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Innovation and Technology Transfer

Framework for a Global Climate Deal

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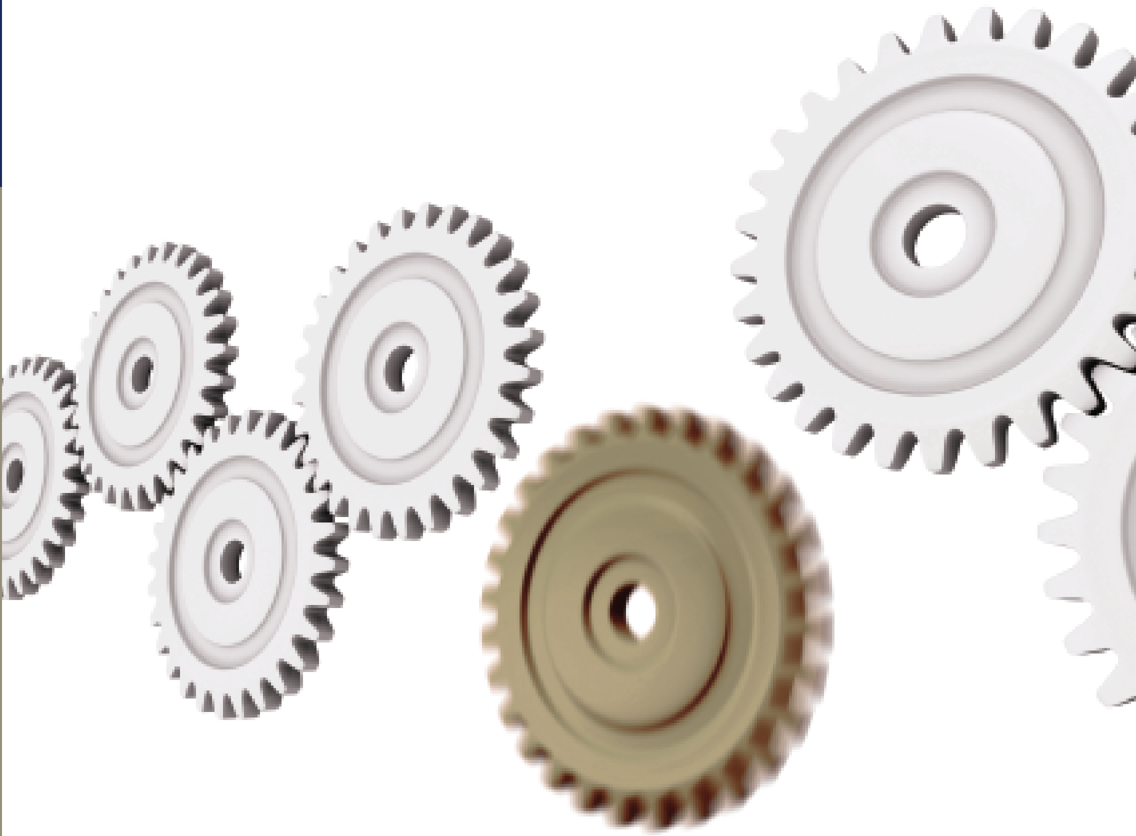

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Contents

Boxes

Figures

Tables

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Further details about this paper, translated versions, downloadable resources and news of related activities are available at www.e3g.org.

Executive Summary

Faster and broader innovation is critical for delivering climate security while preserving energy security

Faster and broader innovation of new technology is critical for achieving low carbon and climate resilient development. Stabilising global temperature increases below 2°C will require global emissions to peak and reduce in the next 10-15 years.[1] Achieving this pathway reduces the probability of exceeding 4°C of warming – where crossing catastrophic climate change tipping points is highly likely – to under 1%; delaying global peaking by 20 years would increase the probability of 4°C to 10%.[2]

Meeting these goals poses a unique public policy challenge: delivery of new technologies and massive shifts of investment on a global scale inside a specific timeframe. The urgency of developing new technology is compounded by the existing global energy system investment cycle. The next 20 years will see an unprecedented increase in energy investment as developed countries replace power plants built in the 1960s and 70s, and rapidly industrialising economies accelerate their construction of modern energy systems. The US, Europe and China will each build around 800-1,000GW of new power stations by 2030. Concerns over energy security and prices are also driving defensive investments in high carbon sources, such as tar sands and coal-to-liquids.

Failure to provide workable low carbon alternatives for these investments will mean much of the world becomes "locked in" to carbon intensive development. IEA scenarios to meet the 2°C target require power plants with carbon capture and storage (CCS) to make up 20% of global power investment up to 2030; from 2030 all new power plants in developed countries will need to be zero-carbon. However, there is currently no commercial scale CCS demonstration plants planned to be in operation before 2015, making this schedule highly unlikely. Even under an optimistic technological scenario the IEA estimates that 15% of existing fossil fuel plant - around 350 GW - needs to be retired before the end of their economic lifetime. Similar issues exist in all major emitting sectors: energy, transport, industry, infrastructure and buildings.[3]

While these scenarios require only an 18% increase in investment over business as usual, they imply a huge investment shift from high to low carbon technologies.[4] The additional investment needs in clean energy technologies and energy efficiency are 18 times the current level of investment in these areas. A significant amount of the

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1 Barker et al., 2007
2 Meinshausen, 2005
3 IEA, 2008a
4 IEA's BLUE Map Scenario in IEA (2008a)

additional $45 trillion investment needed to 2050, around 70%, will occur in the transport sector as it shifts to more expensive low carbon vehicles with lower fuel costs.

