Analytical Audit

Full report

This paper is based on analysis prepared by the Office of Climate Change to facilitate discussion within government departments – it is not a statement of Government policy.

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The OCC Board commissioned this audit to provide a consistent analytical base for climate change policy

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All Departments with an interest in climate change conduct high quality analysis.

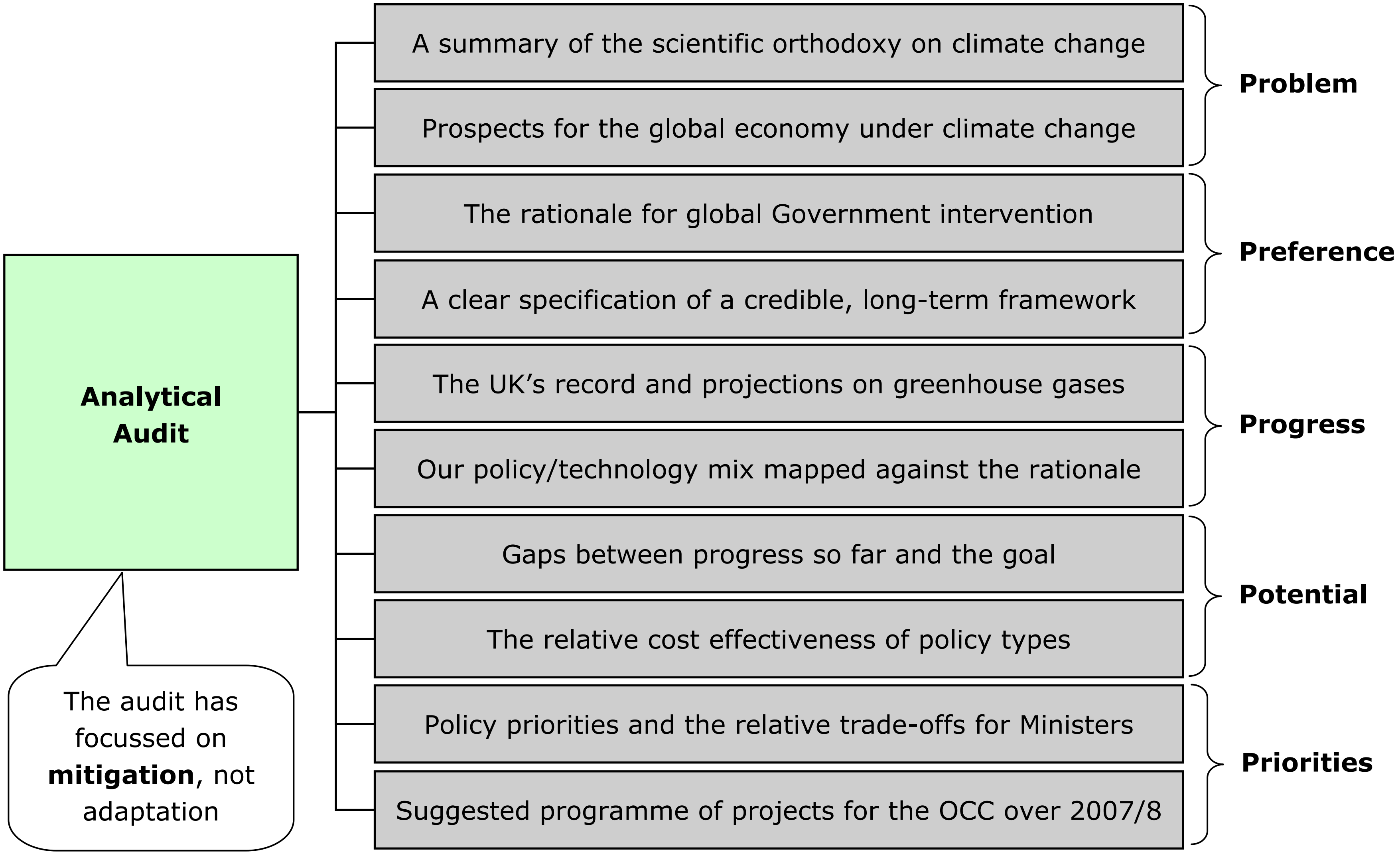
However, there is a perception that this is not always presented consistently across government.

Analytical Audit – Terms of Reference

The project will present an analytical audit on issues, progress and priorities in climate change by:

- auditing our current knowledge and policy choices, to advise on progress and evidence;
- consolidating the existing analysis on UK and international climate change issues and our existing and projected emissions;
- presenting a balanced view of the trade-offs that Ministers face, based upon a consistent overview; and
- identifying priorities that Ministers may want to explore further.

Its findings will give us a common understanding of the problem we face and the priorities for tackling it



This full report is organised into four sections plus annexes – an executive summary is available

Analytical Audit

Sections of the full report

- The problem of climate change and the case for action
- How much emissions need to be cut and UK progress to date
- How UK policy compares with the recommendations of the Stern Review
- The synergies and trade-offs with other policy objectives

Annexes

- The science of climate change
- The measurement and projections process
- Sector-specific analysis
  - Electricity
  - Buildings
  - Energy-intensive
  - Transport
  - Agriculture
  - Waste

An executive summary of the full report and all of its accompanying annexes are available separately

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Our *scientific annex* demonstrates that there is a resounding consensus on the central scientific case

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- **Global warming is real**: average surface temperature has increased by 0.74°C over the last hundred years, a rate and scale likely to have been greater than at any time in at least the past 1000 years
- **Global warming is man-made**: most of the warming over the last 50 years is attributable to greenhouse gases from human activities

2°C

Even if mitigation was sufficient to contain annual emissions at today's level, the world is likely to experience a 2°C warming above pre-industrial levels by 2050

The risk of serious human impacts increases strongly without mitigation

There will be an increasing severity in the number of people dying from hunger, water shortages, heat-related stress and malaria

5°C is the difference between temperatures now and the last ice age

5°C

Without significant mitigation, on business as usual trends, there will be a 50:50 chance of exceeding a 5°C temperature increase by the end of the 21st Century

Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (2007). Stern Review (2006).

Furthermore, the Stern Review has shown that there is an undeniable economic case for urgent action

'Greatest market failure the world has ever seen'

- Global externality
- Uncertain and long term
- Potentially large scale irreversible effects

1% GDP

Cost of mitigation in 2050 of recommended stabilisation path

vs

5% GDP

Income loss if we do nothing (market impacts only)

20% GDP

Income loss including non-market impacts, risk and equity

Stern Review (2006): Global costs (1%) are in 2050 compared to projected GDP in 2050 (± 3% on macro model); Global income loss (5-20%) is equivalent to an "average" annual loss of GDP each year now and forever.

Criticisms surrounding the science behind, and scale of, climate change impacts in the Stern Review do not affect the case for action

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Criticisms of the Review	Assessment	Does this critique reduce the urgency of action required?
Doubts over science of climate change	A minority of commentators continue to suggest climate change is not man-made. There is debate and uncertainty in the science but the view that man-made global warming is not occurring has been virtually discredited.	X
Climate change impacts overstated in the Review	Partly stems from the Review producing higher estimates of damages than previous work. However this is because the calculations in the Review were based on the latest scientific information, and: • focused on a wider range of temperatures and took account of risk • gave more weight to future generations (see discount rate discussion) • measured a wider range of impacts (in some scenarios)	X
Discount rate too low	The Review makes some ethical judgements which differ from those of other studies, leading to a lower discount rate and thus larger impact estimates. This is discussed in detail in later slides.	?

Criticisms have also been levied against the appropriateness and costs of mitigation policy, but we do not believe they affect the case for action

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Criticisms of the Review	Assessment	Does this critique reduce the urgency of action required?
Mitigation should be postponed until technology cheaper	At a global level, technology costs will arguably fail to fall in the absence of some innovation policy. In addition, the risks (in terms of climate change impacts) associated with delaying mitigation could outweigh any cost savings.	X
We should focus on adaptation rather than mitigation	Since future generations will be richer, and likely to have greater adaptive capacity, some argue that policy should be focussed on adaptation rather than mitigation. But the potential impacts of unmitigated climate change are so great that in some circumstances adaptation simply wouldn't be feasible.	X
Mitigation costs underestimated	It is fair to argue that the Review's 1% estimate of mitigation costs is optimistic, since it is dependent on designing policy to cut emissions in the least cost way. This is an argument for good policy design, and does not weaken the case for action.	X

The discount rate – which is used to weight impacts on future consumption relative to current consumption – has been a big source of debate following Stern

- The higher the discount rate, the less weight is given to future impacts
- The rate itself is made up of a number of elements

Discount rate

$$r = \delta + \eta . g$$

Income growth
expected into the future

δ, comprised of 2 elements:

- **Catastrophe risk** – the probability that there will be some event so devastating that all impacts (positive and negative) are eliminated
- **Pure time preference** – reflects a lower weight placed on the future, simply because it is the future

η, the **elasticity of marginal utility of consumption.** Reflects the fact that £1 means more to a poor individual (or country) than a rich individual (country)

η and g combine to form a term which reflects the fact that our value of future impacts is dependent on how rich we are likely to be in the future – the more income we have, the less significant any given change in consumption.

Stern makes a series of ethical judgements in setting the discount rate – these are economically and ethically defensible but are open to debate

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Belief driving Stern's discount rate	Effect on discount rate
Future generations should not be valued less than current generations simply because they are in the future (i.e. we should not discriminate simply on the basis of **birth dates**)	Implies that the pure rate of time preference is zero, therefore putting downward pressure on δ and leading to a **lower** discount rate as a whole
However, our **attitude to inequality** suggests the consumption of future generations should be weighted less heavily as they will be richer	The weighting of future income growth (g) is given by η*, so increasing the weight leads to a **higher** discount rate
In addition, income growth is dependent on climate change impacts (i.e. **larger damages will reduce income**)	Means g is endogenous, and will fall if estimated damages rise, leading to a **lower** discount rate
Finally, we should take account of the small probability that the impacts of climate change could become irrelevant (i.e. if the **human race is wiped out** at some point in the future).	Increasing the probability of catastrophic risk increases δ, leading to a **higher** discount rate.

Sensitivity tests show that even if η were doubled and δ increased 10-fold, the mean estimated damage costs in the baseline-climate scenario would still be 1.6% of GDP and so **the case for action would remain** (although would be more marginal)

* NB. η also represents a measure of risk aversion and point-in-time inequality aversion in the *pre-discounted* damage costs, so the overall effect of η on the damage costs is complex. More academic work is needed to separate these effects.

The Stern discount rate was also different to that recommended by the Green Book, due to the uniqueness of climate change and alternative ethical judgements

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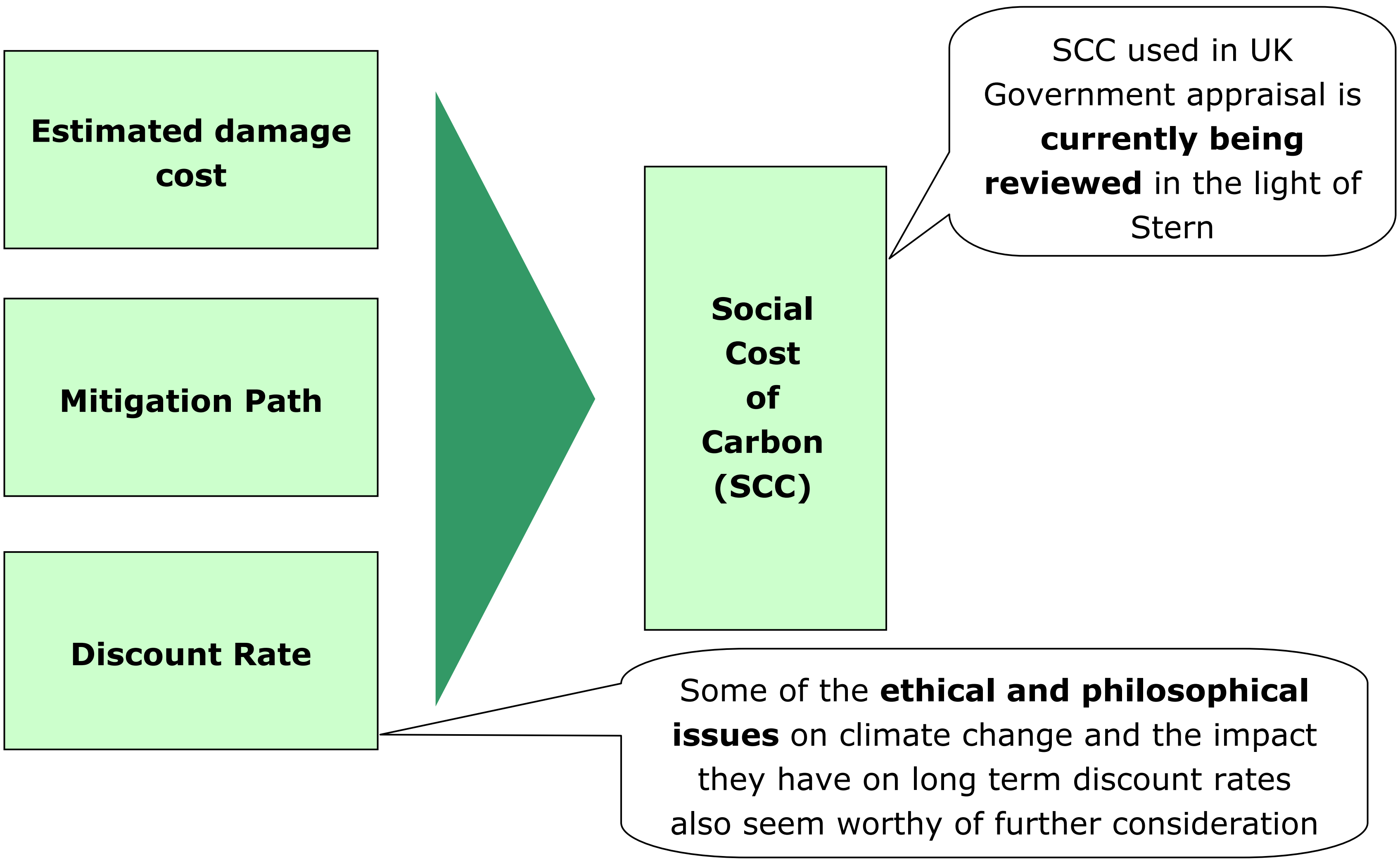
	δ	η	g	TOTAL
Stern Review	0.1	1	Current growth (2-4%) falling to 1.3% in long run	Approx 2.1%-4.1% falling to 1.4% in long run
Green Book	1.5	1	2 (declining in long run)	3.5%
Other literature	0.1 - 1.5	0 - 3	Various	Various
Comment	The Green Book δ is higher because (i) **catastrophe risk** is higher for individual projects than for the risk of the world ending; and (ii) contrary to the Review, it reflects an ethical judgement to effectively discount on the basis of **birth date**, reflecting individual impatience.	η = 1 implies that if future income were double what it is today, any cost would reduce utility by half the amount. The issues surrounding η are complicated, as this parameter also reflects a measure of risk aversion in the (pre-discounted) damage costs.	The "g" used by Stern varies because **climate change itself causes economic growth to vary** (i.e. climate change is not marginal). But projects appraised using Green Book guidance generally do not change economic growth (i.e. they are marginal).	Climate change arguably justifies a different discount rate because: (i) **catastrophe risk** is lower for the world than individual projects (ii) ethical judgement that generations should not be discounted on basis of **birth date** (iii) tendency for **g to vary** with climate change.

NB. The discount rate is based on ethical judgements and therefore isn't a matter of right and wrong. Any approach is open to debate and criticisms have come on different values being too high/low for different reasons

Work is already underway within Whitehall looking at the Social Cost of Carbon, but some of the ethical issues may also be worthy of further consideration



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Conclusions

The challenge is to stabilise global greenhouse gas concentrations at a level that will affordably avoid the worst of the climate change risks

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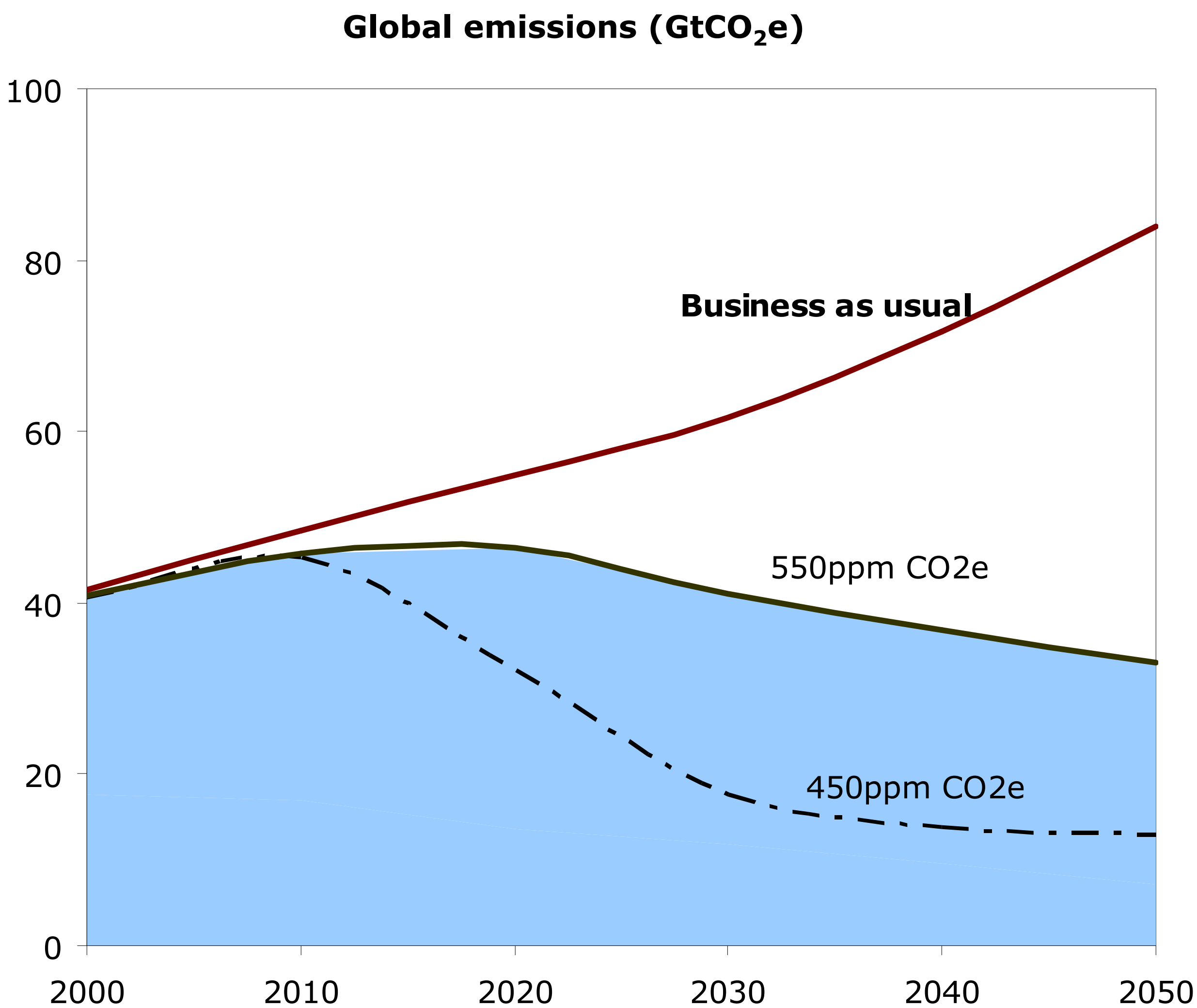

- The Stern Review recommends a stabilisation goal of **no more than** 550ppm CO_2e
- To achieve this would require that global emissions peak in the next 10-20 years
- Delaying the peak in emissions by 10 years would double the rate of reduction required

Stern Review (2006); CO_2 = Carbon dioxide; 'CO_2e' = Carbon dioxide equivalent; 'ppm' = parts per million concentration (of CO_2e) in the atmosphere.

