a Green Investment Bank. Help overcome market distortions and foster markets.
- Together policies on GHG externality, R&D, networks, capital and property markets, information, etc., if well directed and stable, can, combined with good institutions, particularly on finance, deliver change. (see, for example, Aghion et al. 2009; Otto and Reilly 2008; Fischer 2008; Fischer and Newell 2008).
- Policy + institutions + governance + infrastructure = **investment climate**

The role of community, collaboration, networks

- Cannot recycle and re-use without community.
- Public transport.
- Scale – public action – ‘Green Deal’.
- Power of example and sharing experiences.
- Changing values.

Policy uncertainty

- The role of policy uncertainty and implications for technological innovation. Government is key source of policy risk.
- “Stable rules that are not changed retroactively are a necessary condition in order to provide an appropriate risk-adjusted return to induce private capital to flow to low-carbon investments” Hepburn (2010).
- “The government must convince firms that it will not renege on its promises once investment costs are sunk. A credible carbon policy...solves the time-inconsistency problem and provides...a degree of security that promises will be met” Helm et al. (2003).
- For example, solar feed-in tariff policy in the UK. What does this mean for the future credibility of government policy?
- In contrast Germany has maintained a stable feed-in tariff policy regime with clear points of revision – induces the learning process.
- Rules for revision are fine if the basis of revision is clear and reasonable, e.g., relating to industry-wide cost reductions.

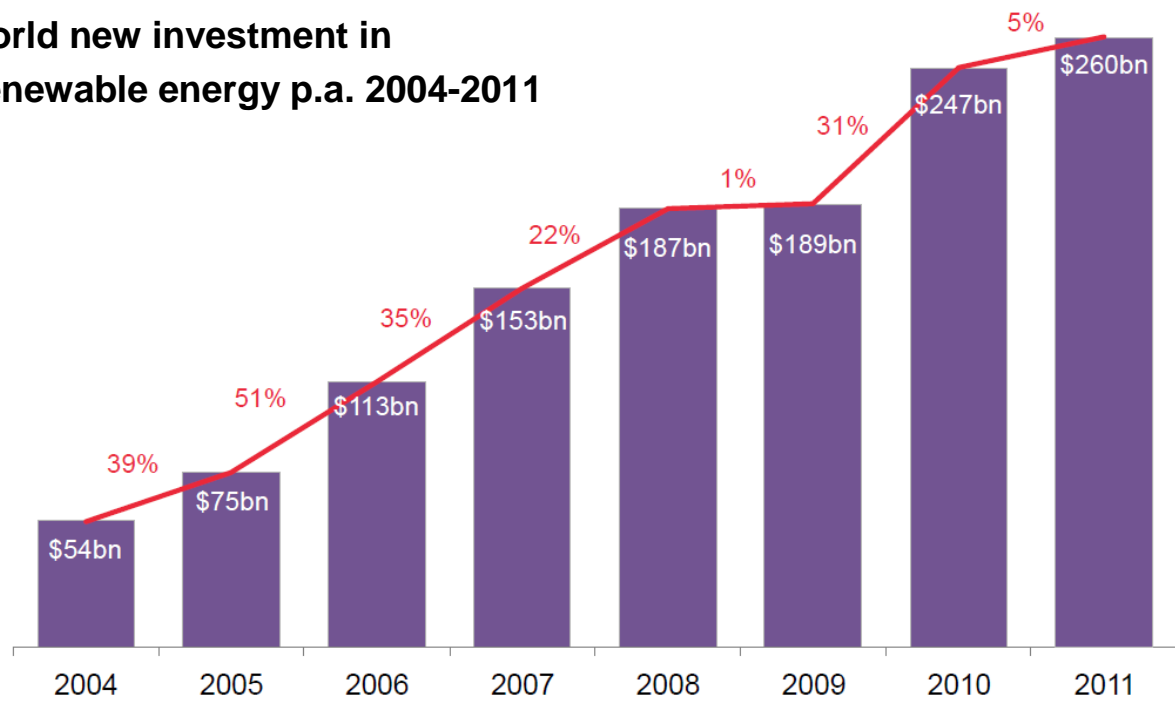
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Private sector clean energy mitigation investment (I)

- The majority of additional investment required to manage climate change will be private sector - around 86% (UNFCCC, 2007).

Total world new investment in clean renewable energy p.a. 2004-2011



Note: Includes corporate and government R&D, and small distributed capacity. Adjusted for re-invested equity. Does not include proceeds from acquisition transactions