Avoiding carbon lock-in will require countries to immediately adopt low carbon development pathways and increasingly invest in technologies which provide emissions reductions while enhancing security of supply. It will be important to plan ahead, even for countries with no binding reduction commitments; for example, by making all new fossil fuel plants carbon-capture ready or capable of biomass co-firing. This will allow retrofitting when targets deepen and technologies are further developed.

Innovation and diffusion of low carbon and adaptation technologies will require concerted action along the innovation chain. Innovation will also be needed to drive radical market transformations, to rapidly adapt technology to developing country conditions and drive effort on 'orphan' research areas, such as drought resistant crops. This will require incentives for innovation in new areas and in a wider set of countries than at present.

The basic economic and technical systems exist to deliver these technological advances; the global economy has shown its ability to deliver transformative solutions in areas from the space race to the pharmaceuticals industry. The critical issue is how to provide the right policy frameworks and incentives to focus this innovative capacity on solving multiple climate change, energy security and climate resilience problems. National policies alone are unlikely to support the global public good aspects of low carbon innovation, and there will be a global undersupply of innovation in many areas. Multilateral action is required to give incentives for additional national actions, drive international collaboration and help correct critical market and policy failures.

Current low carbon innovation programmes are not adequate to manage the risk of policy failures and higher ranges of climate sensitivity

There is widespread agreement that current low carbon innovation programmes are not adequate to meet the climate change challenge. Despite some recent increases, public energy R&D funding has fallen by up to 50% in real terms in major developed countries over the last 25 years.[5] Energy RD&D as a share of total RD&D in OECD countries has declined from 11% in 1985 to 3% in 2005.[6] Public spending remains a higher proportion of research spending in the energy sector than in other areas, and up to 60% of public funding is spent supporting private sector R&D. Studies such as the Stern report have called for a doubling of R&D funding, and a much larger increase in deployment funding. Unfortunately, estimates for adaptation innovation needs are

[5] IEA, 2008a

[6] Ibid.

virtually non-existent, and represent a major gap in knowledge which must be prioritised in the international climate change process.

These figures probably underestimate the amount of R&D needed, as they assume an efficient least-cost pathway to known levels of global emission reductions. In reality future mitigation pathways are highly uncertain. The IEA estimates that over 50% of abatement by 2050 will come from energy efficiency measures, but experience shows these savings are often hard to capture and policies often fail; savings from reducing deforestation rates also face very challenging policy delivery environments. Estimates of climate sensitivity to greenhouse gases may continue to worsen; increasing the rate of emission reductions needed to meet temperature stabilisation goals. Some technologies which play a large part in many scenarios, for example, advanced biofuels, advanced nuclear power, may fail to emerge owing to technological failure or public acceptance issues. In all cases a larger range of low carbon energy alternatives - especially in power generation and transportation – will be needed earlier than current models predict.

Aggressive innovation efforts across a portfolio of critical technologies is part of a responsible risk management approach which hedges against climate policy failures, technology failures and worst case scientific scenarios. Failure to incorporate these potential scenarios into future mitigation plans will dramatically lower the likelihood of successful climate stabilisation.

Delivering a portfolio of critical low carbon options by 2020 will require large scale demonstration of key technologies, the building of lead markets and rapid development of large scale supply chains. This will often be beyond the capacity of individual countries to achieve; as shown by the 2008 G8 proposal for a global programme of 20 large scale CCS demonstration plants. Other technologies which will require similar scale and focused support include solar thermal power, distributed grids, power storage, advance flood management and low carbon vehicle technology. Enhanced international cooperation is needed but must be rigorously prioritised – focusing on portfolios of technologies critical to achieving aggressive mitigation scenarios, and areas requiring large-scale investment with high public good components; especially those with high benefits to developing countries.

The Stern report and the UNFCCC estimate that research, development and demonstration (RD&D) funding into low carbon technology would need to be increased by an additional $10 billion per annum, although it is acknowledged that these estimates are highly uncertain. Taking into account the need for a wider portfolio of technologies to give adequate risk management and funding to accelerate the demonstration of critical technologies, a global RD&D increase of $15-$20 billion per annum would seem a more adequate average for the next 10-15 years. This sum is not without precedent for accelerated public RD&D programmes by the USA alone, as it lies between the peak RD&D spending on the War on Terror ($12bn) and the Apollo Programme ($20bn in 2002 prices).