Stern showed that the benefits of a global move to a 450ppm-550ppm CO_2e trajectory exceeded the costs of action

Do nothing	Move to a 550ppm CO_2e trajectory	Move to a 450ppm CO_2e trajectory
5%* income loss to global GDP if we do nothing (market impacts only) **20%* income loss of global GDP**, including non-market impacts, risk and equity	Costs of mitigating action are expected to average 1% of GDP in 2050 but are lower in earlier years, e.g. 0.2-0.4% in 2015 and 0.6-0.9% in 2025	Stern calculated that the costs of this level of mitigation could be as much as **3 times the cost** of the 550ppm trajectory
The is a **50% chance** of exceeding a **5°** temperature rise under the do nothing scenario	There is approximately a **50% chance** of exceeding a **3°** rise in temperatures	There may be no more than a **50% chance** of remaining below a **2°** change

All temperature changes quoted are relative to pre-industrial temperature levels.

*Global income loss (5-20%) is equivalent to an "average" annual loss of GDP each year now and forever.

Globally, all countries and sectors will ultimately have to decarbonise…

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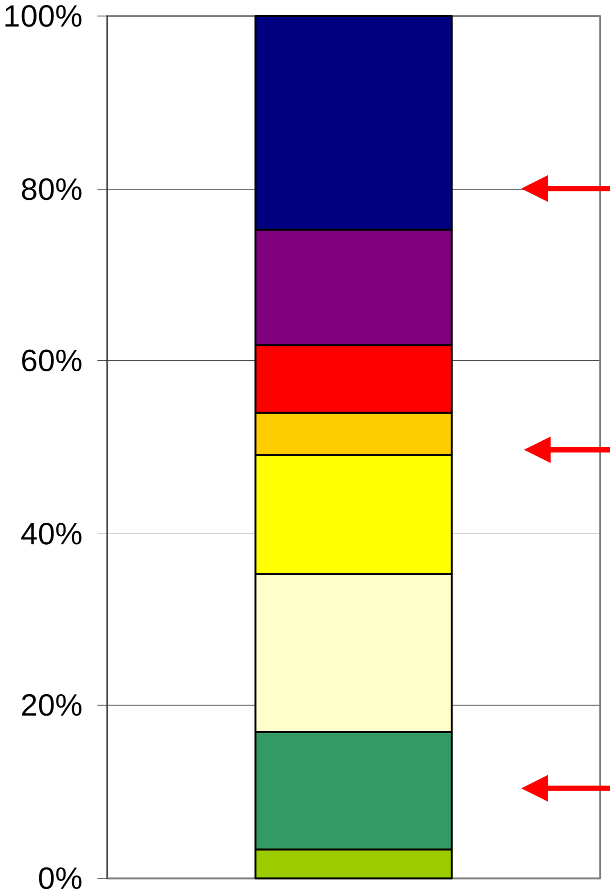
Global GHG emissions*



To achieve a 550ppm CO2e trajectory;

By **2050**, total emissions should be **80%** of 2000 levels

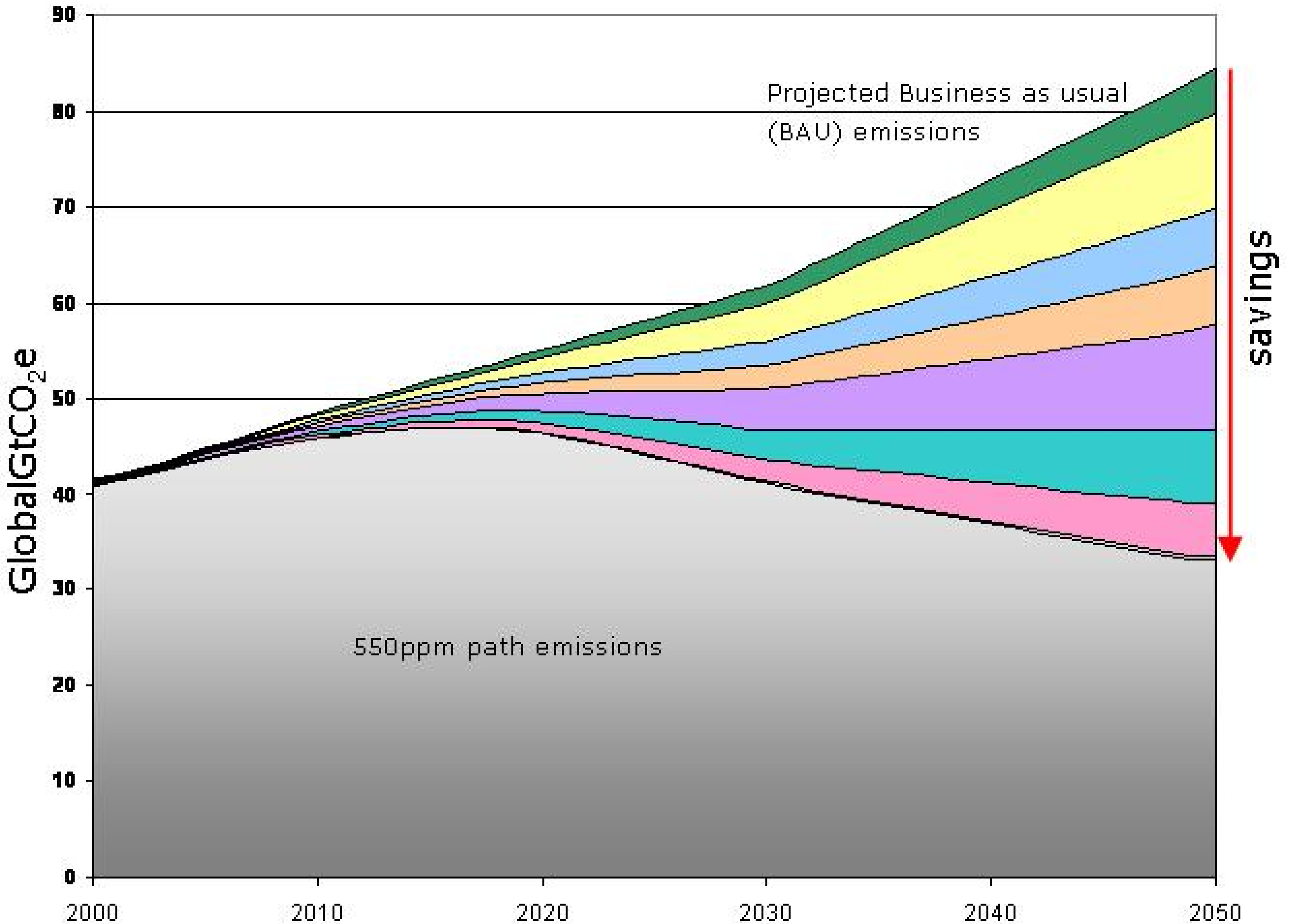
By **2100**, total emissions should be **50%** of 2000 levels

By **2200**, total emissions should be **10%** of 2000 levels

Achieving these emission cuts will require abatement from **all sectors and countries**.

* 2000 figures. Stern Review (2006).

… and Stern suggests that savings can be made across a range of areas



This graph gives a **very illustrative picture** of the potential contribution of different sectors or technologies to the savings necessary* to reach the 550ppm path by 2050.

* Savings estimates in 2050 taken from the Stern Review; pathways extrapolated from these figures and the BAU case. Emissions savings by technology are sensitive to assumptions used and the pathways are illustrative.

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Developed countries should take responsibility for most of these emission cuts

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International Agreement

The UNFCCC called for "**common but differentiated**" responsibilities for emission abatement between developed and developing countries. This principle reflects the fact that developed countries:

- are **richer** so more able to pay
- account for the largest share of **historic** and current emissions
- have higher **per capita emissions**, and developing countries require increased per capita emissions to support their development objectives.

Stern Recommendations

Stern quantifies these ethical principles in terms of target levels of abatement that countries should take responsibility* for by 2050:

- **450ppm** CO2e trajectory requires developed countries to take responsibility for cutting their emissions by **70-90%** on 1990 levels and developing countries to cut emissions by **50-65%.**
- **550ppm** CO2e trajectory requires developed countries to take responsibility for cutting their emissions by **60-80%** on 1990 levels and developing countries to grow emissions by **25-45%****.

E.g. If the **richest 20%** of the world's population agreed to pay 20% more of the costs (or **1.2%** of their GDP), this would allow the **poorer 80%** of the world's population to shoulder costs equivalent to only **0.2%** of their GDP.

Sources: The UNFCCC and Stern Review. * The emission abatement that developed countries are responsible for could be undertaken within their own borders or from other countries.

Both developed and developing countries should do more to decarbonise infrastructure in developing countries

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To **decarbonise** developing country infrastructure, Stern recommends:

Developed countries:

Developed countries should **increase carbon finance** going to developing countries. In particular:

- **CDM** should be transformed, scaled up, and given more certainty post 2012.

Developing countries:

Developing countries should:

- promote a more **enabling environment** for investment by building human and institutional capacity and
- supplement this with **domestic action**.

Over time, more responsibility for cutting emissions from developing countries should rest with developing countries

The incremental cost to developing countries of decarbonising is likely to run into tens of billions of pounds

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Stern* quotes IEA and world bank reports which suggest…

- Developing countries need to invest **$10 trillion** in their energy infrastructure to 2030
- In the **power sector** alone:
  - Developing countries need to spend **$165bn pa** to 2010, rising by 3% per annum between 2010 and 2030
  - Incremental cost of making this low carbon is around **$20-30bn per annum***.
  - Incremental costs are 10-20% of the total costs on these estimates
- But developing countries often face a trade-off between climate change measures and further investment in energy or other infrastructure for development
- These estimates are subject to much uncertainty (e.g. a background paper to Stern suggested that incremental costs for the **energy sector as a whole** could be **£25bn in 2015** rising to **£120bn in 2025**^

*Stern Review (2006), Chapter 23

^ (per annum) 'Costs and finance of abating carbon emissions on the energy sector', Dennis Anderson, Oct 2006.

A transformed Clean Development Mechanism (CDM) could provide substantial flows from developed to developing countries

- Oct 2006 estimates suggested that the value of certified emissions reductions (CERs) expected from projects up to 2012 could be around **$14billion** (Stern)
- If scaled up, CDM could transfer **$40bn/year** to developing countries*.
- To make CDM **suitable for scale up**, it would have to be **transformed**.

Current CDM:

Possible ways of transforming CDM:

Current CDM	Technology CDM	Programmatic CDM	Policy CDM
Project based CDM High transaction costs associated with this because emission savings are verified at an individual project level.	**Technology CDM** Standardised approach to selection of technologies and baselines.	**Programmatic CDM** Aggregates smaller projects within a programme, e.g. by incorporating savings from energy efficiency policies.	**Policy CDM** Provide credits directly to developing country governments that introduce an emission saving policy.

* If developed countries cut their emissions by 90% on 1990 levels by 2050, but make half of these savings via CDM, this would generate a transfer of $40bn/year, assuming a carbon price is $10/tCO2 (around E25/tCO2).

The Clean Energy Investment Framework will also play a key role in transferring finance from developed to developing countries

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The World Bank and regional development banks are a conduit for transferring money into developing countries. A significant outcome from Gleneagles was the call on the multilateral development banks to create a new Clean Energy Investment Framework (CEIF)

Clean Energy Investment Framework

Aim: to foster the scaling-up of public and private investment into low carbon energy technology and adaptation.

How?

- By facilitating the transfer of finance and technology
- By helping to combine the different sources of finance effectively (e.g. carbon finance and risk finance)
- Give technical assistance to developing countries.

This needs to be supplemented by building **human and institutional capacity** in developing countries to attract international investment and mobilise domestic private sector investment.

The CEIF is estimated to generate up to **$11bn/year extra** from private sector and official agencies

Measuring international progress on emissions can be difficult because of the quality of data available

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Most non Annex I parties emphasise the need for financial and technological support to develop their technical and institutional capacity.

IPCC default emission factors for several source categories are not applicable to LDC national circumstances.

Most sector estimates pose problems but in particular, land use change, energy and domestic combustion are subject to large uncertainty because of a lack of data or low quality data.

Most parties to the UNFCCC (largely Less Developed Countries, LDCs, with some emerging economies) find that their technical and institutional capacities are inadequate for meeting their reporting obligations for national GHG inventories under the UNFCCC.*

*Source: UNFCCC; http://unfccc.int/resource/docs/2005/sbi/eng/18.pdf ; para. 86

Therefore, Stern also recommends the use of comparative statics to measure progress

Problem: Incentives to Action	Problem: International Comparisons
Framing international climate change agreements in terms of national absolute targets does not offer countries incentives to undertake some important activities to reduce global emissions such as: •Recycling •Sustainable Consumption •Increasing R&D investment •Decarbonising economic activity	Real structural and behavioural change towards a low carbon economy is not necessarily captured by progress towards absolute targets. International negotiations may be complicated because absolute targets may not take account of exogenous factors affecting total emissions such as; •Population growth rate •Economic Performance •Exports or imports of carbon intensive goods

- Measurement of real structural and behavioural progress could be helped by tailored indicators such as;
  - Carbon intensity of electricity
  - R&D investment/GDP
  - Recycling rates
  - CO_2e emissions per capita
  - Fuel efficiency of vehicles

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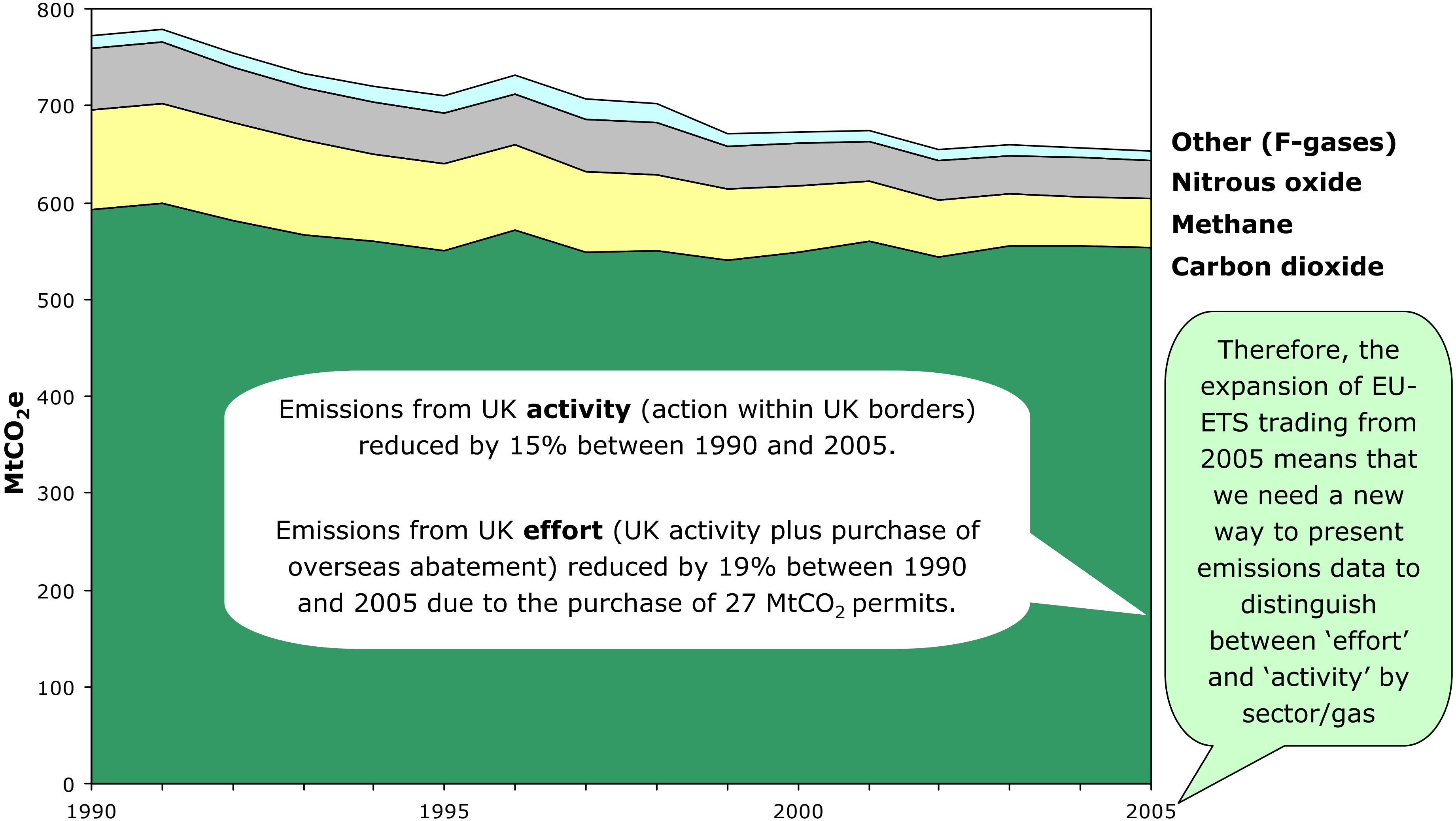
Our *measurement annex* shows that the UK has made significant progress in tackling greenhouse gas emissions