Source: Bloomberg New Energy Finance



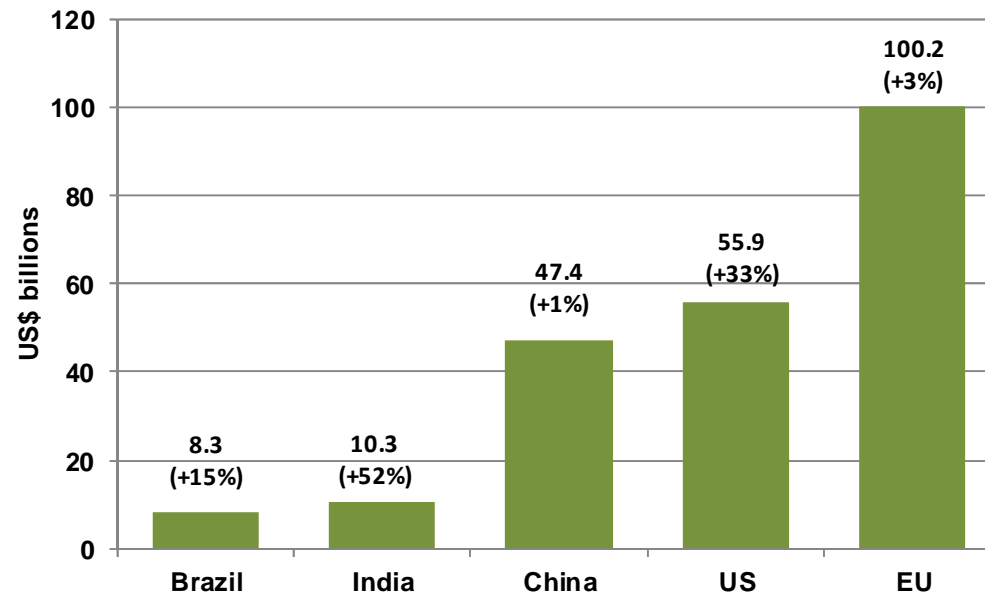
Source: BNEF, Global Trends in Clean Energy Investment - Q4 2011 Fact Pack. <http://bnef.com/free-publications/presentations/> (Note: includes government R&D – less than 2% of the total in any given year).



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Private sector clean energy mitigation investment (II)

New investment in clean energy 2011 - selected countries
(% change on 2010)



- **US** - increase driven by US federal loan guarantee programme and a Treasury grant programme - these policies have now expired.
- **India - increase** - driven by grid-connected solar investment, up from \$0.6bn in 2010 to \$4.2bn in 2011.

Private sector - driver of innovation (I)

- With strong public policy and support, the private sector has a crucial role in driving the low-carbon transition forward.
- Examples are already emerging of firms and initiatives that are at the forefront of the new-energy industrial revolution.
- **From ideas that are being implemented now:**
 - Energy efficiency measures have saved DuPont around \$6 billion in energy costs over the period 1990 to 2010 (DuPont, 2011);
 - Waste Management, Inc., a \$14 billion US waste firm, set up 'Green Squad' to generate value from waste. Identified potential \$9 billion in value from reusable materials it currently sends to landfill (Nidumolu et al. 2009);
 - Plastic Bottle Lights in Philippines: local entrepreneurs trained to construct simple solar lights from used plastic bottles, saves households around \$6 a month in electricity;
 - Public and private collaboration, e.g.: sustainable biofuel trials between US Navy and Maersk; Low-Carbon Oxford Programme, which fosters collaboration between private, public and non-profit organisations with aim of reducing Oxford city emissions 80% by 2050.

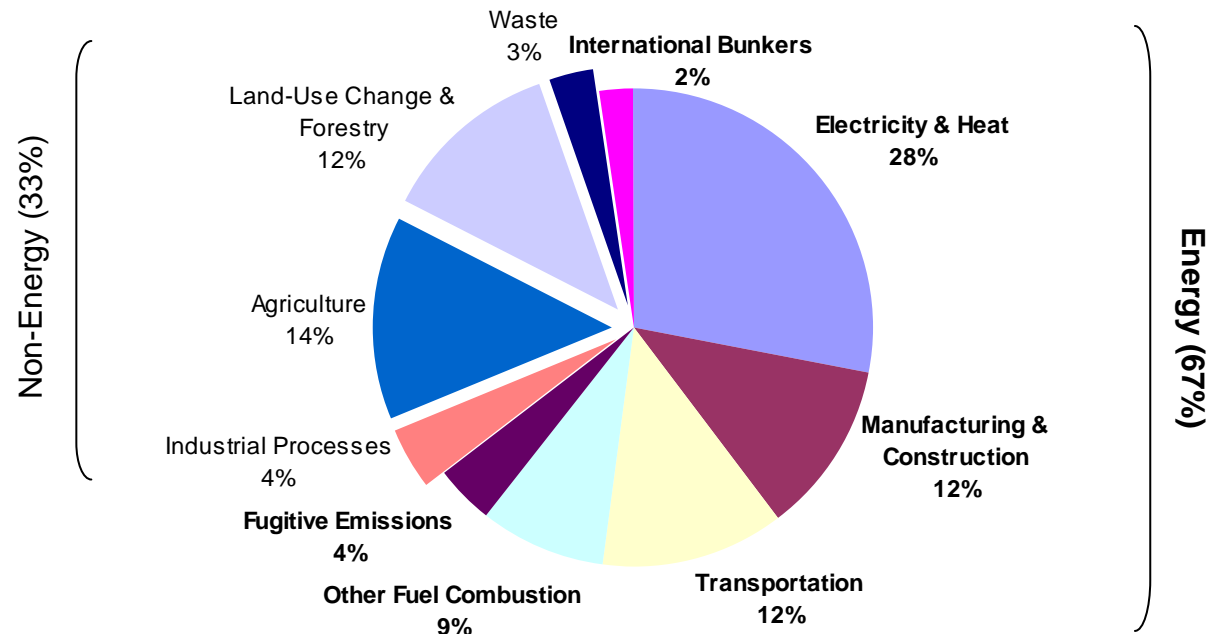
Private sector - driver of innovation (II)