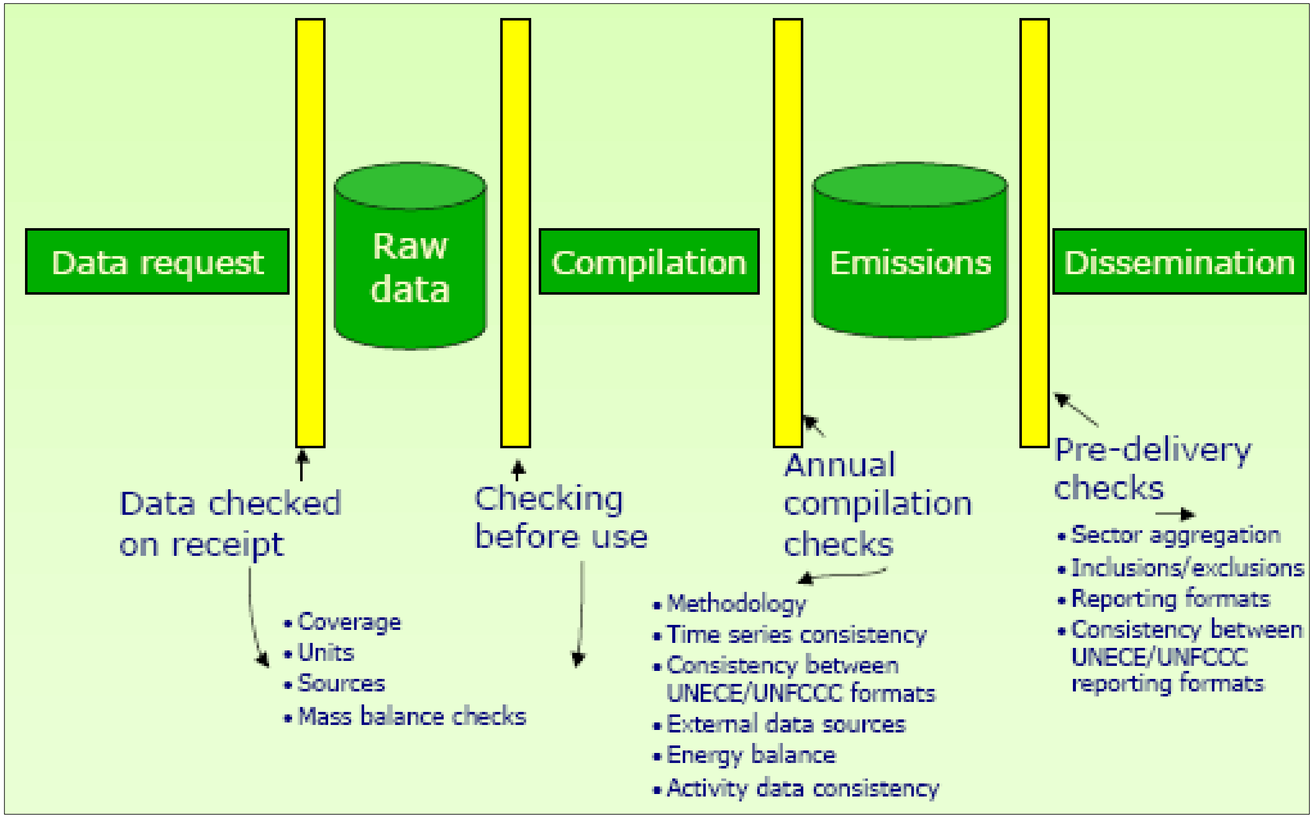
Defra Statistical Press Release (31 January 2007), *2005 UK climate change sustainable development indicator and greenhouse gas emissions final figures.* EU-ETS = European Union Emissions Trading Scheme.

Most of this has come from energy supply and business sectors…

(Share in 2004)	Progress	Driver
Energy supply (34%)	17.5% decrease from 1990	A shift since the early 1990s from coal and oil to gas (driven by the market and energy price changes)
Business (22%)	33.5% lower than 1990 levels	A shift from manufacturing to service industries and improved industrial processes
Transport (21%)	9.5% higher than 1990 levels	Increased road transport demand has offset gains in vehicle efficiency
Domestic (home heating) (14%)	14% higher than their 1990 levels	Growth in demand for energy services due to smaller households, rising population
Agriculture, forestry and land (7%)	22% lower than 1990 levels	Increased forestry area, reduced livestock, reduced fertilizer use

Sectors are on a source, rather than end-use, basis. Main figures based on final 2004 emission figures published in 2006 except where otherwise stated.

… and we can be confident this is an accurate reflection of the UK's performance because data quality is good



UN Expert Review Team reports in recent years all indicate that the UK submissions conform to international standards

The yellow bars represent 'gates' through which data should not pass until the appropriate checks have been performed

The UK has a target of cutting CO_2 emissions by 60% by 2050 – some commentators are challenging whether this is ambitious enough

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Stern recommends no more than 550ppm as the stabilisation goal

Stern recommends that developed countries should take on **GHG** cuts of 60-80% by 2050 to help reach this target

The UK 60% **CO_2** reduction target corresponds with possible GHG reductions of 58-72% depending on reductions in non-CO_2 gases, *i.e.* at the lower end of Stern's range

550ppm is associated with approximately 50% chance of exceeding a 3° rise in temperature

Commentators have been criticising the UK target as;

- Not ambitious enough and
- Inconsistent with a stated aim to limit climate change to a 2° rise in temperature.

David King*: "I feel that a 60% target is challenging but achievable, and strikes a reasonable balance between the different factors involved… it sets a clear policy direction and provides the impetus to accelerate early progress towards this."

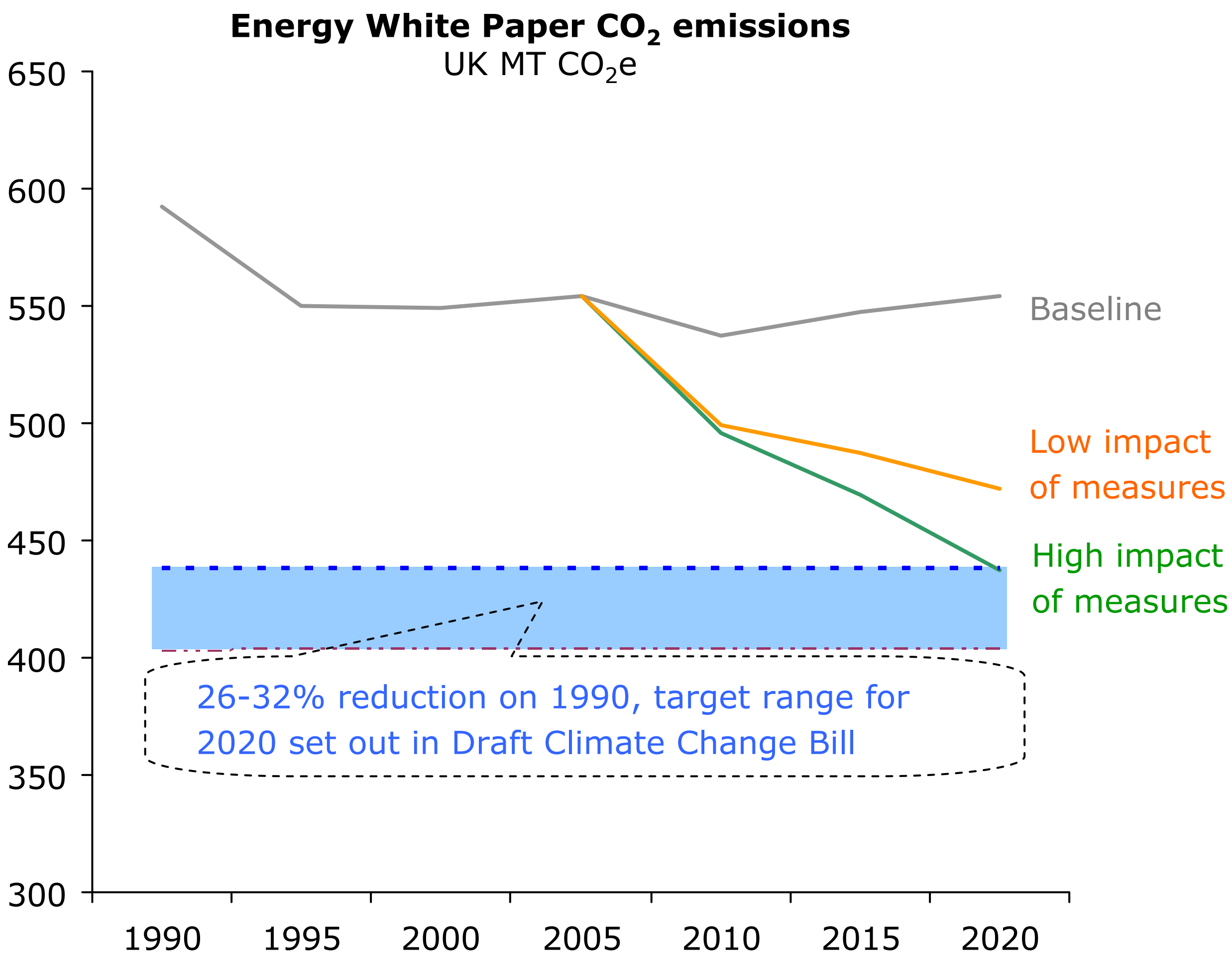
However, to set a UK target now greater than a 60% reduction by 2050 involves many risks;

- That the costs exceed the benefits
- That the UK acts unilaterally
- That UK competitiveness is damaged
- That international negotiation positions are compromised.

Draft Climate Change Bill provisions state that the unilateral reduction target of at least 60% is subject to amendment in the event of significant developments in either knowledge about climate change in international law or policy (e.g. Kyoto).

Temperature changes quoted are changes in degrees Celsius from pre-industrial levels. * David King is Chief Scientific Advisor to HM Government.

And the scale of challenge in meeting the government's CO_2 targets is significant



Key points
• Energy White Paper measures are projected to put the UK just within the 2020 target range of 26-32% reduction on 1990 CO_2 levels set out in the Draft Climate Change Bill. • These projections include effort of EU ETS compliance.

Source: DTI (2007) Energy White Paper.

This abatement can be achieved within and outside UK borders…

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Total UK emissions

Measure used to track progress to the UK's carbon budget.

=

UK National Allocation Plan 'cap' for traded sectors

The UK's cap has already been set until 2012 (end of EU ETS phase 2).

In 2005, the cap was 245 $MtCO_2$.

+

Actual emissions from non-traded sectors

In 2005, this was 282 $MtCO_2$.

-

Emissions UK Govt chooses to 'buy in'

The Climate Change Bill allows the UK Govt to 'buy in' emission savings from abroad, such as CDM.

To date, the UK Govt has not purchased any overseas abatement its self.

… but the maximum allowable emission savings that can come from overseas is yet to be agreed

Marrakesh Accord

The supplementarity principle states that:

"the use of the [Kyoto project] mechanisms shall be supplemental to domestic action and… domestic action shall thus constitute a significant element of the effort made by each Party…"

Possible UK interpretations of it

- The Defra negotiating position is to interpret the supplementarity principle as requiring **at least half** of emission savings by developed countries to take place domestically.
- Question: should 'domestically' be defined as within UK borders, or within the EU? Both are signatories to the Kyoto Protocol.

Method of resolving this

- The draft Climate Change Bill will propose that the **government gives advice** to the Committee on Climate Change (CCC) on how to interpret this guidance.
- The CCC will find this advice useful because it will be giving advice to government on how to meet its emission targets.

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    c. Is UK policy flexible?
    d. What is the UK doing to stop deforestation?

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Stern makes a series of policy recommendations to keep global abatement costs down to 1% GDP

Credibility can reduce abatement costs if policy is endurable, enforceable and realistic

Flexibility over 'what', 'where' and 'when' abatement takes place will minimise costs

Carbon pricing	Technology policy	Removing other barriers
The first of Stern's market failures: the damage costs imposed on the world by greenhouse gas emissions are an 'externality' that needs to be reflected in the prices of goods	The second of Stern's market failures: uncertainty and knowledge spill-overs mean that carbon pricing alone will not be enough to induce low carbon technology at the pace and scale needed	The third of Stern's market failures: imperfections such as information asymmetry and capital constraints mean that abatement will be more costly if you rely on carbon pricing alone

International cooperation overcomes risks of free-riding, as the climate is a 'public good'

Least cost abatement (globally, costs constrained to 1% GDP in 2050)

Stern Review (2006)

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Tax, trade and regulation can all be used to address the carbon price market failure, each has different merits

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- Each form of pricing has its merits, which may make some policies more suited to particular situations than others. Merits of pricing instruments:-

Tax	• Useful when there is uncertainty over the abatement cost, as it provides an upper limit on cost. • Good for small-emitters because lower transaction costs.
Trade	• Provides certainty over emissions levels • In practice, this may be the best instrument for getting a common carbon price across sectors and countries.
Regulation	• Most appropriate when there is significant behavioural inertia.

- **All policies can play valuable roles**; some will be better suited to particular situations than others.

EU ETS is one of the key tools for introducing a carbon price into the UK economy, future design of EU ETS will be critical to making sure this is effective

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Stern makes the following policy recommendations for the EU ETS. These are consistent with the **flexibility, credibility and predictability** criteria which are essential for stabilising permit prices and minimising mitigation costs.

Cap setting

- Tighter cap needed, with a more credible price for EUAs
- Clearer, more transparent rules on effort levels across EU.
- More predictable emission reduction trajectory.

Allocation Methodology

- Free permit allocation should be phased out, towards auctioning, where possible. Benchmarking preferred to grandfathering.
- Greater harmonisation and transparency between countries.

Expansion

- Extend the EU ETS to include more sectors, gases, countries.
- Links with other trading schemes.

Certainty

- Increased certainty of future emission constraints.
- Should allow for banking/borrowing between periods.
- Increased certainty in the role of CDM.

The UK has already put substantial effort into influencing the development of the EU ETS, largely consistent with Stern's design principles

Examples of actions the UK has taken, consistent with Stern's recommendations for emissions trading schemes:-

Cap setting

- The UK has **set tight caps** relative to the majority of other Member States in both Phases of the Scheme.

Allocation methodology

- The UK developed the most stringent **benchmarks** for Phase II.
- The Climate Change Bill will require government to give an indication of the distribution of effort between traded/non-traded sectors for the next 15 years, so enhancing **predictability.**

Expansion

- UK advice on **sectoral definitions** was adopted by the Commission is assessing Phase II NAPs.
- The UK has been pro-active in considering the role for other sectors and gases (e.g. **aviation**) and links with other trading schemes (e.g. US).

Certainty

- The UK **signals** its commitment to the EU ETS by making it the central plank of its climate change strategy.
- The Climate Change Bill also enables the UK government to purchase **CDM** credits, which signals some certainty for the future of this instrument.

Other policies often interact with EU ETS and it is important to understand the implications of these interactions

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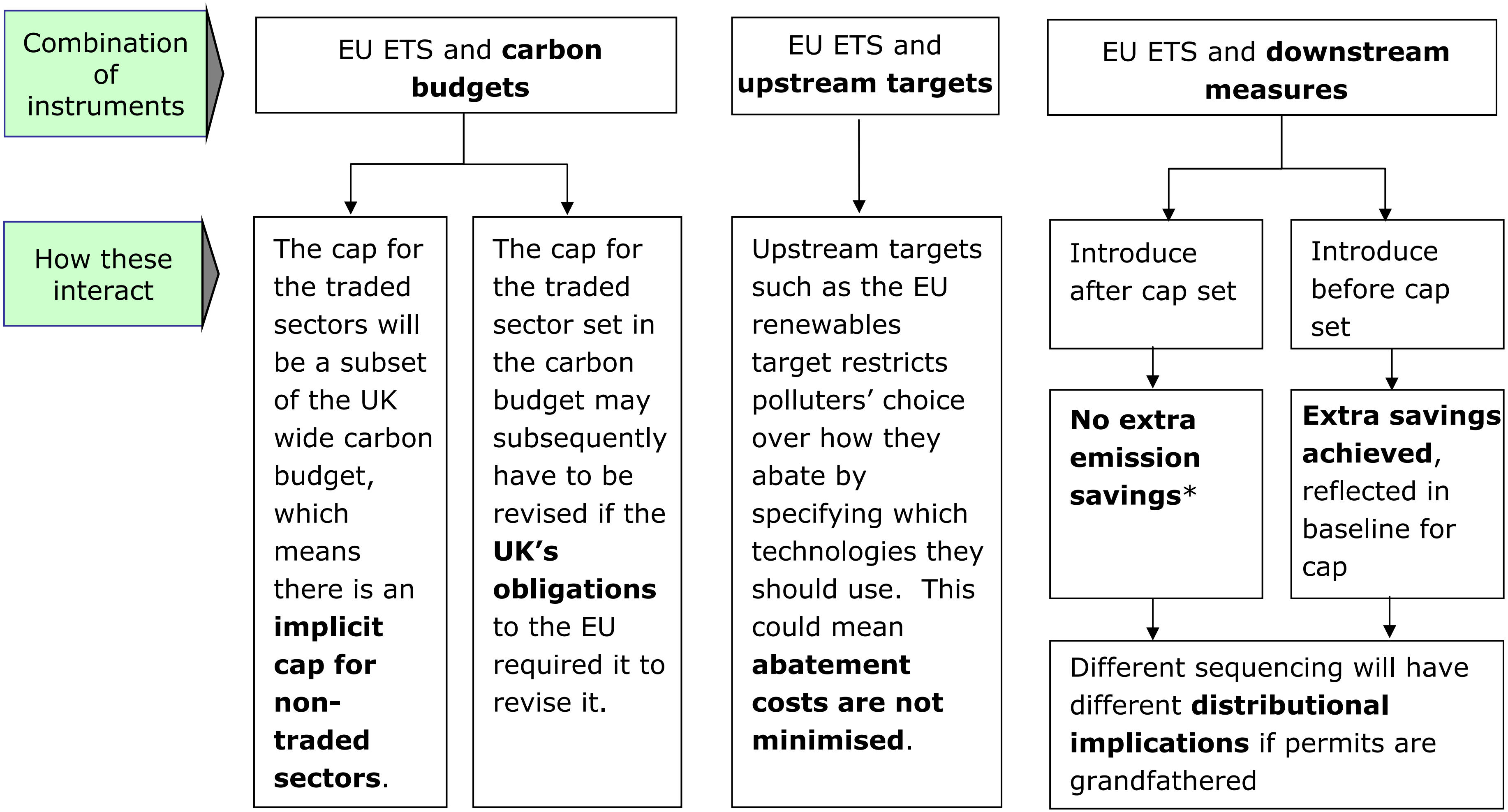

* But these measures may still be worthwhile because they help tackle fuel poverty, energy security problems. They also help realise lower abatement cost opportunities and may enable to UK to set a tighter cap in a subsequent period.

Regulation is sometimes overlooked as a carbon pricing policy

Tax and trade are well understood as creating a carbon price, but regulation less so.

An instrument imposes a carbon price if it raises the cost of doing the emissions intensive activity.

Tax/trade* increases the **cost per unit** of emissions intensive activity.

For example:

- Fuel duty increases the cost of buying petrol/diesel.

Regulation^ increases the cost of the emissions intensive **infrastructure**.

For example:

- EU Voluntary Agreements for fuel efficiency make it more expensive to produce/buy cars.

* There are some examples where a tax or trade acts at the production/sale of infrastructure. e.g. Vehicle excise duty is graduated according to fuel efficiency. ^In theory, regulation could also increase the cost per unit of activity

Pricing instruments work best when directly linked to the emissions, but many regulations are not specified in this way

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Current energy efficiency regulations:

Specified in terms of **energy efficiency** (the building's ability to keep heat insulated inside).

This can be met by **improving the energy efficiency of the building** (e.g. cavity wall insulation, loft insulation, etc).

BUT the regulation does **not incentivise low carbon technologies** because these do not count towards meeting the regulation.

2016 zero carbon homes regulation (proposed):

It is proposed that domestic properties built after 2016 are zero carbon (i.e. produce zero net emissions from all energy use in the home).

This is a well designed regulation because it **incentivises both conventional energy efficiency** measures and **low carbon technologies** – the developer will choose the cheapest way of meeting the regulation.

For the future: consider how to **extend this style of regulation** to new non-domestic buildings and existing buildings.

The UK has some explicit carbon pricing measures but also quite a few measures which are implicitly affecting prices in the system

Examples of carbon pricing measures

Explicit

EU ETS

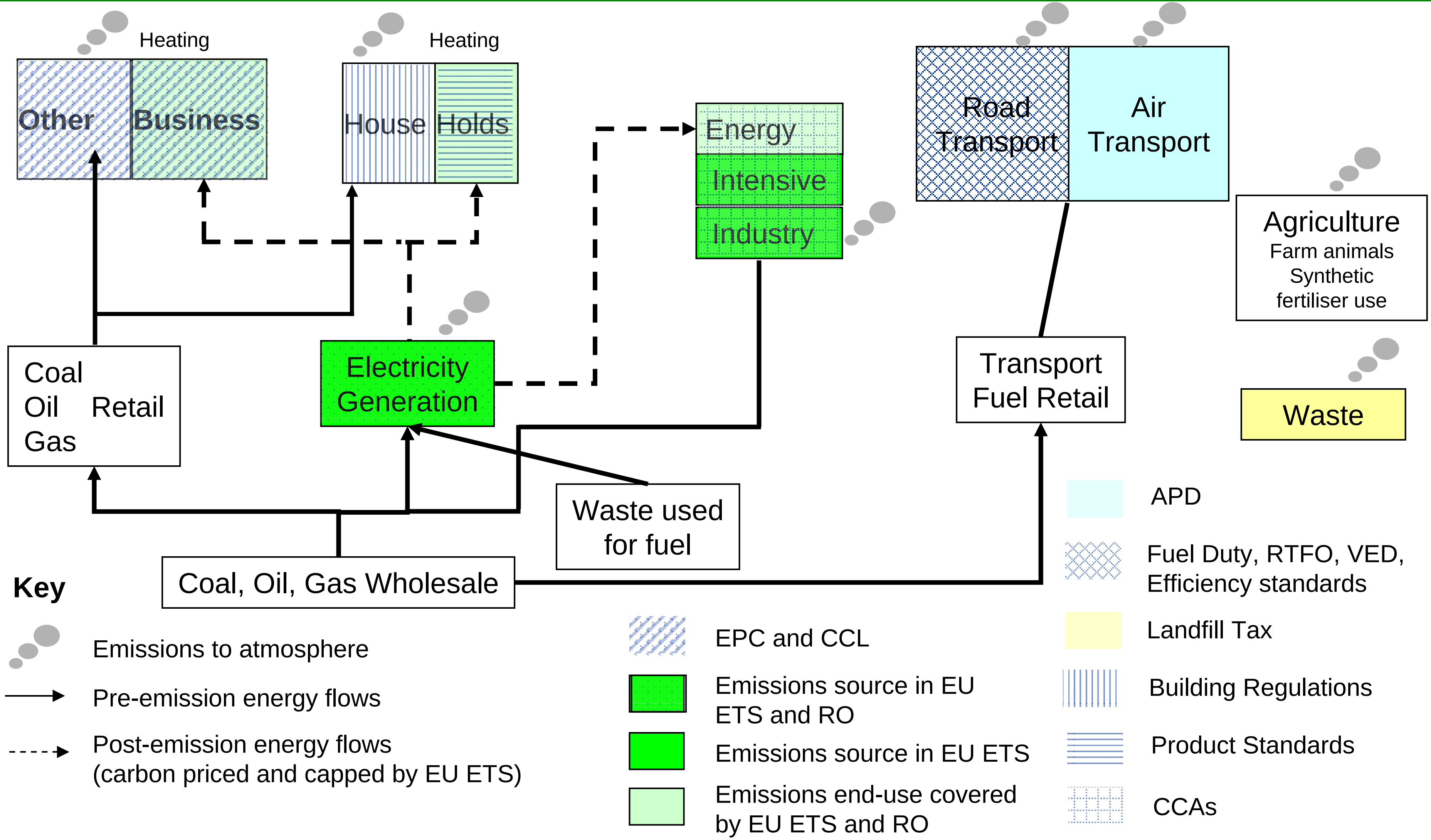
The carbon pricing effect of these measures is **not always recognised**. This may be because they have **other purposes** (e.g. to address other externalities, to raise revenue, etc). But they will have an impact on the relative price of carbon intensive activity.

This is important because it impacts on Stern's recommendation of a common carbon price across the economy.

Implicit

- CCL
- CCAs
- Renewables Obligation
- Energy Performance Commitment
- Building regulations
- VED differentiation
- Agreements on fuel efficiency
- Renewable Transport Fuels Obligation
- Agricultural Regulations
- Landfill tax
- Fuel Duty

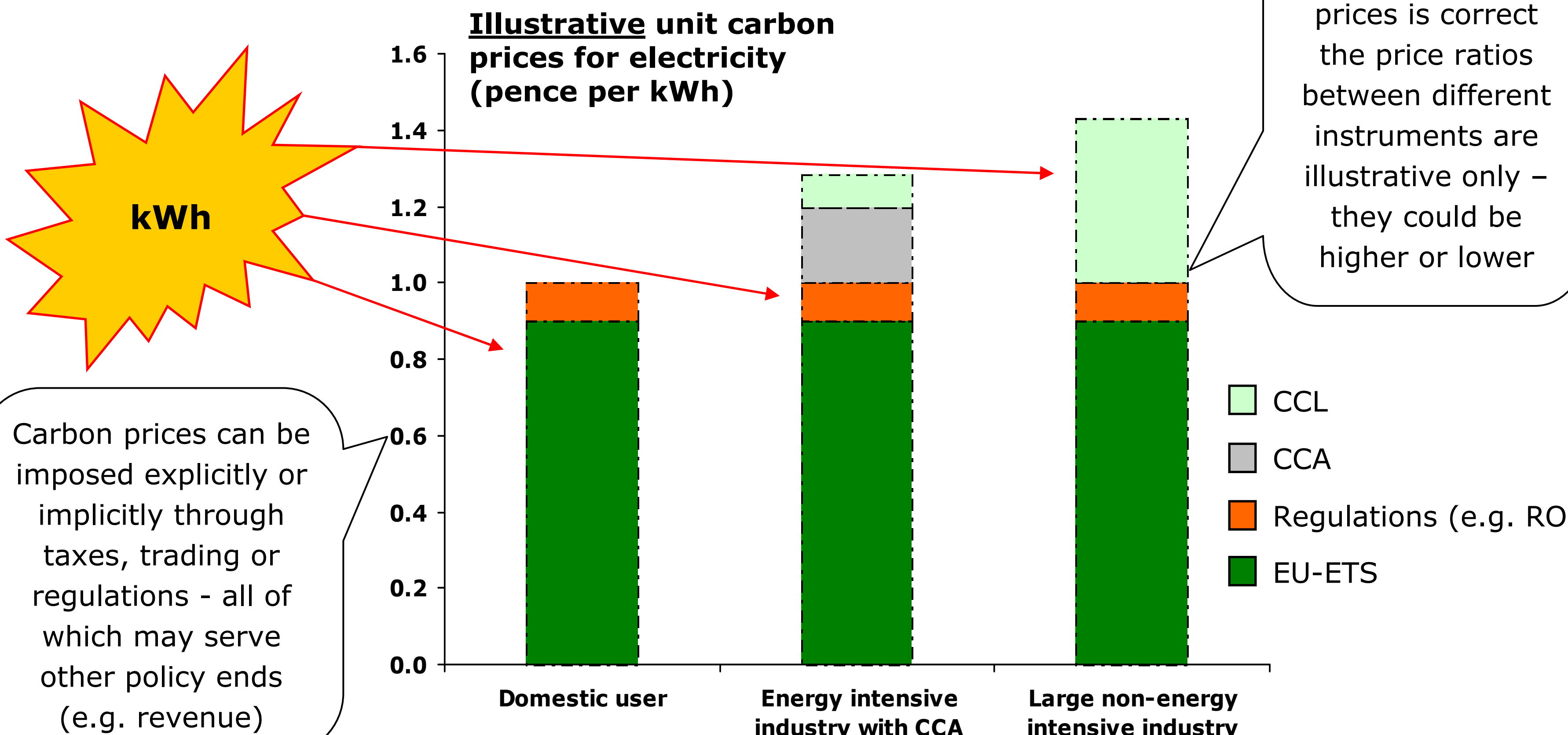
This simple illustrative* schematic demonstrates how some of the various pricing measures are affecting the carbon price of different activities in the economy



* This schematic gives an illustration of the broad emissions activities in the economy and some of the measures which will affect their price. It is not comprehensive and boxes and shaded areas are not proportionate.

The interaction between different measures can generate a range of different carbon prices

For example, for a given carbon-based source of electricity (e.g. coal) a different price results depending on its end-user…



Although the ordering of these prices is correct the price ratios between different instruments are illustrative only – they could be higher or lower

Carbon prices can be imposed explicitly or implicitly through taxes, trading or regulations - all of which may serve other policy ends (e.g. revenue)

Notes: EU-ETS = European Union Emissions Trading Scheme; RO = Renewables Obligation; CCA = Climate Change Agreement; CCL = Climate Change Levy; kWh = kilowatt hour (unit of electricity)

Understanding what impact measures are having on prices is very important because Stern recommends a common carbon price across the economy

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Different carbon prices

Different incentives for mitigation and abatement across and within sectors

Low-cost abatement opportunities potentially missed

Lack of understanding of carbon prices in the economy

Potential **lack of clarity** about impact of current policy on carbon prices

Potential for poorly designed future policy and missed low-cost abatement opportunities

We think an analytical piece of work to try to **clarify how the existing policy framework is affecting prices** would provide a very useful evidence base for future policy

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Stern highlighted the range of innovation market failures, which suggest an important role for technology policy

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Insufficient technology innovation

Knowledge spillovers

It is impossible to capture all the returns from innovation as once new information has been created, it is virtually costless to pass on

Risk and Urgency

Uncertainties and risks of climate change are of a scale and urgency not reflected in the decisions of private investors

Market structure

Markets occupied by multiple small polluters are ill equipped to invest in R&D. Highly regulated markets may be risk averse (e.g. electricity)

Energy is homogeneous

Consumers are unwilling to pay the price premium on clean energy because clean and dirty energy are identical to the end user

Full benefits not perceived

Even if future carbon price was certain, full benefits of innovation may not be perceived by investor with short planning horizon

New infrastructure

Clean technologies may require new infrastructure (e.g. hydrogen fuelling stations for cars)

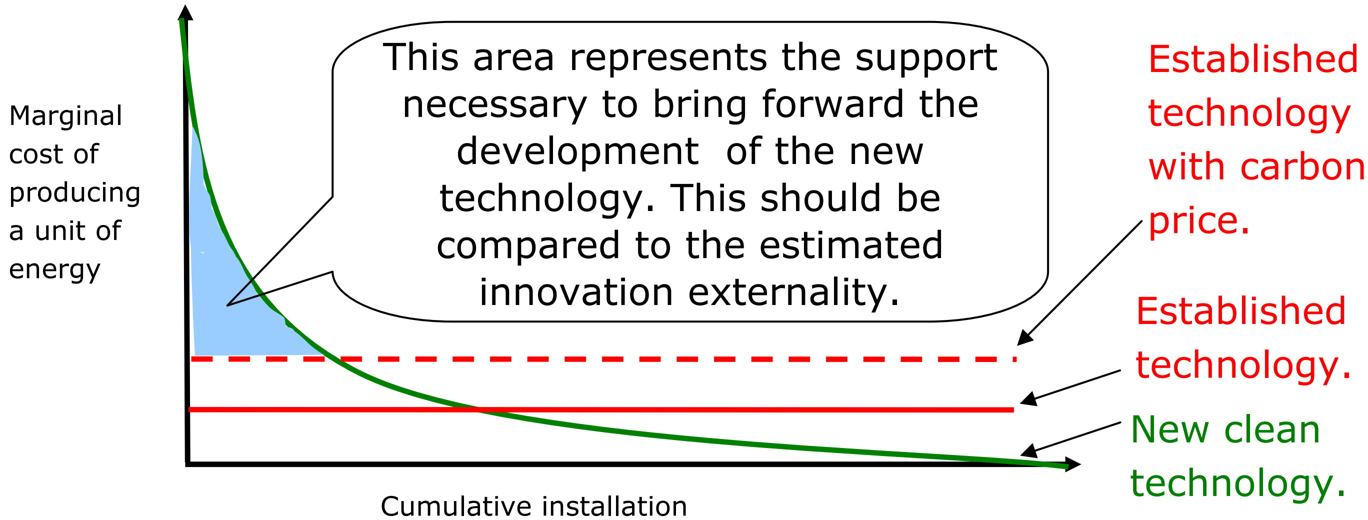
Consumer preferences

Consumers are socially conditioned to prefer the conventional fossil fuel technology (e.g. energy efficient building design)

The case for technology policy is made by economic theory, modelling work, and the unique features of the climate change problem

Economic theory

Illustrative experience curve for a new technology



Modelling work

Modelling for Stern* shows that **deployment policy** could be more important than carbon pricing for bringing forward clean technologies in the next few years.

Unique features of climate change

Climate change is uniquely challenging in terms of technology innovation. Whilst knowledge spillovers and learning externalities do exist in other markets, the combination of the range of market failures, risk and urgency makes low carbon innovation particularly challenging.

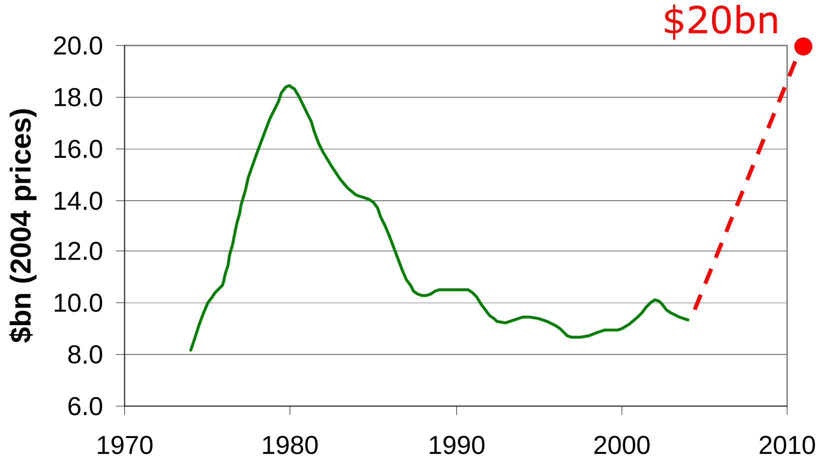
* Chapter 9 in which global mitigation costs are estimated to be 1% of GDP in 2050. Required global balance of support between carbon pricing and technology deployment policy is as high as 66% in 2015, falling to 16% in 2050.

Stern recommended that support given to low carbon technology should more than double globally…

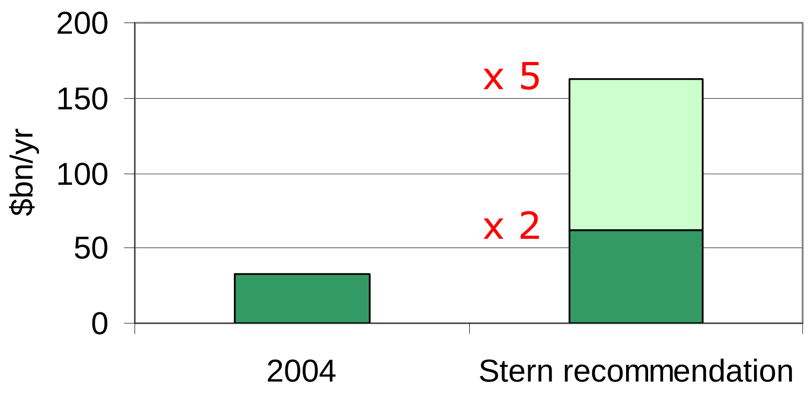
Output of low-carbon energy must increase **20-fold** over the next **40-50 years** to reach a 550ppm CO2e stabilisation trajectory.