- **To the more speculative:**
 - Nuclear waste as fuel for new generation reactors (could power the UK for 500 years);
 - High-capacity batteries made with titanium dioxide coated carbon nanotubes;
 - Carbon capture and storage (CCS) with storage in cement (Calera);
 - Solar paint using nanoparticles of titanium dioxide coated with semiconducting cadmium nanocrystals;
 - Meat from stem cells.

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Emissions by sector



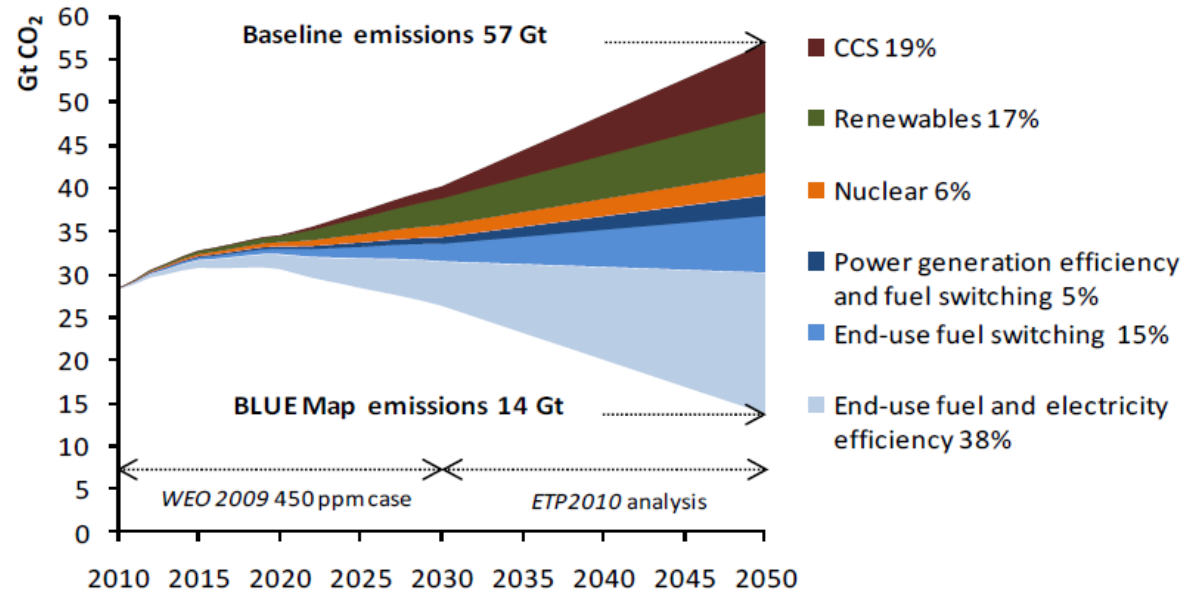
Based on 2005 global emissions (CO₂e).

Source: Climate Analysis Indicators Tool (CAIT) Version 7.0. (Washington, DC: World Resources Institute, 2010).

- Strong action necessary in all sectors and all countries.

Key areas of action

- Three key areas for action are:
 - energy efficiency;
 - developing and deploying low-carbon technologies and activities;
 - halting deforestation.
- Will likely need all technologies, including nuclear. Mistake to discard any ex ante – may increase risks and costs.
- Crucial role of infrastructure particularly in rapidly urbanising developing countries.



Source: IEA Energy Technology Perspectives 2010, Scenarios and Strategies to 2050.

Note: This is CO₂ (energy only) and works on the basis of stabilisation of CO₂e concentrations at 450ppm.

Energy efficiency

- Energy efficiency can give around 50% of necessary energy-emissions reductions.
- Great scope - examples include: China's 12th plan with targets for a 16% increase in energy efficiency and promotion of seven strategic lower-carbon industries; innovative energy saving schemes by many firms such as DuPont, Wal-Mart and Dow Chemicals; government policy such as the 'Green Deal' in the UK.
- Links with ICT revolution. For example, smart technologies including smart motor systems, smart buildings, smart-grids, smart logistics, could reduce global emissions by 15 per cent p.a. by 2020 and deliver cost savings of around €600 billion. (Climate Group, 2008).
- Role for standards in these areas of overlap between low-carbon/ICT.