To achieve this, Stern finds:

Global annual public energy **R&D** expenditure must double:



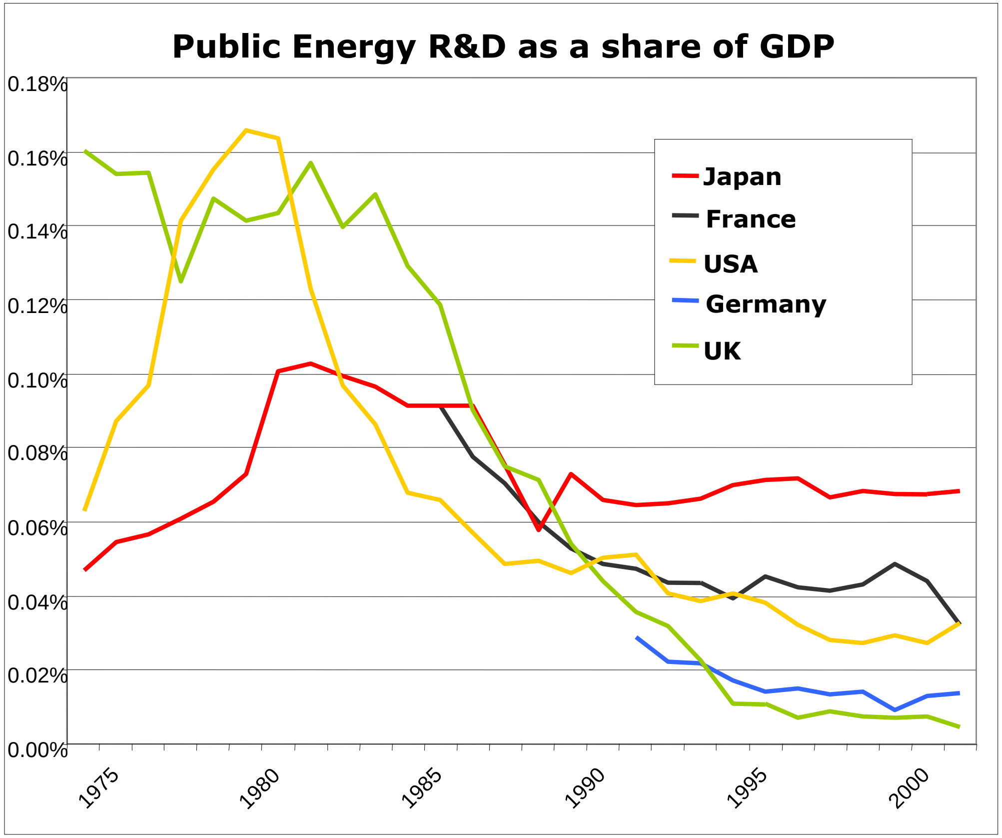
Global annual support for **deployment*** of low-carbon technologies must increase 2-5 fold:



* Deployment support is defined as technology specific interventions. This excludes carbon taxes and emissions trading because these do not target specific technologies.

… but on current trends the world, including the UK, does not appear to be on track to meet this challenge

Globally, **public energy R&D has fallen** since the early 1980s*:



To meet Stern's challenges for global R&D, these trends must be reversed. In particular, R&D on **CCS, renewables, hydrogen, fuel cells** and **energy storage** should be significantly scaled up.

The **UK** has among the **lowest rates of R&D expenditure** in the world.

How much should the UK be contributing to the global R&D challenge?

* Attributed to: post-1970s oil price shocks energy R&D budgets declined; 1990s liberalisation of energy markets reduced R&D effort for new technologies; and declines in R&D on nuclear following others' experience of cost overruns.

International cooperation on technology policy is crucial…

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International cooperation on technology policy is crucial because:

National technology policies may not deliver **global priorities**.

Where technologies could have significant global potential but are very expensive or risky, it may be better to pool R&D resources. Stern identified solar PV, CCS, bio-energy and hydrogen as among these.

International cooperation can secure more **cost effective transition** to a low carbon economy.

This is because in the R&D stage, countries are not "reinventing the wheel"; and in the deployment stage, coordination of product standards can boost cost effective reductions by increasing the scale of new markets across borders.

Technology transfer to developing countries will be necessary to avoid **locking in** to a carbon intensive capital stock. Developed countries should help developing countries pay for the incremental costs of undertaking these low carbon investments*.

* The principle that rich countries should help finance abatement in developing countries is discussed in this report, in the section: "How much emissions need to be cut and UK progress to date".

... this can take a variety of forms, many of which the UK already engages in

Ways in which countries can cooperate	Example of what the UK is doing here
Information sharing For example, sharing knowledge and coordinating R&D priorities in different national programmes.	UK participates in a range of international fora including through the **IEA**, the **EU** and **UNFCCC**.
Pooling R&D For technologies with high costs and risks, it may make sense for countries to pool R&D resources (e.g. CCS).	The **Commission** is raising the R&D budget for the 7th Framework Programme by 50% and the Intelligent Energy Europe Programme by 100%.
Product standards Coordination of regulations and product standards can be a powerful way to encourage greater energy efficiency.	Members of the **EU** have to adhere to energy efficiency standards.
Technology transfer to developing countries Essential to avoid lock in to carbon intensive infrastructure.	The UK is pursuing international technology transfer through mechanisms such as the **Clean Energy Investment Framework*** and the **Environmental Transformation Fund.**

The UK's **strategy** on international technology cooperation is overseen by the **"Technology and innovation" workstream** under the cross-departmental International Climate Change Programme

* The Clean Energy Investment Framework is discussed in this report, in the section, "How much should emissions be cut and what progress has been made in the UK?"

Stern says that technology policy should account for risk inherent in the innovation process…

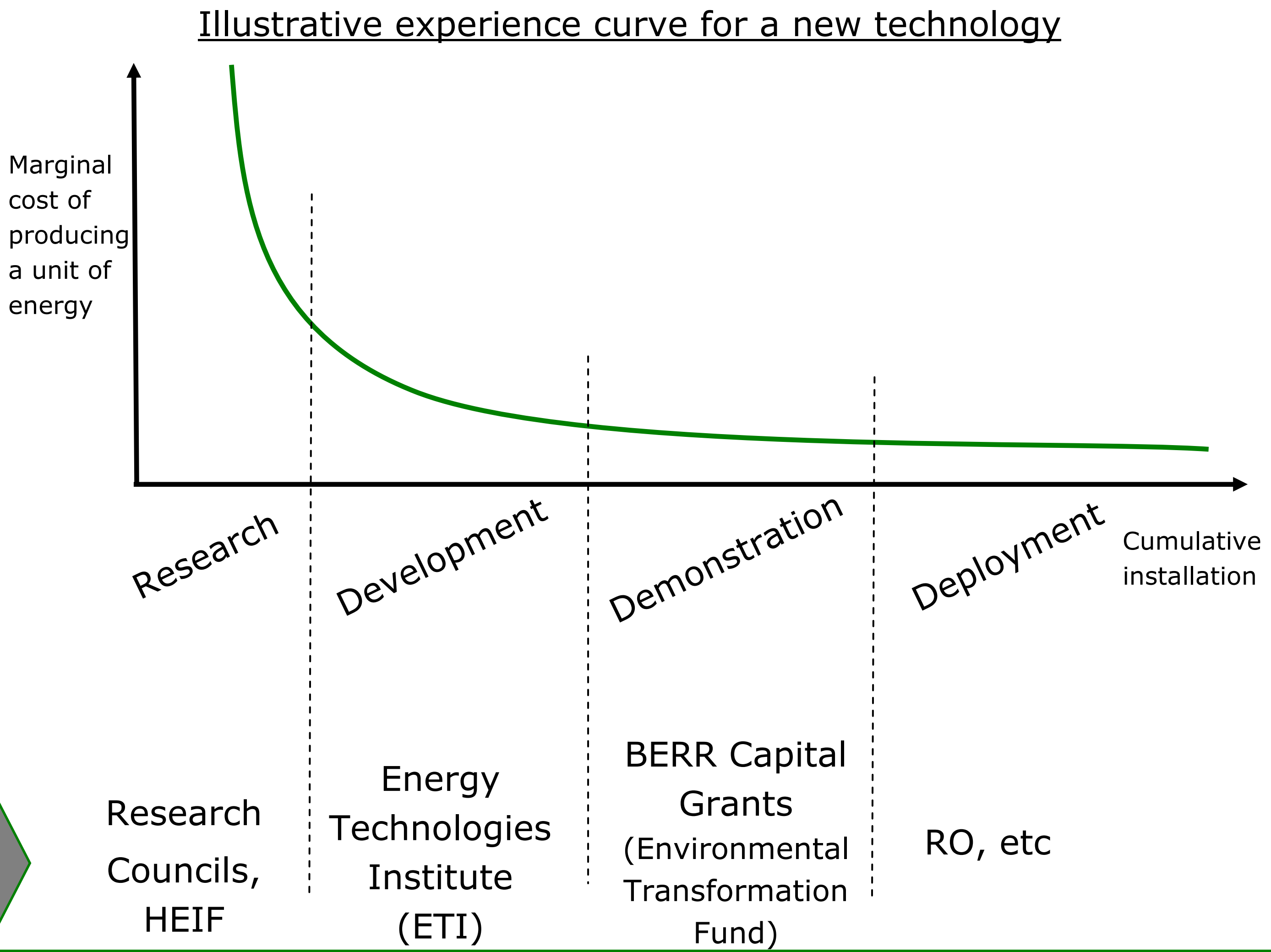
Features of good technology policy	**Why?**
Portfolio approach	Innovation is inherently risky, so policy should be designed to pull forward a portfolio of technologies as a 'hedge' against some technologies failing.
Planning	Capital infrastructure lasts years, so need to plan for its replacement.
Credible and predictable	Helps promote private investment and enables research bases to thrive.
Promote private investment	Public R&D should focus on fundamental, long term, risky projects. Joint partnerships can promote private investment (e.g. UK Energy Technologies Institute).
Exit strategy	Some technologies will fail, and equally some will succeed and no longer require government support.
Technology neutral…	Markets are best placed to identify the technologies with likely commercial success...
… with technology specific support	… but markets will be bias towards nearer to market solutions so additional measures may be needed to pull forward the longer term technologies and to address technology-specific barriers.

… and should support technologies at each stage of their development

Innovation theory tells us that technologies typically **fall in cost as output increases**.

So to secure **cost effectiveness** over the long term and bring forward a **portfolio** of technologies, it is necessary to have policy **support at all stages**.

UK policy is designed with this in mind e.g.:



Stern's analysis raises some interesting questions about the role of technology neutral / specific policy

There are 2 basic approaches to design of technology policy

Technology neutral policy

The market tends to know technologies better than government. Using technology neutral policy, the market can select which one is best.

Technology specific policy

This can help to overcome barriers specific to individual technologies and help bring them down their cost curve.

On an initial analysis, **technology specific** policy appears to be more appropriate the more **different** technologies are in terms of their **cost, riskiness** and **barriers faced**. Applying technology neutral policy to technologies that are very different could result in inadvertently "picking a winner" because the market will tend to be biased towards technologies which are least cost, least risk and have least other barriers in the short term – but these will not necessarily be the least cost technologies in the long term. This suggests technology specific policy may be best suited to technologies in their **early stages of development**.

On an initial analysis, technology **neutral** policy appears to be better suited for use when technologies are more **similar**, which may be when technologies are **close to market**.

Stern's analysis prompts the question of whether the UK could learn anything from the private sector on how to consider risk…

Stern suggests that governments should be aiming to bring forward a **portfolio** of clean technologies with the **lowest cost over the long run**.

Currently, government makes **estimates** of **future expected cost** of **individual technologies** to help inform its decision about which ones to invest in.

But this is prone to difficulties because what we are really interested in is the expected cost extending out into the long run, which is **very difficult to estimate**.

Can government learn anything from how the private sector deals with risk?

e.g. Fund managers look at the **expected return across a portfolio** of investments, rather than looking at the expected returns from individual ones. They also tend to select investments whose risks are **not correlated**.

Could government learn anything from this approach?

… and whether the UK's technology policy is of the appropriate scale and design

UK's contribution	What should the **UK's contribution** to the global level of technology R&D and deployment effort be? The UK could spend more, and attempt to achieve **first mover advantage**.
Balance between instruments	Do we have the balance right between **carbon pricing** and **technology policy**? Stern analysis suggests deployment policy could be more important for bringing forward clean technologies in the early years.
Technology neutral / specific	**Further analysis** on the role for technology neutral / specific policy may be helpful.
Public R&D spending	Is the UK public expenditure on energy R&D diverted into the appropriate technologies? Stern suggests that public R&D should be focused on technologies that are more **risky and long term** (e.g. energy storage, CCS, hydrogen).
International cooperation	Could the UK's technology strategy benefit by being more **international** in nature?

Looking across all sectors raises the question of whether the UK has an economy-wide technology strategy?

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A lot of activity in some areas…

Electricity sector has the most technology strategy, initiatives and incentives.

Transport sector technology strategy is being developed in LCTIS and the Stern/King Review of vehicle and fuel technologies.

But are there lessons for other sectors of the economy?

Other sectors e.g. agriculture, buildings, energy intensive processes have technology incentives and programmes, but from a low carbon perspective it is a more **piecemeal approach**.

Is there value in asking some of the **strategic long term** low carbon technology questions for other sectors of the economy?

For example, are there technologies and areas of expertise where the UK holds a **comparative advantage** which it could exploit?

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In addition to the carbon and technology externality, Stern highlights the existence of other market failures that may need tackling in climate change policy

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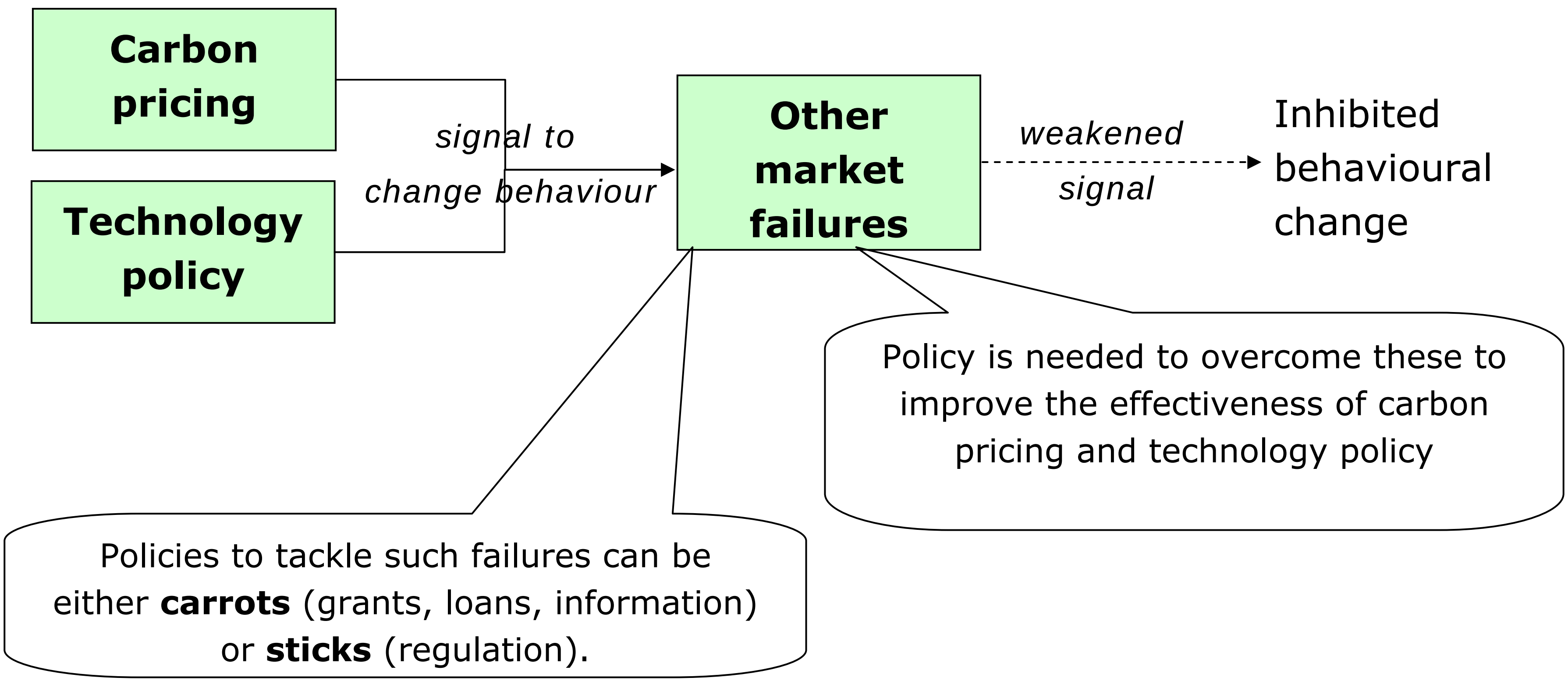
The ability of carbon pricing and technology policy to bring about behavioural change may be inhibited by other failures in the market.

Without policies to tackle these other market failures cost effective emission savings may not be realised.



For example, in the buildings sector, there are a plethora of market failures inhibiting the take up of energy efficiency measures

Carbon pricing

Tech-nology policy

Other market failures/barriers in the buildings sector

1) Transaction costs
Cost of researching investment options, inconvenience of waiting in for tradesmen, and opportunity cost of diverting resources away from core business activities.

2) Liquidity constraints
Lack of capital for investment in energy efficiency.

3) Misaligned incentives (Landlord-tenant)
The owner of the property (landlord) faces no incentive to invest in energy efficiency is s/he cannot reap the benefit through lower fuel bills or higher rent.

4) Misaligned incentives (Payback times)
The owner of the property may expect to move out of the property before the full benefits of any investment have been perceived and may not be able to capture the benefits through the selling price.

5) Complex decisions
People may be unable to calculate the long run value of energy savings so resort to simple, suboptimal decision rules.

6) Habitual behaviour
People may be socially conditioned to behave in particular way with energy, rather than responding to information.