Hydrocarbons (I)

- Carbontracker.org project - proven reserves of fossil fuels could produce 2,795 billion tonnes of CO₂ if burned, about double the carbon budget for a (50-50 chance) 2°C path (i.e. a round double the 40 year emissions budget of 1,200 to 1,400 billion tonnes).
- Probably many times this will be useable with confirming/proving of reserves, new technologies and exploration.
- Proven reserves of top 100 listed coal companies and top 100 listed oil and gas companies worldwide could produce 745 billion tonnes of CO₂, far more than half of the entire GHG budget for the next 40 years.
- Fundamental contradiction between current valuation methods and declared world climate policy. Cannot believe both (a) that hydrocarbon reserves are properly valued (b) that 2°C (50-50) target will be achieved (unless suggest a massive and very rapid deployment of CCS).

Hydrocarbons (II)

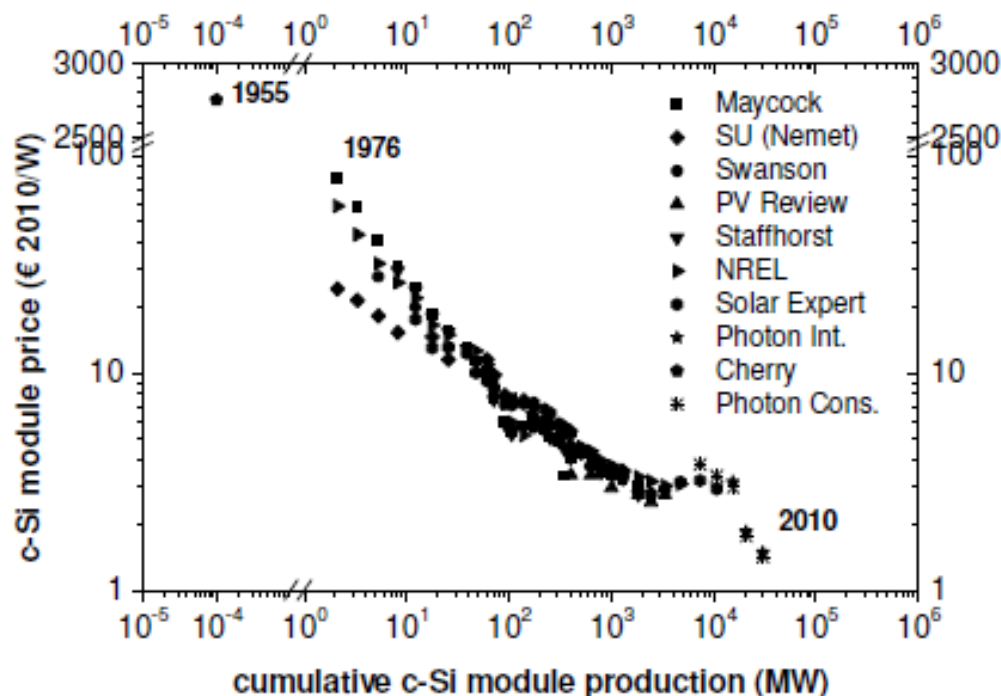
- Is there a role for hydrocarbons in the transition?, e.g. gas as a “bridge technology”.
- Horizontal drilling and “fracking” has enabled “unconventional” gas resources to be exploited economically (tight gas, shale gas and coal bed methane). Technical progress occurs in hydrocarbons too. US gas prices have fallen sharply.
- If a role for gas as a “bridge technology”, how to substitute ‘gas for coal’ and not ‘gas for renewables’? Policy could include a credible floor price for carbon.
- The development of Carbon Capture and Storage. Slow progress. Cross-country collaboration could accelerate?

Energy - smart-grids

- Smart-grids will be key to the low-carbon energy transformation.
- Will facilitate more *integrated, competitive* and *secure* energy markets.
- Will also allow renewables to be located much more *efficiently* – solar where it is sunny and wind where it is windy.
- *Diversity* of **supply** will allow for more effective management of the intermittency associated with some renewables such as solar and wind.
- A role for gas as a peak, back-up technology.
- Will also enable network operators to manage **demand** more effectively (e.g. draw power from EV batteries, switch washing machines away from peak periods, turn down thermostats) reducing the need for costly “rapid-fire” gas back-up.

Falling costs of renewables - solar (I)

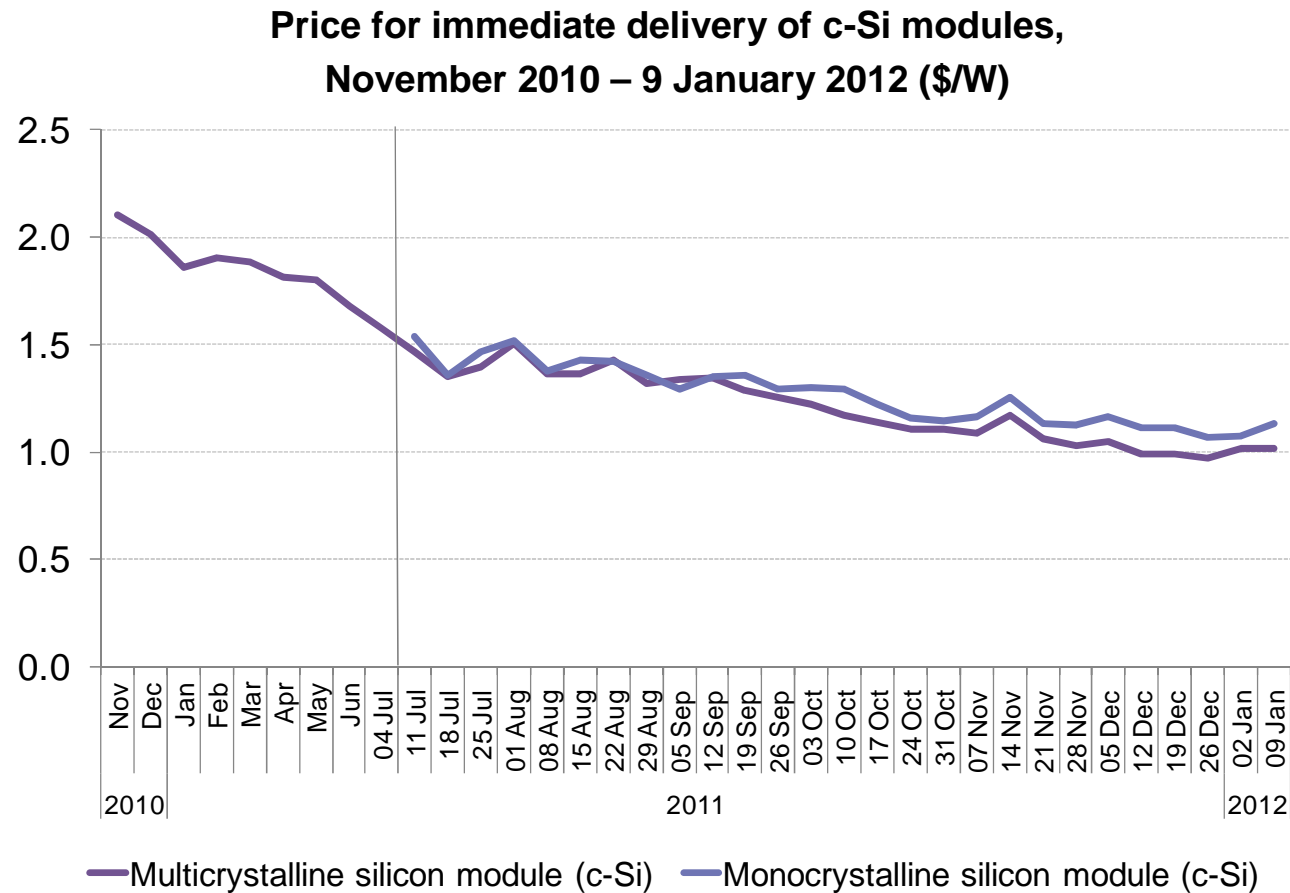
- Solar PV module learning rate (percentage decrease in cost for each doubling of production output) of nearly 30% 1976-1988 and 17% 1988-2010.



- Solar PV module prices have declined from around \$2,800/watt in 1955 to under \$2/watt in 2010.

Falling costs of renewables - solar (II)

- Solar PV module prices have fallen around 50% since 2010: currently just over \$1/watt (BNEF, 2012).



Falling costs of renewables - solar (III)

- Innovation and learning has driven rapid cost reductions:
 - **Solar PV:**
 - Suntech - divided capital cost by factor 5 or 6 in last 5 years. Could fall to around \$0.50/w in next few years.
 - Grameen Shakti, Chairman Muhammad Yunus, selling solar units strongly in Bangladesh at \$1/w. They say they “could cover the country” at \$0.50/w.
 - **Solar thin-film:**
 - Solarmer Energy Inc. - developing solar cells from thin, flexible, “rollable” plastic sheets. Aim to reduce costs to under \$1/watt in 5-6 years.
- Calculations of grid parity for much of solar PV relate to *delivered* costs (could be 2x more expensive than price of generation). Grid parity expected in some southern states (Italy, Spain) in next year or two, and across Europe by 2020 (EPIA, 2011).