Inhibited behavioural change.

Cost effective emission savings not taken up.

These other market failures imply the need for tailored policy responses, although regulation may be particularly effective

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The following table shows which policies economics would suggest are appropriate for addressing the various market barriers/failures:

	Information	Financial incentives	Loans	Regulation
Transaction costs	✓	✓		✓
Liquidity constraints			✓	✓
Misaligned incentives		✓		✓
Complex decisions and habitual behaviour	✓			✓

Regulation is a **particularly good instrument** because:

- It is the only instrument that **addresses all** of the "other market failures/barriers".
- Provides greater **certainty** over emission savings because it mandates behavioural change, rather than persuading people to change (i.e. regulation is a 'stick')*.
- Regulation also works across Stern's **other 2 legs**, by imposing a carbon price and technology policy.

* 'Carrot' measures can struggle to reduce emissions because these market failures are compounded by low demand elasticities and consumer preferences.

We have a lot of different policies trying to tackle these other barriers, and this raises a question about efficiency and effectiveness

For example, all of these policies were introduced into the buildings sector with the primary intention of tackling 'other barriers'…

Some of these are sticks (regulations) and some are carrots (e.g. grants/loans)

Some have a carbon pricing effect

Some have a technology effect

- Climate Change Agreements/Levy
- UK Energy Performance Commitment (proposed)
- Building regulations*
- Enhanced Capital Allowances
- Low Carbon Buildings Programme
- Planning policy
- Support for sustainable public sector procurement
- Code for Sustainable Homes
- Stamp duty relief for zero carbon homes
- Energy Efficiency Commitments
- Warm Front
- Revolving loan fund
- EST information campaign
- Carbon Trust
- Reduced VAT for domestic efficiency measures
- EU Energy Performance of Buildings Directive
- Better billing and metering

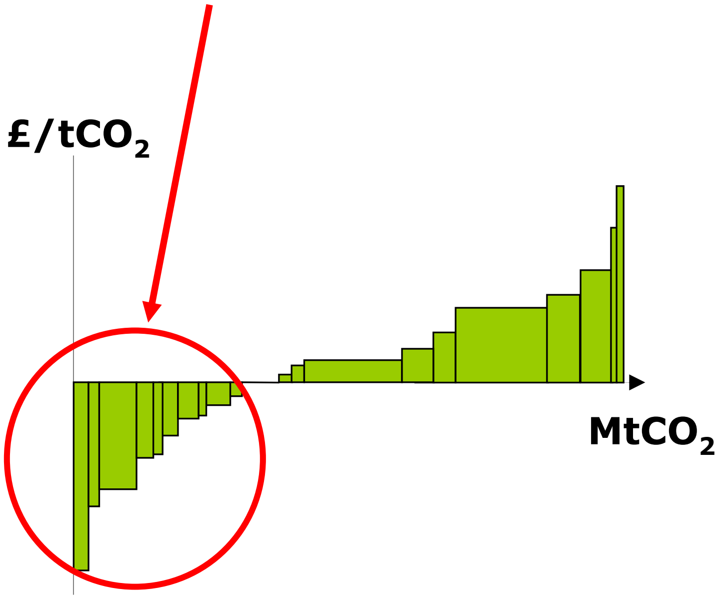
Key

- Household
- Business
- Public sector
- Combination

* Building regulations apply to new build and substantial refurbishment (including boilers) only.

The marginal abatement cost (MAC) curve is a good way of checking whether policies to remove "other barriers" are working

Some energy efficiency measures are so cheap that they more than pay for themselves during their lifetime. These are **negative cost measures on the MAC curve**.



But people do not make these changes because of the **existence of the "other market failures"** described earlier.

So if government introduces policies to tackle these "other market failures", then these **savings should be realised**.

It is a **test of how effective government policy** is to see whether people have taken up these measures after policy has been introduced.

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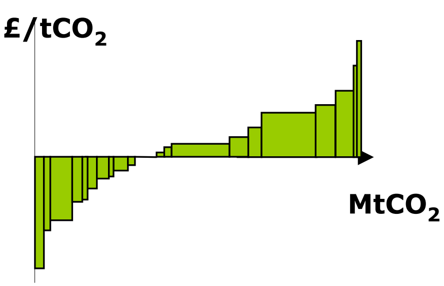
Most of our analysis to date has focused on the MAC curve – the analysis is robust and consistent across sectors…

Marginal abatement cost (MAC) curves show the **cost of abating one tonne of CO2** in a range of different ways. The cost of meeting the carbon target can be minimised by choosing the cheapest measures, from among the subset of measures being considered.



The MAC curve has played an **important role in climate change policy making**.

For example, MAC curves were produced for the CCPR and Energy Review. This analysis has been praised as **robust, high quality and consistent between departments** (National Audit Office reports, 2006).

There are two sorts of MAC curve:

- **Technology curve** (includes resource costs associated with technology)
- **Policy curve** (same as technology curve, but it also includes other welfare costs associated with the particular policy used to implement it, such as congestion, air quality, etc.)

… but the MAC by itself does not give us a framework for ensuring all market failures are tackled and abatement costs are kept down

Selecting the cheapest policies along the MAC will help us **meet the carbon target at the least net cost**, from among the **subset of measures** being considered.

But the MAC does not give us a framework for **ensuring that the 3 market failures** (carbon externality, innovation externalities and "other market barriers") are being **corrected appropriately***. In particular, the MAC does not tell us whether:

- **Carbon prices** are equalised across sectors
- **Technology policy** is optimally designed
- All "**other market barriers**" are being tackled

Result:

Low cost abatement could be missed if any of these 3 market failures are not addressed appropriately.

* For example, if we appraise the policy, "tighten fuel efficiency standards for vehicles" and it proves very costly, we don't know if this is because (i) the carbon price implicitly imposed by the regulation is set too high, (ii) the technology is far up its cost curve because it is experiencing innovation market failures, or (iii) the policy is poorly designed.

Stern suggests an analytical framework in which the market failure determines the nature of the policy response; this is necessary for least cost abatement

Identify the **market failure**	**Carbon externality**	**Innovation market failures**	**Other market barriers** (information asymmetry, capital constraints, etc)
Identify the **nature of the policy** intervention required	**Tax, trade or regulation**	**R&D, deployment support**, etc.	**Information provision, grants, loans**, **regulation**, etc.

Identify the **detail of the policy design**

Details of exactly how the policy is designed (e.g. up/downstream; national or international intervention; mandatory or voluntary, etc) should then be considered.

Exact policy design will be determined by, for example:

- outcome of **cost-benefit** analysis
- **conflicts/synergies** with other policy objectives
- **fit with existing policies**, etc.

Having established the nature of the policy intervention needed, there are a range of issues to consider regarding detailed policy design

Global scale at which instruments are implemented

- Could be international, EU or UK. Although EU or UK are the main options at the moment
- Most appropriate level will depend on a range of factors including:
  - Existence of appropriate institutional framework
  - Competitiveness issues
  - Carbon leakage
  - Trading rules (e.g. EU single market)
- This needs to be assessed on a case by case basis

Upstream or Downstream?

- A rather different issue is whether measures are applied upstream, to the source such as fuel suppliers, or downstream to end-users such as drivers of vehicles
- **Market characteristics** and **transaction costs** will inform where it is best to levy the instrument.
- It is important to understand that whether an instrument is levied up/downstream should have **no impact on who bears the cost** (i.e. consumers or producers or suppliers). Industry structure will determine this.

Ideas for new analysis that could be helpful in building our analytical framework

	Carbon pricing	Technology policy	Removing other barriers
Key question posed by Stern	Do we have a **common carbon price across all sectors**?	Do we have technology policies that take appropriate account of the **risk** inherent in the innovation process and is sufficiently **international** in nature?	Are all the other market failures being **appropriately addressed**?
Further analysis that could help answer this	An analytical piece of work to clarify **how the existing policy framework is affecting carbon prices** faced across sectors would be helpful.	Could we **learn anything from the private sector about how to manage risk**? e.g. Fund managers who look at the expected return from a portfolio of assets.	Comparing the **MAC curve with abatement actually taken up** would help identify other market barriers that are not being addressed.

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Credible policy helps keep costs down

Policy is credible if society believes the policy will **endure**, be **enforced**, and can **realistically** be achieved.

Credible policy

↓

Low carbon investment is more likely to be undertaken because certainty over future policy, for example the carbon price reduces the **required rate of return** on low carbon investment

↓

Lower abatement costs

- Credibility of policy into the long term is particularly important because much energy infrastructure has a **long lifetime**. Once built, carbon intensive assets will be there for a long time, and to retrofit or retire early will be expensive. Example capital lifetimes include:
  - Buildings: > 45 yrs
  - Coal power station: > 45 yrs
  - Gas turbine: > 25 yrs

The Climate Change Bill will help improve credibility of climate change policy…

The Climate Change Bill aims to improve **predictability** in terms of:

- the expectations of a framework for carbon pricing*;
- the split of effort between capped and non-capped sectors; and
- the timing of policy making and the conditions for possible revision.

Credible climate change policy

The Committee on Climate Change will publish a report recommending levels for carbon budgets and the split between capped and non-capped sectors for the next 15 years.

The **timing** of policy decisions will be to a large extent standardised into a 5 year timetable.

The **conditions** under which carbon budgets may be revised will be made more transparent.

* The draft Bill only sets targets for CO_2, so these points only apply to carbon dioxide emitting sectors and activities.

…but there is some way to go to improve credibility further

Areas of Uncertainty

International climate change policy	• The **future EU ETS** (uncertainty over future permit allocation methodology, the length of trading periods, level of permit price, and design of scheme post 2012.) • Future **technology policy** globally. • Future international finance flows from developed to developing countries; this will be informed by how the **supplementarity principle** is interpreted.
Domestic climate change policy	• Credibility of the UK's long term targets will be affected by our ability to demonstrate progress towards them. The fact that we are off-track for the **2010 target** is not helpful here, however, the EWP demonstrates we should be on track for **2020**. • Whether future governments will adhere to the 60% target is unclear. Will they **stick to it** if other countries do not follow?

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Flexibility over "what, where, when" keeps costs down

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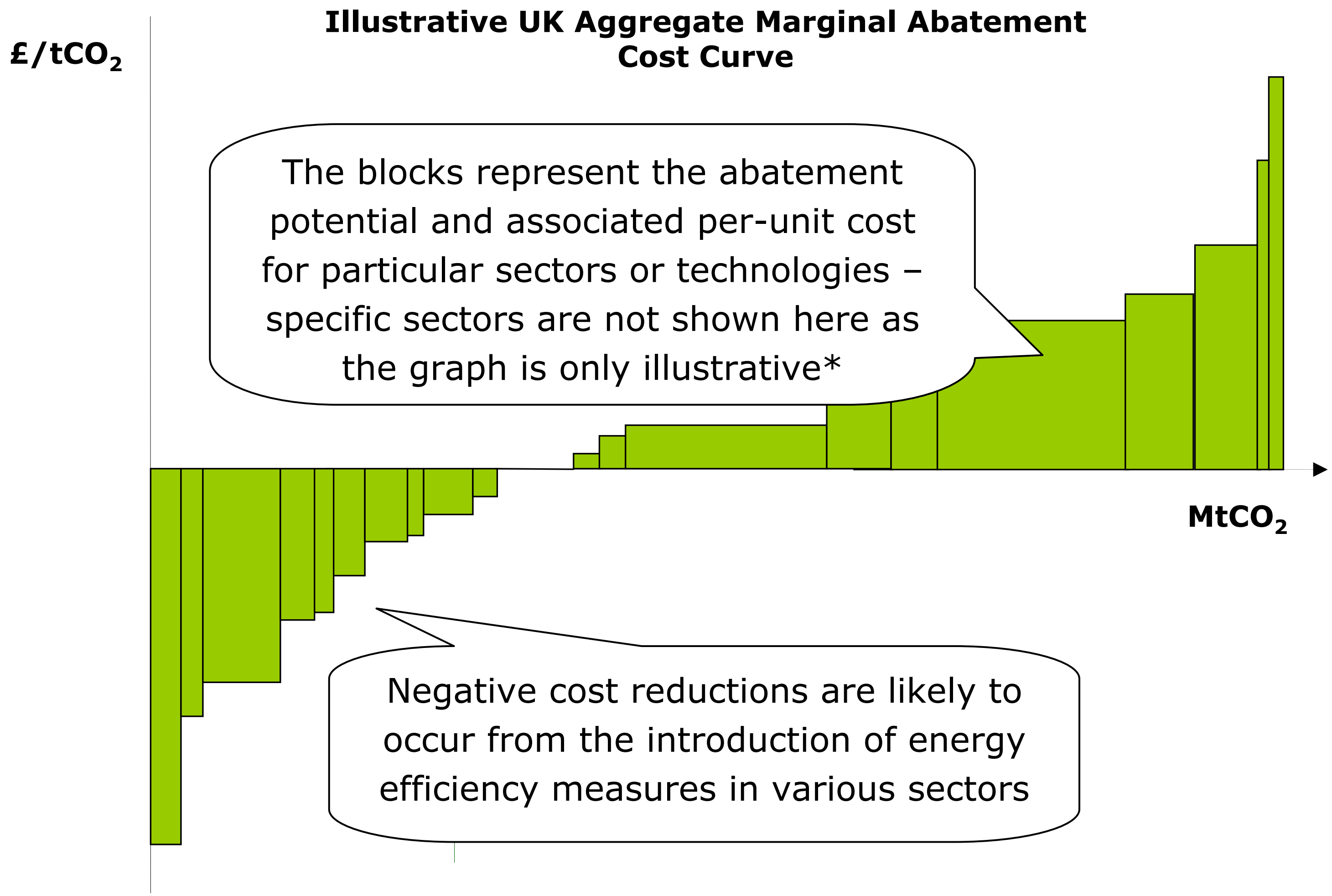
- Flexibility over what, where and when emissions reductions take place can help to minimise the associated mitigation costs.

- Using this principle means emissions reductions are allowed, or indeed encouraged, to take place where and when it is cheapest to do so, and in the sectors with the cheapest abatement options.

- Stern's 1% global mitigation cost is premised on flexibility over how emissions are cut.

What flexibility	• Relates to which gases are targeted, the sector in which abatement occurs, or the technology used to achieve the abatement
Where flexibility	• Refers to the geographical location of the emissions reductions, for example domestic versus overseas reductions
When flexibility	• Concerned with the emissions trajectory into the future, and the reductions that take place at specific points in time.

Marginal Abatement Curves show that abatement is likely to be significantly cheaper in some sectors than others…



* A quantitative policy-specific curve was developed for the Energy White Paper. In addition, consultants McKinsey are compiling a global abatement curve.

…and so 'what' flexibility over sector and technology choice can aid cost-effective abatement

- 'What' flexibility implies equalising carbon **price** across sectors, technologies and gases, and allowing the **market** to determine the sectors in which abatement takes place (since Government is not generally best placed to do so)

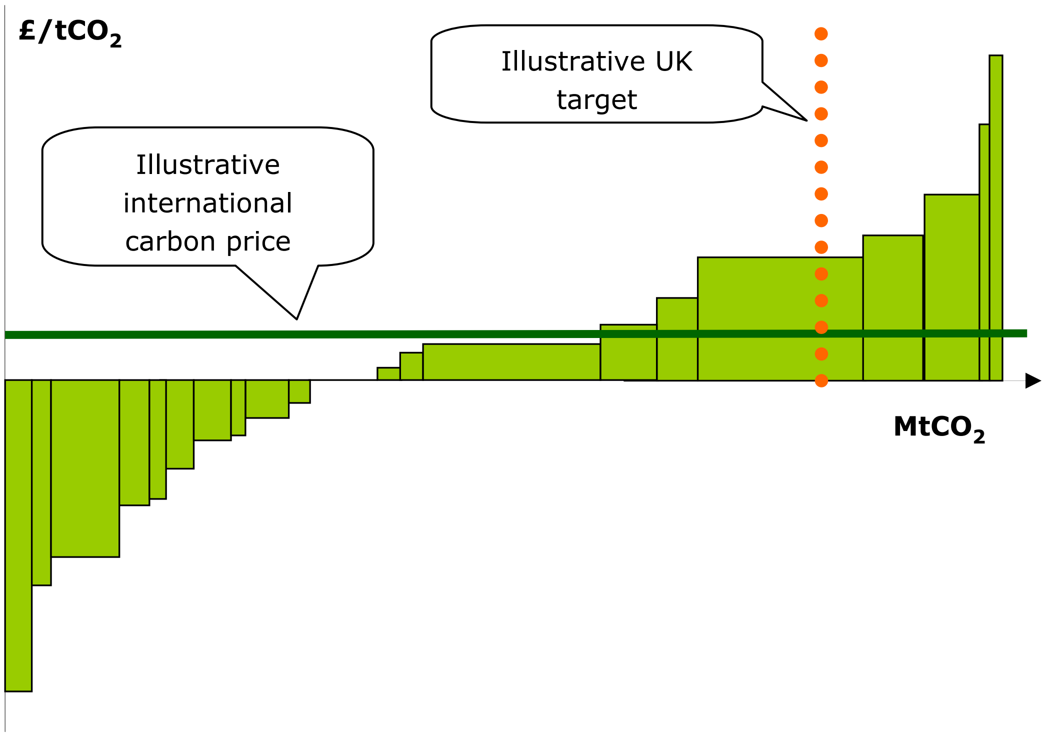
- In contrast, aiming for specific levels of abatement effort in particular sectors would require imposing different carbon prices to reflect the different abatement costs – an expensive and inefficient way of meeting a given emissions reduction target.

- With this in mind, Marginal Abatement Cost (MAC) curves show where it may be more cost effective to pursue emission savings – for the UK, this is currently energy efficiency measures

- Inflexibility over technology choice can have significant effects on total costs:
  - According to BERR's Markal model, the combined exclusion of nuclear power and Carbon Capture and Storage technology could increase the annual abatement cost in 2050 by 24%, or 0.2% of GDP, from the baseline scenario

‘Where’ flexibility – overseas is likely to be a source of cheap abatement opportunities, although there may be some restrictions on the purchase of overseas credits

Illustrative UK Aggregate Marginal Abatement Cost Curve including international abatement



Key points

- This version of the MAC curve includes an illustration of the cost of ‘buying in’ abatement from overseas through the EU ETS or CDM
- Per unit of emissions, the costs of buying in could be lower than the cost of abatement in some sectors. For example, Government estimates of international carbon prices fall below the expected cost of some more expensive domestic abatement measures in 2020 e.g. energy crops and hybrid vehicles
- This suggests that overseas abatement could be more cost effective than some domestic measures
- However, the supplementarity principle and its interpretation could impose a restriction on the extent to which the UK can buy in emissions reductions credits from overseas

The interpretation of the supplementarity principle could have a big impact on total abatement costs associated with the 60% emissions reduction target…

For example, if the UK were to meet its emissions targets by making:

only **2/3** of savings from within **UK borders**

and **1/3** of savings bought-in from **overseas***

(for example, through the EU-ETS)

Abatement costs are lower

e.g. by an order of approximately 25-33% compared to doing all abatement within UK borders

Preliminary analysis by Oxford Economics suggests that the GDP impacts of meeting the 2020 (26-32%) target could be lower by nearly one-third

Illustrative analysis for the Climate Change Bill RIA suggests costs of meeting the 2050 60% target could be reduced by around a quarter in 2050**

* Assumes carbon credits will continue to be available, with UK willing and able to purchase them. **Assumes credit price of €25/tCO_2 in 2050. A range of €10-€50/tCO2 would imply savings of 17%-31%. Figures in 2000 prices.

…and allowing abatement overseas could enable a more manageable transition to a lower carbon economy

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Scenario 1: All domestic abatement

- Electricity generation almost completely decarbonised
- Average house emits just 30% of current levels
- Carbon intensity of the whole economy falls by 85% per unit of GDP
- Would require a 1.7% p.a. fall in emissions from 2005

Scenario 2: 2/3 domestic abatement, 1/3 bought in from overseas

- Still requires major infrastructure change consistent with moving to a low-carbon economy, but…
- Average house emits almost 50% more than in Scenario 1
- Carbon intensity of the whole economy 50% higher than in Scenario 1
- Would require a 1.1% p.a. fall in emissions from 2005

Stern found that, historically, countries have found it hard to cut emissions faster than 1% p.a., even after adopting significant emissions savings measures.

Source: UKERC MARKAL-MACRO scenarios consistent with 60% and 40% domestic reduction targets.

'When' flexibility could also keep abatement costs down

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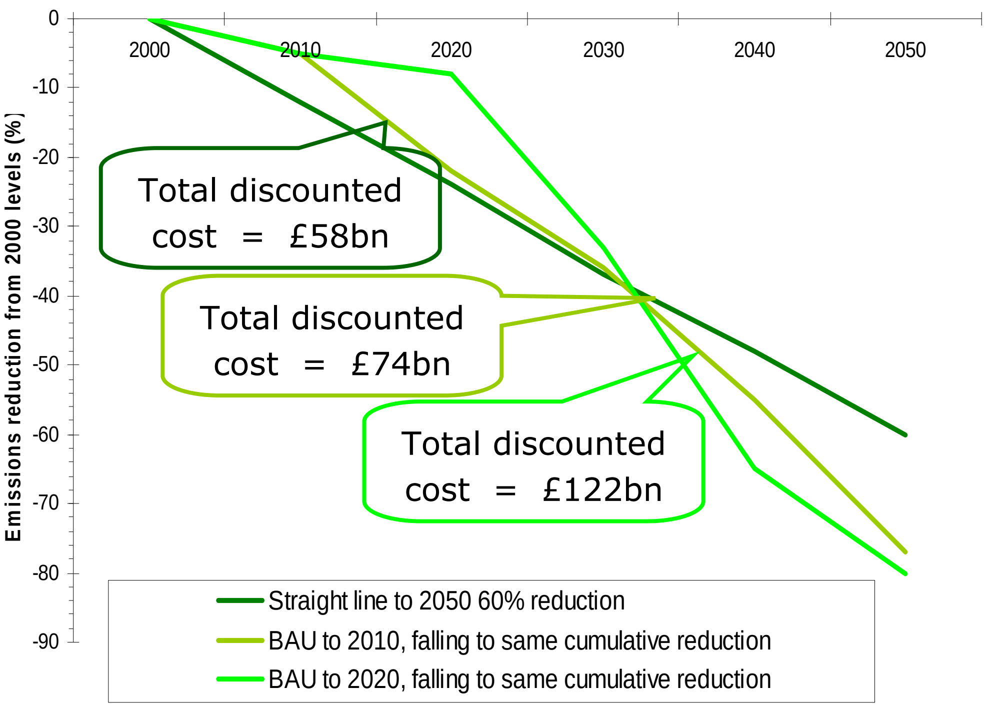
Trajectories to same cumulative reductions as straight line reduction to 2050 60% reduction goal, and associated mitigation costs



Key points

- In attempting to meet its 60% **target**, acting later could reduce costs as the required technology would likely be cheaper.
- However, delaying action towards the target requires subsequent abatement to occur **faster**. This is likely to increase **transitional costs** (such as scrapping of existing capital and the costs of retrofitting), which could easily outweigh any savings from cheaper technology
- In a scenario in which the same level of **cumulative** reductions were required (as in the chart), then **delaying** action would also substantially **increase** the costs
- In addition, early action could both show **leadership** and give the UK **competitive advantage** in new technologies, plus investment now could reduce technology costs

Source: DTI MARKAL results 2003.

For these reasons, a significant degree of flexibility has been built into the Climate Change Bill

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Flexibility and the Climate Change Bill

5 year carbon budgets and the provision for banking/limited borrowing* between budgets provides flexibility over **timing** of abatement.

Enabling powers in the bill allow emissions trading schemes to be introduced more easily. Reaffirms UK commitment to these as a key mechanism which can provide certainty to emission limits, and flexibility over **where** and **how** emission cuts occur.

The bill makes provision for flexibility over **where** and **how** emissions are cut by allowing government to purchase overseas credits to help meet its carbon budget.

The Bill requires the CCC and the Government to be flexible and take account of other impacts (competitiveness, fuel poverty, etc) when making their recommendations. This should make the budgets appear more **realistic** and achievable.

* Full details of the banking/borrowing provisions will be advised by the Committee on Climate Change. Details of the design will influence to what extent flexibility is improved.

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Land use change accounts for 18% of global GHG emissions, most of which is from deforestation

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Land use emissions in a given year = Release of carbon from biomass, soils, etc - Carbon absorbed by biomass, soils, etc

Most land use change emissions are from deforestation in **developing countries**. Many developed countries have small net negative land use emissions because they are pursuing afforestation programmes.

The **natural carbon cycle** means that there is always a flow of carbon released from and absorbed by biomass, soils, etc. In **pre-industrial times**, these were in equilibrium, making net land use emissions **negligible**…

… but nowadays high levels of **deforestation*** are the **major measurable anthropogenic cause of high net land use emissions**.

Stern recommends stopping deforestation **urgently** because it is a major source^ of global emissions and it is a relatively **low cost** way of cutting emissions (because it does not require any technology breakthroughs).

* When trees are cut down or burnt, the carbon stored in them is released into the atmosphere. ^Estimate of LU emissions as 18% of total is a good one if tropical beat burning in Asia is included.

Though there are many causes, conversion to agriculture is the single biggest driver of deforestation

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Agriculture	Conversion of forest land to agriculture is the most important direct cause of deforestation. Available **fertile land for agriculture** is scarce in the tropics.
Infrastructure development	**Development of roads** indirectly causes deforestation by facilitating colonisation and opening of remote areas of forest.
Logging	Research indicates that logging alone does not lead to deforestation particularly where logging is selective. Only a few tropical tree species have a commercial value. However logging activities **open remote areas** to agriculture and increase risk of **forest fires**.
Policy and institutional factors	These factors play a role by either **directly or indirectly** promoting economic activities that clear forested land.
Poverty	Wealth is inversely linked to deforestation as poorer countries exhibit higher deforestation rates. This is mainly because less developed economies offer less employment opportunities and **subsistence farming** is more common.

Despite the complexity of the drivers for deforestation, the underlying market failures are simple

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Property Rights	Externalities
• **Poorly defined or enforced** property rights for forests mean that standing forests may hold little or no value for local communities. • Policies that promote **land use or conversion to agriculture** to secure property rights are a major cause of deforestation in the tropical world. • In places, such as **Niger**, where property rights to standing trees and forests have been restored to local communities, the rate of deforestation has significantly **decreased** or even reversed.	• The carbon storage externalities of forests, particularly tropical forests are generally **not valued in the market**. • Other externalities to forests such as **water and soil quality benefits** are also not valued. • This undervaluation of standing forests leads to **overexploitation** of forests for conversion to timber and or other land uses.

Stern makes recommendations for how measures to stop deforestation should be led and financed

Stern recommendation		**Examples of UK action**
Developing country leadership	Policies on deforestation should be **shaped and led** by the nation where the forests stand…	
International finance and support	… but there should be **strong help from the international community** which benefits from their actions. In particular, **compensation** from the international community should be provided. **Carbon markets** could be a means of delivering this finance in the **long term**; but there are risks in the short term of destabilising the market.	In his 2007 Budget Speech the Chancellor announced a contribution of £50 million to a Congo Basin Forest Fund as part of a new international window of the **Environmental Transformation Fund** Development of sustainable timber **procurement** policies
Synergies and trade offs	The significant **synergies** and **tradeoffs** between stopping deforestation and **development** should be carefully managed to increase the benefit and likelihood of continued participation by developing nations	

Stern makes recommendations for how measures to stop deforestation should be administered

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Stern recommendation | **Examples of UK action**

Property rights

At a national level, establishing and enforcing clear **property rights to forestland**, and determining the rights and responsibilities of landowners, communities and loggers, is key to effective forest management.

The UK supports efforts to improve **forest governance and law enforcement.**

Additionality at programme level

Additionality may be difficult to achieve at the project level because deforestation could be displaced to other areas. But additionality at **programme level*** may be more feasible. For example, Papua New Guinea and the coalition of rainforest nations* have proposed that countries establish a **national baseline** rate of deforestation and negotiate a voluntary commitment for reducing emissions below the baseline. Any reductions achieved below the baseline could then be traded on a carbon market.

In addition to the specific examples of UK action highlighted, the **UK works to influence other countries** through international negotiations. For example, at the German G8 Summit in Heiligendamm (Jun 07) and UNFCCC COP13 in Bali (Dec 07).

* Programme level could involve using satellite technology to monitor areas of forest land over a whole region or country.

Stern's analysis throws up a number of issues worthy of further consideration

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Cost effectiveness	The costs of avoiding deforestation presented by Stern were indicative estimates. It may be useful to have more research into the **costs** to determine the level of international funds required.
Frameworks and policies	Further research into the **incentives** required to stop deforestation and the **policies/frameworks** capable of bringing these about could be helpful.
Emission estimates	Estimates of emissions from land use are uncertain so further research into the **science** and **measurement** could be very useful. For example, the estimate of emissions from deforestation used by Stern is greater than the officially reported statistics from some developing country governments.
Priorities	Given the significant potential for cost effective emission abatement identified by Stern, does the UK have the correct **balance of resource** between deforestation and other international or domestic activities?

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Climate change mitigation policies can contribute to or conflict with other policy objectives

- Stern suggests that to reduce the costs of mitigation policy, policy synergies should be exploited and conflicts avoided where possible.

- This section explores how policy choices can affect synergies and trade-offs of mitigation policy with the following policy objectives

  - Fuel Poverty
  - Competitiveness
  - International Development
  - Energy Security of Supply

- This paper only covers mitigation policy and does not cover synergies and trade-offs with adaptation policy.

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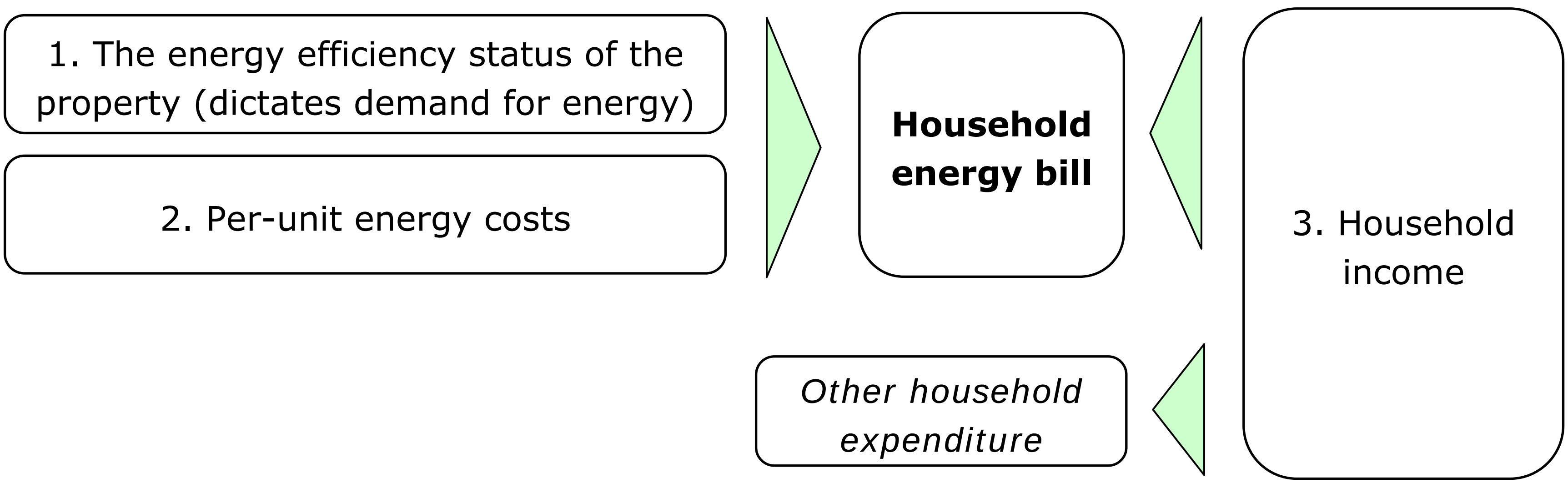
Conclusions

Fuel poverty affects 2 million UK households, and is caused by the interaction of a number of factors

- A household is said to be in fuel poverty if it needs to spend more than 10% of its income on fuel to maintain a satisfactory heating regime*
- Latest estimates suggest that in 2004, 2 million UK households were in fuel poverty
- Fuel poverty is driven by the interaction of 3 main factors:



* Source: BERR website. 'Satisfactory' is defined here as 21 degrees for the main living area, and 18 degrees for other occupied rooms.

Climate change policy could have a positive effect on fuel poverty in the long run, but short run transition costs must be taken into account

Element of climate change policy	What effect would these policies have on fuel poverty? Short run	Long run	
Carbon pricing	Tax and trade on fuel would increase per-unit energy costs, making fuel poverty worse. There are transitional costs to changing behaviour.	Building regulations could improve energy efficiency, reducing fuel demand and thus reducing fuel poverty	**-**
Technology policy	There are short-run costs associated with investing in these technologies	Technology deployment could improve energy efficiency and thus reduce fuel demand.	**?**
Removing inertia	Policies here would reduce short term transition costs for fuel poor households.	Removing barriers to investment in energy efficiency would reduce fuel poverty	**+**

Fuel poverty policies should act here to reduce transition costs for fuel-poor households in the short term

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Conclusions

Loss of UK competitiveness has a negative impact on economic growth, and may lead to carbon "leaking" abroad

If the UK has more stringent climate change policy than other countries, this can lead to a loss of competitiveness. This can yield a reduction in **economic growth** and possibly **carbon leakage**, via the process described below.

UK introduces **unilateral climate change policy**

Structural change in the economy as the costs of producing carbon intensive goods/services rises. Some firms may close down UK operations.

Increase in overall costs of production across the economy as the higher cost of carbon intensive goods/services are passed on in a ripple pool effect.

Together, these effects represent a **contraction in the supply-side** of the UK economy and act to **diminish UK competitiveness**.

Reduction in UK **economic growth** (part of this will be a **short** term* reduction as resources reallocate in the economy; but some of it will be **long** term^ as the economy switches to more expensive capital).

If firms choose to relocate from the UK and continue polluting, this is **carbon leakage**. (But in practice climate change policy alone is unlikely to have a significant impact on firms' location choice.)

* The faster that resources are reallocated to alternative uses the lower the impact on economic growth. ^Some of the reduction in economic growth will be long term; at a global level, this is Stern's 1% of GDP.

Competitiveness is likely to be an important concern for a small minority of sectors, but less of an issue for the overall UK economy

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Overall effect on UK economy	Preliminary analysis by Oxford Economics* estimates that **unilateral** UK climate change policy could cost up to **1.6% of GDP in 2020**. But this is a big **upper bound estimate** because it assumes: • The level of **ambition**. Assumes the UK achieves an ambitious level of abatement (30% abatement by 2020) while other countries do nothing. • All abatement is undertaken **within UK borders**. In practice this is unrealistic because the UK is part of the EU ETS. Abating only in the UK may mean that cheap abatement opportunities abroad are missed. • The **nature of the model** will tend to mean its estimates are upper bounds.
Specific UK sectors likely to be most adversely affected	Sectors worst affected by the UK unilateral climate change policy (reduction in GVP in 2015-2020 relative to no mitigation policy)*: **basic metals** (23%); **paper** (6%); **wood and products** (6%); **food** (5%); and **agriculture** (5%).

* Oxford Economics (2007) - in the baseline case the UK cuts its emissions by 17%. The scenario presented here looks at the cost to UK GDP of increasing abatement to 30% by imposing a carbon price that increases over time.

Membership of the EU ETS helps to overcome competitiveness issues, but some concerns still remain

Good for competitiveness?

Europe

Membership of EU ETS

- Firms from same sectors face **same allowance price** → ✓
- But **allocation methodology** for permits differs by country → X

Outside Europe

More stringent climate change policy in UK compared to other trading partners (e.g. US?)

- To the extent that production of carbon intensive goods/services is **relatively more expensive** in the UK compared to other countries, the UK faces a loss of competitiveness. → X

Other ways of helping prevent loss of competitiveness include sector-specific interventions and economy-wide supply-side measures

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Sector-specific interventions

Intervene in sectors at risk of loss in competitiveness and engineer ways of counteracting this effect, for example:

- Sectoral agreements
- Grandfathered permits
- Border tax adjustments

These measures are risky because they can be used as a form of **protectionism** and may be difficult to **phase out**. These measures also help stop **carbon leakage**.