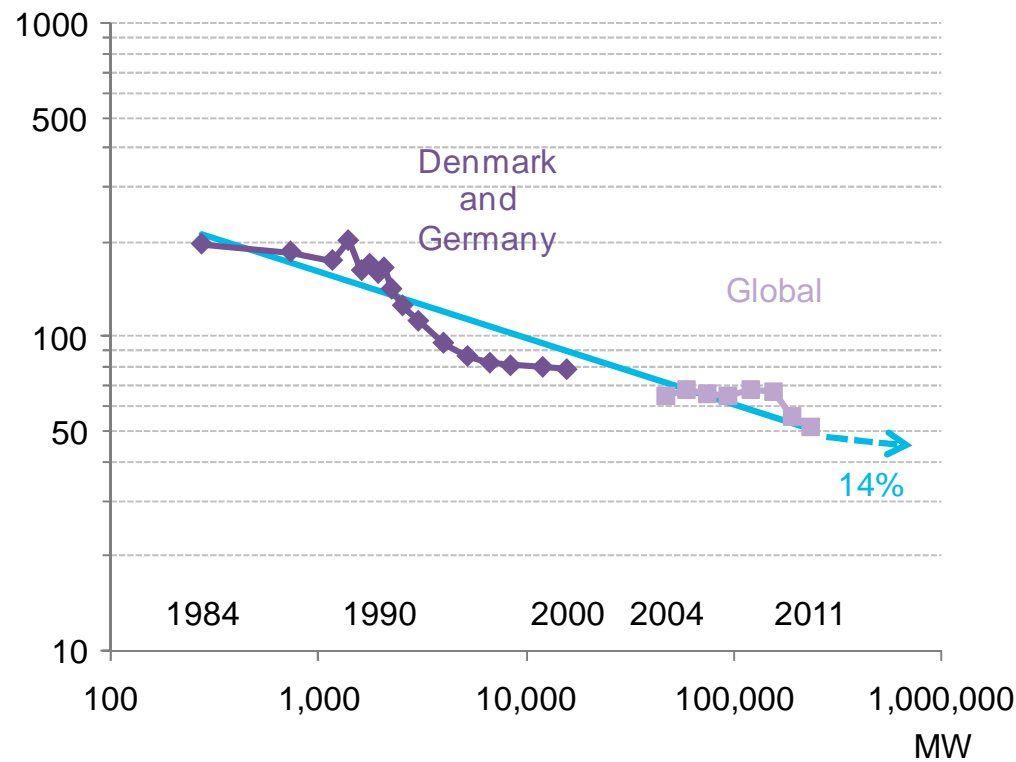
Falling costs of renewables - solar (IV)

- Rapid and likely future cost reductions reflect the changing economics of the solar PV industry:
 - Fall in demand from economic slowdown, credit constraints, policy uncertainty, exploitation of economies of scale in China, and a decrease in silicon prices;
 - Silicon supply bottlenecks finally overcome in 2008, partly due to the entry of a large number of new firms in the market. Prices of silicon fell sharply and are predicted to fall 30% p.a. 2010-2014 (EPIA, 2010). Also possibility of replacing silicon cell with a far cheaper and more efficient nano-cells;
 - The outcome is falling module and system prices;
 - But a rapidly developing industrial revolution will have its failures for those whose strategies fail to anticipate the next market move (e.g., Solyndra guessing wrong on silicon prices);
 - Large government subsidies (in China especially) causing trade tensions, e.g. between the US and China.

Falling costs of renewables – wind (I)

- **Onshore** wind - turbine capital costs fell from \$2m/W in 1984 to around \$0.88m/W in 2011 - learning rate of 7%.
- Levelised cost of energy (LCOE) produced has fallen from €200 per MWh in 1984 to €52 per MWh in 2011 (expressed in 2011 real terms).

Onshore wind - average levelised cost of energy, 1984–2011 (€/MWh)

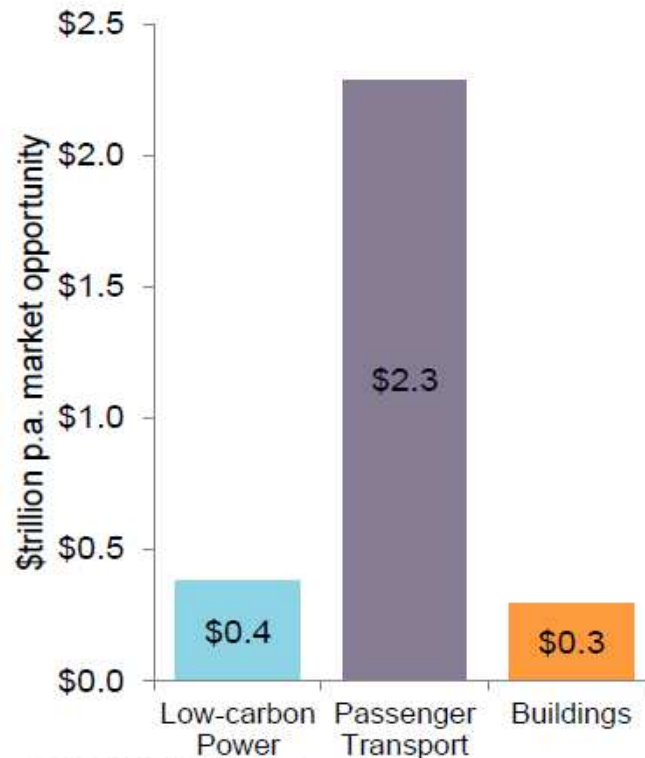


Falling costs of renewables – wind (II)

- Fall in LCOE for onshore wind due to falling operations and maintenance costs, in addition to falling turbine prices.
- Onshore wind now only €6 per MWh more expensive than the average cost of a combined-cycle gas turbine plant in 2011 (BNEF, 2011).
- But continuing concerns around cost, intermittency and aesthetics.
- **Offshore** wind - LCOE has increased in recent years (from around \$150/MWh in Q2 2009 to \$225/MWh at the end of 2011). A range of factors have driven up costs including: financing constraints; rising materials, commodity and labour costs prior to 2008; increasing depth and distance; supply chain constraints; and planning and regulatory approval delay.
- Some evidence that capital costs may now have peaked. For example, Walney wind farm in UK opened February 2012. *“It has been built more cheaply and quickly than previous schemes, and has been supported by foreign pension funds”* (Dong Energy). (See also UKERC, 2010).

Transport - market potential and EVs

Figure 23 The global low-carbon passenger transport and fuels market could be more than \$2 trillion in 2050



Source: IEA (2010) & Vivid Economics calculations
Notes: data is for IEA BLUE Map scenario (50 per cent reduction on 2007 energy related CO₂ levels by 2050)

- Potential size of p.a. investment in low-carbon transport and fuels far exceeds low-carbon power by 2050.
- IEA (2011b) - 450ppm scenario - around 7m EV and Plug-in hybrid-EV sales p.a. by 2020 and 100m sales p.a. by 2050.
- Key issues:
 - reducing battery costs and increasing battery lifespan. Will require R&D;
 - the recharging infrastructure.

Industry

- Innovation and energy efficiency will be key. Architects and engineers producing many ideas for energy efficiency in buildings, e.g. chilled beams that use water rather than air to cool. Combined with natural ventilation can save up to 30% of conventional energy costs.
- Many firms are taking a long-run view:
 - DuPont - total energy consumption decreased by 6% 1990-2010 with production growth of 40% - avoided at least US\$ 6 billion in energy expenditure over this period;
 - The UK co-operative has cut emissions 35% 2006-2011 (50% by 2020) and water use 20% 2006-2011 (30% by 2014);
 - BP established an internal ETS to reduce emissions 10% 1990-2007. Emissions target achieved in 2001 with net savings (through eliminating waste and improved competitiveness) estimated at around US\$ 600 million;
 - Dow Chemical will invest \$100 million in energy efficiency and conservation improvements through an internal competition for funds.
- Household appliances/fridges much more energy efficient. New fridges consume around 75% less energy than an equivalent model made in the 1970s. The most efficient GE refrigerators sold today are up to 30% more energy efficient than refrigerators sold in 2001.*

Footloose?

- Some are resisting change claiming action will reduce “competitiveness” and lead to carbon “leakage”. Usually more slogan than substance. Little evidence of movement to “dirty” places (Stern Review, Ch.11).
- Climate/environment policies only one determinant of plant and production location decisions.
- Little evidence of significant competitiveness impacts for most industries (see, e.g. Aldy and Pizer, 2009).
- Most countries are moving towards carbon and must anticipate.
- Measures are available to assist energy-intensive trade-exposed industries, such as allocation of permits, which can adjust over time.
- Strong evidence of rapidly changing technologies and cost reductions for innovators.
- Those countries which choose to fall behind may eventually find dirty products shut out of markets as well as falling behind technologically.

Agriculture

- Climate Smart Agriculture (CSA) – mitigation, adaptation, efficiency/productivity interwoven.
 - 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.
 - *Niger*: crops protected from desertification by planting a variety of species of trees “shelter belts”; secure tenure over trees helped encourage planting and reverse desertification in parts of the Sahel through agroforestry. *Nigeria*: planting of alternate rows of *Leucaena leucocephala* (legume) with maize and cowpeas has improved soil fertility (FOA and WB);
 - “New Vision for Agriculture” 20% increase production, 20% reduction emissions, 20% reduction poverty, every decade. Investing strongly through CGIAR. Presidents of Tanzania and Ethiopia leading strong initiative; WB, FAO, WEF, African Union all involved.

Forests

- Deforestation accounts for between 10% and 20% of global emissions (much uncertainty – need for more reliable data). Similar to total emissions from US or China.
- Innovative ideas are emerging to protect forests (Ecuador – funds to avoid oil extraction. Indonesia – moratorium supported by Norway. Brazil – reduced reforestation by nearly 80% over last 7 years through advanced satellite monitoring and enforcement on the ground, including an elite forest protection police force). Use of degraded land for palm oil.
- The Durban process established a role for “appropriate market-based approaches” after many years of objections, and REDD and REDD+ now firmly established at the international level.
- Emissions from deforestation roughly around 5-10 billion tCO₂ p.a. At \$20/tonne have a market worth >\$100bn p.a. Around a quarter could be avoided at \$5/tonne or less - cheap abatement option.
- Rio+20 in June 2012 could be a key opportunity to move forward on forests.

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How are countries moving?

- Although international action varies greatly (Lecture 3) many countries are moving.
- Faster progress depends on recognising attractiveness of alternative paths and increasing understanding of the growth benefits of transition to the low-carbon economy and of the low-carbon economy itself. In addition, of course, to increasing recognition of severe risks of climate change.
- Many countries (and states) now recognise this is the way forward and are looking to lead the 'green race'.
- For example: China's 12th plan; Korea, Ethiopia and Rwanda's low-carbon growth and development plans, Colombia's 'Green' National Development Plan.
- Combination of recognition of risks and sense of responsibility. Has reduced "blame game": still here but less prominent. Meles Zenawi: "It is not equity or justice to foul the planet because others have done so in the past", Durban 2011.
- Nevertheless past responsibilities are relevant to case for support. It is the position of "no support, no action" which is changing.