Economy-wide supply-side measures

Loss of competitiveness arising from mitigation policy can be minimised by:

- Designing **mitigation policy** in-line with the Stern framework (credible, predictable, flexible, international, 3-legs)
- Adopting other policies that make the UK **attractive to businesses** (e.g. well trained labour market)
- Ensuring resources can be **flexibly redeployed** (e.g. flexible labour market)*

These are **first best** measures because they do not distort international competition and they support wider economic goals. But these measures do not help stop **carbon leakage**.

* The UK already has a fairly flexible economy.

Multilateral action on climate change reduces costs arising from loss of competitiveness, but creates costs for the UK as the global economy contracts

If other countries act to cut carbon emissions, the cost of doing so could prompt a **contraction in the global economy** which would have a knock-on effect on UK economic growth, via the process described below.

Other countries introduce **climate change policies** (e.g. carbon tax).

Contraction in the global economy as the costs of production abroad increase and demand declines.

Increase in **costs of production in the UK** as imports to the UK become more expensive.

Reduction in demand for UK exports as the overall level of global demand declines.

UK economic growth falls

To minimise adverse impacts on economic growth, the UK should use **general supply-side measures** to improve the economy's ability to flexibly adapt (see slide 5)*.

Stern estimates this would keep costs in 2050 down to **1% GDP globally**.

* The faster that resources are reallocated to alternative uses (e.g. redundant workers are re-employed elsewhere) the lower the impact on economic growth.

The cost to the UK of engaging in multilateral action is minimised if all countries adopt "fair" shares of effort with policy in line with Stern's recommendations

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This table illustrates that the costs to the UK of "**well designed**" multilateral action could be significantly lower than costs associated with "**poorly designed**" multilateral action.

		Do countries adopt their "fair share" of effort?		Are these emissions reduced in a way that is consistent with Stern's policy recommendations? (i.e. credible, flexible, 3-legs)	Cost to UK economy
"**Well designed**" multilateral action scenario (Stern)	✓	Rich countries take responsibility for 60-80% emission cuts by 2050, leaving poorer countries to have emissions growth of up to 25% on 1990 levels by 2050.	✓	Yes. Emissions are reduced in the least cost way using credible, predictable, flexible, international and 3-legged policy.	**1% GDP** in 2050 globally (no figure available for UK). (This cost reflects contraction in UK and global economy as world switches to new infrastructure.)
"**Poorly designed**" multilateral action scenario (Oxford Economics)*	X	The UK has a higher level of effort than other countries. (UK cuts emissions 30% by 2020, EU has 2/3 this effort, rest of world has 1/3 this effort.)	X	No. The UK abates entirely from within its own borders. This means cheap abatement from abroad could be missed.	**1.6% GDP** in **2020** (Reflects contraction in global economy and costs through loss of competitiveness.)

* Preliminary analysis by Oxford Economics – this scenario is the same as the one quoted earlier, except that other countries also adopt a proportion of the additional action the UK is taking to cut its emissions from 17% to 30%.

There are a range of competitiveness issues worthy of further analysis

Dynamic analysis of competitiveness

- When considering the impact of climate change policy on competitiveness and the case for government intervention, does existing analysis take a **"dynamic" approach**? Does it consider whether, in the long term, keeping the industry in question in the UK is sustainable and profitable?

Competitiveness impacts of CDM

- All of the work on competitiveness to date has focused on the implications of unilateral climate change policies. But there could also be **competitiveness implications from CDM financial flows**. e.g. To what extent might investment in low carbon technology in China increase Chinese productivity and make the UK relatively less competitive? How big might these effects be?

There are also questions about the impact on the UK economy of multilateral action

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Impact of multilateral action on the UK economy

- What is the **impact on the UK economy** of other countries cutting their carbon emissions? The Oxford Economics study (quoted here) considers one scenario. There may be value in considering other scenarios, and perhaps other models*. What would be the effect on the overall UK economy, and which sectors would be most affected?
- What **policies would be needed** to help the UK adjust to the contraction in the global economy as the world switches to low carbon infrastructure?

* DTI have already commissioned some work looking at the impact on the UK on different scenarios of EU action.

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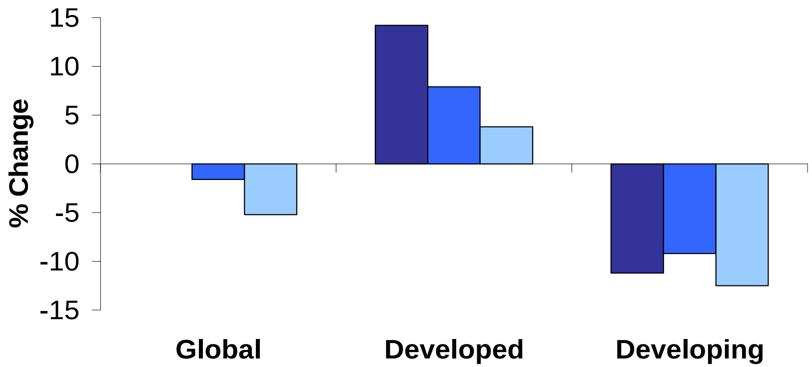
Adaptation to climate change is a major challenge for developing countries, but this is not covered in the scope of this report

Impacts of climate change will be greater for developing countries than developed

Change in cereal production in developed and developing countries for 3°C warming*



Climate change will affect poor countries much worse than rich countries because of their

- Geography
- Dependence on agriculture, and/or
- Lower incomes and access to resources.

Implication

Adaptation is a more immediate concern for many developing countries than mitigation

* The blue bars relate to the names of the three simulation models used. Source: Stern Review.

There are challenges associated with reducing emissions from developing countries

There will be **different mitigation challenges** in different developing countries. e.g.:

- China is a large industrialised country – savings could come from **energy efficiency** and switch to **low carbon infrastructure**.
- Africa has lots of land use and agriculture emissions – savings could come from **stopping deforestation**.

Emissions from developing countries should be cut whilst:

- Ensuring that developing countries, particularly the poorest, can continue to **grow their economies**
- Balancing the **synergies/trade offs** associated with mitigation.

International carbon finance will be crucial for helping with this transition.

Sources: The UNFCCC and The Stern Review. *The emission abatement that developed countries are responsible for could be undertaken within their own borders or from other countries.

The transition to a low carbon economy in developing countries should carefully manage the potential synergies and conflicts with international development

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Potential synergies	Access to energy	Use of renewable technologies and microgeneration technologies can provide access to energy for those people living far away from fossil fuel reserves or not connected to the electrical grid.
	Energy security of supply	Switching to renewable technology and increased energy efficiency could reduce developing countries' reliance on fuel imports.
	Freeing up public funds	Governments in developing countries currently spend around $160bn* a year on fossil fuel subsidies. These funds could be spent on health or education to promote development.
	Health	2.5 bn people in developing countries depend on wood or charcoal as their primary fuel. Switching away from traditional biomass could reduce premature deaths from local air pollution.
	Other env't impacts	Reduced dependence on traditional biomass will have broader environmental benefits through reduced degradation and biodiversity conservation.
Potential conflicts	Public funds	Public expenditure on mitigation could potentially be used for development objectives, such as health and education.
	Food security	Large scale bio-crops could potentially use water resources and land that would otherwise be used for food.

*Stern Review (2006)

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Energy security means the reliability of the fuel supply and also the reliability of the domestic infrastructure to deliver energy to end users

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Reliability of Fuel Supply

- The focus here is generally on **price risk** rather than the risk of physical interruption to the fuel supply.
- Physical interruption of fuel supplies is generally seen as an outside risk as there will usually be some source from which fuel can be bought.
- However, there are many factors that can distort or significantly increase the price of fuel; fuel supplying countries can control the market, and the UK is becoming increasingly dependent on imports

Reliability of energy delivery

- Reliability of energy delivery depends on reliability of **infrastructure** and interconnectors; a well functioning competitive market can ensure sufficient investment in infrastructure takes place.
- Some climate change policies can have an effect on the reliability of energy delivery at the margin – e.g. renewable energy, when connected to grid infrastructure as a high percentage of total generation, can have negative effects on electrical system reliability.

Energy security is important for the economy: a DTI study* estimated that a 3 week interruption of the gas supply to industry in 2006 would have had an immediate impact on the UK economy of 0.09 to 0.4% loss in annual GDP.

* A report by ILEX to DTI, January 2006.

Energy supplies may not be reliable for a variety of reasons, all of which contribute to price volatility

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Geopolitical risk to fuel supply

Globally some of the main sources of oil and gas are concentrated in politically volatile regions

Concentration of market power in a few hands

Reserves of oil and gas are concentrated in a small number of countries. This level of concentration entails control over fuel prices and potentially gives political power to the endowed countries. A dispute between Russia and the Ukraine lead to jumps in the gas prices across Europe in 2005.

Risk to Processing plant

Dependence on a limited amount of refining and transport infrastructure for oil and gas adds to supply risk and price volatility – as shown by price increases when Hurricane Katrina interrupted operation in oil refineries in New Orleans in 2005

Price Volatility

Risks to energy supply and the costs of price volatility to the economy can be difficult to quantify in advance. Further research to understand this would aid in the comparison of climate change and energy security policies.

Increased fuel prices would be a large concern because of the extensive influence this can have on the economy as a whole

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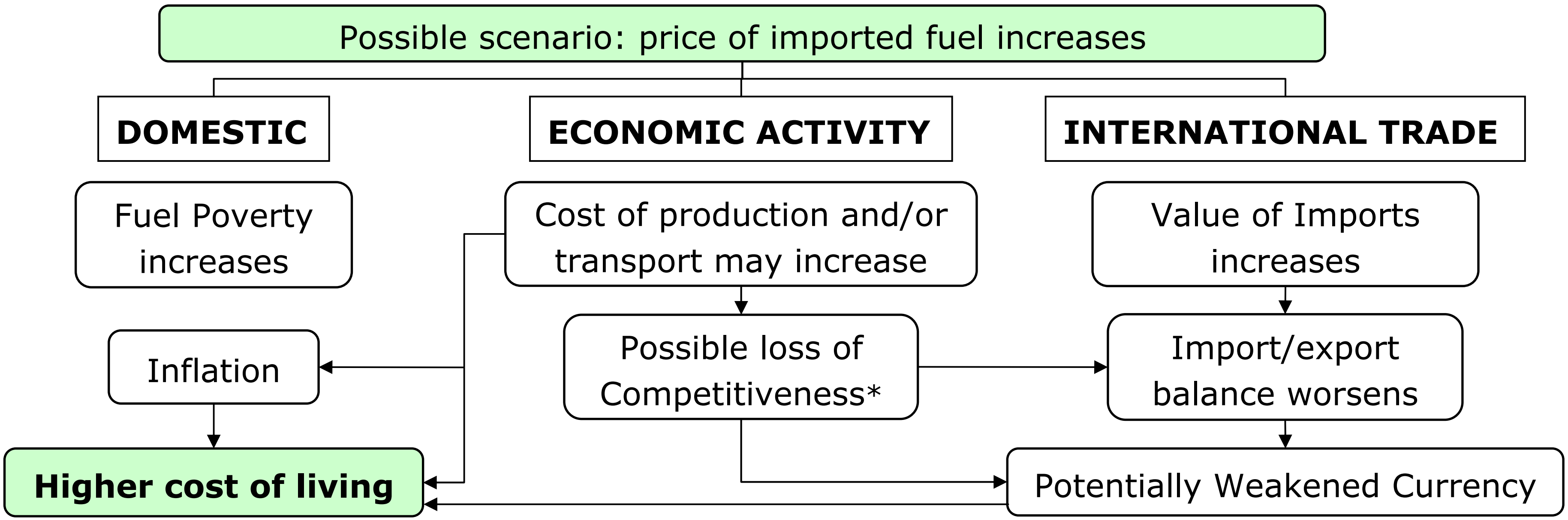

Fuel prices generally have a limited impact on fuel **demand**, so tend to feed through to the economy as an increase in the **living costs** (as above). But other responses are possible, e.g.

- Some companies might choose to switch off, rather than bear increased costs, which would also affect competitiveness
- If their profit margins allow it, some energy companies might choose to absorb the price increase rather than pass it on to the consumer, thus mitigating some of these effects
- In the long run, companies would undertake compensatory measures (akin to energy security policy) such as reducing energy demand or switching to different energy sources

* Relative to countries that are less dependent on fuel imports.

There are different ways to address energy security concerns; some of which contribute to and some of which conflict with climate change goals

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Contributes	Energy Efficiency	Reductions in energy demand lead to both lower emissions and reduced exposure to energy security risk
	Non-fossil fuel energy sources and new energy technologies	Associated with lower/zero carbon emissions, and can contribute to energy security by increasing the amount of energy generated from domestic or politically stable sources – e.g. nuclear fuel from Canada
	Market Reforms	Can improve energy security by reducing the concentration of market power and increasing investment in delivery and storage infrastructure, whilst also encouraging suppliers to be more efficient, thus reducing energy demand
Conflicts	Government efforts to secure oil & gas supply	The costs in defence and international diplomacy of maintaining and securing supplies of oil and gas are not reflected in consumer prices, so oil and gas are over-valued relative to low-carbon alternatives
	Switch to Coal	Can contribute to energy security due to large global reserves held in many different countries – but without CCS, carbon emissions from coal are around twice that from gas in electricity production
	Coal to Liquid (CTL) Technology	Developed as an alternative fuel for transport in lieu of oil – but without CCS its lifetime emissions are double those of oil

Some Climate Change policies could have negative effects on energy security, but CCS technology could eliminate many of these conflicts

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Switch to gas

Generating electricity from gas produces approximately half the greenhouse gas emissions per Megawatt hour compared to coal. However, supplies of gas are less secure than coal.

Applying an internationally determined market carbon price

Just as price volatility in fuel can have negative effects on the economy, volatility in the price of carbon could have similar effects, especially if the price of carbon comes to be set in another currency.

Greatly increasing early deployment of Renewable Energy

Under current technology, connecting a high proportion of intermittent energy, such as wind, marine or solar generators, to a grid network can have negative effects on the infrastructural security of energy delivery. This can increase the risk of blackouts.

- The deployment of Carbon Capture and Storage (CCS) technologies would eliminate many of the conflicts between energy security and climate change policy goals.
- Electricity Storage technologies and nuclear technological development could also be solutions to both energy security and climate change problems.

Contents

Executive summary (separate paper)

1. The problem of climate change and the case for action
2. How much emissions need to be cut and UK progress to date
3. How UK policy compares with the recommendations of the Stern Review
4. The synergies and trade-offs with other policy objectives

Conclusions

In conclusion, there are a number of conceptual issues that we need to embed into policy making

Scale of effort

- We need to give careful thought to whether we are investing enough to address Stern's recommendations, particularly in the area of technology investment.

Policy mix

- There is no shortage of policies in some sectors, creating a complex landscape – are they all necessary? New policies need to make it clear which of the three Stern market failures they address.

Sequencing

- To achieve a low cost transition path for the UK, we need to carefully consider the sequencing and wider implications of any new downstream measures in sectors subject to emissions trading.

Implied targets

- The combination of the new 'carbon budgets' and the EU-ETS means that sectors left outside of the EU-ETS face an implied target which may or may not be more ambitious than the cap on the EU-ETS.

Carrots or sticks

- Taking account of other market failures in the take-up of energy efficiency, it may be more economically efficient to consider a greater role for regulation alongside behavioural incentives.

There are a number of trade-offs that we will need to weigh up – not all of which are obvious

Fuel poverty

- Synergy: technology and efficiency lowers demand in long-run
- Trade-off: carbon pricing will increase fuel poverty in short-run
- **Issue: dealing with the social costs of transition**

Security of supply

- Synergy: energy efficiency and alternative power sources
- Trade-off: coal is more secure than gas, but has high emissions
- **Issue: technological solutions (especially CCS) are vital**

Competitiveness

- Synergy: new technologies open up new markets for growth
- Trade-off: some downsides to unilateral and multilateral action
- **Issue: a dynamic analysis of competitiveness is needed**

International development

- Synergy: many spin-off benefits to cleaner growth (health etc.)
- Trade-off: bio-crops could stress fragile food supply chains
- **Issue: carbon finance potential to assist development**

The Stern framework raises policy questions that it will be important to answer as we move forward

Carbon pricing	• We do not have a clear idea of the carbon prices created by different policies in different sectors, so how can we know if we're on a least-cost transition?
Technology policy	• Outside of the electricity generation sector, do we have a technology strategy for economy-wide decarbonisation? • How can we ensure the world spends enough on technology policy and what should the UK's contribution be? • Is our approach to technology policy consistent with bringing forward a portfolio of low-carbon technologies?
Removing other barriers	• Are we missing low cost abatement in any sectors because of the existence of other barriers?
International cooperation	• Do we have a clear idea of the scale of potential global carbon finance flows and the implications for carbon prices and incentives in the EU? • Do we have the right global incentives to encourage international technology cooperation and stopping deforestation? It is not clear to what extent these incentives emerge through existing frameworks.

There are also implications for the way in which we use analysis to arrive at policy solutions

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We need to balance our redress to the 3 market failures…

…before selecting policies along the marginal abatement cost curve

1. Identify the main **market failure**

2. Select the appropriate **intervention**

3. Develop the detail of the **policy design**

For example:

- Greenhouse gas externality

- Tax
- Trade
- Regulation

- Marginal cost analysis
- Upstream/downstream
- National/international
- Other considerations

If we promulgate its findings, this audit will deliver a shared level of analytical understanding to all of those involved in climate change policy

Science	Our *scientific annex* offers a brief digest of the central scientific case for climate change policy and the arguments to refute the common theories advanced by sceptics. **It should be a valuable part of the induction for anyone new to climate change policy**.
Measurement	Our *measurement annex* offers a clear account of the complex world of progress and projections on climate change emissions. **It should be a valuable reference for anyone who needs to know more about the detail behind the numbers**.
Economics	Our *full report* and the accompanying *sectoral annexes* offer a robust but accessible account of the complex conceptual implications of the Stern Review. **It crystallises a framework for approaching climate change policy** which emphasises that: – there are three separate market failures to address; – carbon pricing alone will not be a low-cost solution; – technology policy would benefit from added emphasis; and – regulation could be a more efficient solution in some areas.