How are countries moving? China

- **China (around 7t/cap)** - China's 12th five-year plan represents a radical change in strategy. It identifies three key new objectives: increasing the share of consumption, moving to a low-carbon and less polluting economy, increasing innovation and R&D (Stern, 2011).
- China already has a target to reduce emissions per unit of GDP (emissions intensity) by 40–45% between 2005 and 2020, with a target of 17% during the 12th plan (2011-2015).
- The 12th plan seeks to achieve this change in part through massive investment in seven strategic low-carbon industries, to achieve a 15% share of the economy by 2020, compared with 3% now.
- Low-carbon investment in renewable energy is strong and growing. China added 47GW of wind and 3GW of solar in 2011 and has increased its share of renewable energy in total energy supply from 8.4% in 2010 to 11.4% in 2011.
- But China heading for 12 Gt CO₂e p.a. by 2020 and potentially 15 Gt by 2030 - clearly incompatible with 2°C path with 2030 budget 32-33Gt.

How are countries moving? Korea

- **Korea (12t/cap)** has adopted a National Strategy and Five-Year Plan for Green Growth.
- Involved a “Green New Deal” launched on 6 January 2009 as part of a wider economic stimulus package. A total of US\$ 30.7 billion (about 80% of the package) was allocated (2009-2012) across a range of low-carbon initiatives, including renewable energy, energy efficiency, transport, and water and waste management.
- The five-year green growth plan 2009-2013 incorporates many projects from the Green New Deal package.
- Outlines a set of three strategies, ten policy directions, and 50 core projects to shift Korea onto a low-carbon growth path. A total of US\$ 83.6 billion will be allocated to the plan, around 2 per cent of GDP. See UNEP (2010) for a more detailed description of the plan.

How are countries moving? Ethiopia/Rwanda

- **Ethiopia (1.8t/cap)** *Climate Resilient Green Economy (CRGE)* Strategy supports its Economic Transformation Plan to achieve middle-income status by 2025 without increasing emissions.
- The CRGE Strategy focuses on key sectors (agriculture, forests, renewables and energy efficiency) and is now being implemented across government.
- Sixty projects identified to achieve this development goal that will also limit emissions to current levels of around 150 Mt CO₂e p.a.
- Around 80% of abatement potential at under US\$15 a tonne CO₂. Will require investment of around US\$ 150 billion over the next 20 years.
- **Rwanda (0.4t/cap)** *National Strategy for Climate Change and Low-Carbon Development* - transform Rwanda into a developed climate-resilient, low-carbon economy by 2050. Consists of a range of low-carbon development programmes including: renewable energy; climate-resilient agriculture; and ecotourism.



Source: Federal Democratic Republic of Ethiopia (2011), and Republic of Rwanda (2011).



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How are countries moving? US

- Much movement outside of Washington DC:
 - US Navy and biofuel trials. Target to run a “Great Green Fleet” a carrier strike group composed of nuclear ships and hybrid electric ships running only on biofuel (and aircraft flying on biofuel). Ambitious 2020 target for 50% of total energy consumption, ashore and afloat, to come from non-fossil fuel sources;
 - California cap-and-trade scheme. Began 1 January 2012;
 - NYC green growth plan “plaNYC”: including target to reduce emissions 30% 2005-2030, currently 13% below 2005 levels (US around 8% below);
 - Texas: largest wind farm capacity of any US state at around 10GW (Iowa second largest at around 4GW). Plans to double capacity by 2013. Attracting investment from China;
 - General Motors - new range extended electric vehicle, ‘Volt’ in US and ‘Ampera’ in EU.
- EPA Mercury and Air Toxics Standards (MATS) for power plants. Will force coal to adopt more stringent pollution controls (many older and dirtier coal plants may close). More rules proposed to regulate emissions, e.g. Cross-State Air Pollution Rule.

Strategies for growth

- The global economy faces a decade of great challenges and risks: major macroeconomic structural imbalances; debts and deficits in rich countries; unfinished financial sector reform; fragile growth in many countries; radical changes in international division of labour and skills; and managing climate change and the beginnings of a new energy-industrial revolution.
- We will do better if we address these great challenges and risks in a coherent and integrated way (both as issues and as a world), rather than separately.
- Now is exactly the time to invest for (low-carbon) growth: in many developed countries private sector sitting on record levels of savings and long-term real interest rates low.
- Government policy can “create viable new markets, boost private investment and innovation, and stimulate the economy without requiring large public expenditure” (Zenghelis, 2011).
- This could see a world recovery driven in large measure by growth and investment in new industries and infrastructure in emerging and developing countries. But also recovery in developed countries with powerful examples and technological discovery for world as a whole. This would foster a dynamic period of innovation and learning with many prospects for collaboration.

Conclusion

- The world's current focus on international financial/economic crises.
- Whilst we are moving towards lower-carbon we are falling badly behind relative to a 2°C (50-50) target: world emissions are rising strongly.
- How can national and international action accelerate?
- What are the prospects for and how can we accelerate change?
- These are the subjects of Lecture 3.

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