The unique nature of the climate change problem requires a more active public approach to risk management and investment in a portfolio of low carbon solutions, only some of which will prove successful at a large scale. The market – even with a strong carbon price – will not automatically bring technologies forward at the pace required, and will not account for worst case scientific scenarios or possible policy failures. Climate security is a global public good, and delivery can only be secured by public action working through markets. As with government spending on defence R&D, an interventionist approach is needed to ensure a high probability of delivering climate security; in this way climate innovation policy differs sharply from standard innovation policies focused on increasing national competitiveness.

Developed countries need to shift their national strategic innovation priorities if international cooperation is to be effective

National innovation will not be sufficient, given the global public good nature of low carbon innovation. Action is required at the multilateral level to build on national policies and correct market failures. At the moment collaborative R&D is very weak, outside long term areas such as nuclear fusion. Current national innovation strategies work against effective cooperation as they are fundamentally designed around national competitiveness priorities, not to produce global public goods. For example, out of €1.3 billion worth of projects under the EU's Framework 6 research programme with Chinese participation, only €35 million went to Chinese researchers.[7] Public R&D collaboration is little better between developed countries in the energy area despite many cooperative agreements at the IEA.

A major shift in strategic innovation priorities and approaches will be needed at the national level to make international collaboration on low carbon innovation work at the scale and pace needed. Incentives for enhanced collaboration could be built into the Copenhagen agreement including through co-financing support for collaborative RD&D with developing countries, agreements on reciprocity of knowledge sharing in national R&D programmes, and MRV criteria on collaboration and knowledge sharing for making national innovation support eligible to count against international obligations.

Developing countries require support to build effective innovation systems *not* just narrow technology transfer

Despite accelerated globalisation, technology invention and innovation is dominated by the developed world; even China estimates that over 85% of patents in many of its

7 Vialatte, 2008

core high tech economic sectors are owned by developed country companies.[8] This concentration of innovative capacity in developed countries does not match the distribution of diverse mitigation and adaptation technology needs.

Traditional concepts of public technology transfer follow a relatively narrow approach with limited funding and capacity building support; private sector approaches focus on balancing market access with limited licensing to local industries, including joint ventures. These approaches are unlikely to transform the way low carbon and climate resilient technologies are diffused to developing countries, especially those without fast growing markets. Diffusion of new innovations is as much about the institutions, structures and organisations in a country as it is about narrow funding support to access specific technologies. Recent work by the World Bank[9] shows that diffusion of technologies differs markedly between countries at similar levels of income. Successful diffusion has a strong relationship with core economic attributes such as ease of doing business, trade and FDI flows and tertiary education.

This research suggests that large increases in low carbon diffusion rates can be achieved across countries at differing development stages through an emphasis on system-wide capacity building to improve internal innovation and absorption systems. This approach must be embedded in the Copenhagen mechanisms for technology transfer, through both policy incentives and direct capacity building support.

There is also a need for international support to ensure a wider spread of innovation capacity which can deliver three important types of innovation in developing countries:

- **disruptive innovation** suitable for new business models designed for developing country markets e.g. equipment to support distributed utility models; low carbon building material technology and design;

- **'orphan' areas** of research where developed markets provide few incentives for innovation e.g. drought resistant African crops; small scale desalination;

- **adaptive innovation** to make new innovations suitable for developing country circumstances e.g. adapting gasifiers to local coal sources; making efficient domestic appliances for tropical conditions; advanced biofuel technology for using local feed-stocks.

Developing countries with significant domestic innovative capacity, such as China, India, South Africa, Brazil and Malaysia have a critical role in undertaking innovation in these areas; either individually or in cooperation with developed countries. By

[8] Liu, J., 2007

[9] World Bank, 2008b

acting as pathfinders for new technologies with wide applications in developing countries they can lay the foundations for future mitigation and adaptation action consistent with countries development and poverty reduction priorities. Other developing countries also need support to build their innovation systems in line with their low carbon development pathway plans. The Copenhagen agreement must provide strong incentives for developing country innovation, cooperation, and sharing; not just technology transfer.

Delivering innovation faster and to scale requires the creation of strong new markets for innovative low carbon products and a diversity of cooperation initiatives

Fundamentally, companies will invest in low carbon innovation and accelerate diffusion into new markets if the risk/reward balance is right. While policy discussion often focuses on issues of R&D funding and intellectual property rights (IPR) protection, issues of market creation and regulation are at least as important in driving change in many areas and delivering the right balance of incentives.

The rate of innovation and diffusion is affected by both market conditions such as size and certainty of the market; size and profile of R&D investment; rate of turnover and number of competitors in a sector. For each innovation chain the balance of these factors will determine where barriers to accelerate innovation and diffusion exist. There is no one size fits all policy, but there are a limited set of factors that can be analysed to create a robust and effective low carbon innovation policy in a specific market. Policy instruments agreed at Copenhagen must be able to address the full range of necessary interventions down the innovation chain.

Increasing the size and certainty of the global carbon market will be essential to pull technologies down the innovation chain. However, the carbon market will not necessarily deliver when other barriers prevent uptake of low carbon technologies; this is particularly acute for energy efficiency where market failures are critical. Other mechanisms will be needed to provide market certainty for innovative products and services. Within the UNFCCC framework sectoral agreements have the potential to catalyze such action:

- technology-driven sectoral agreements, as part of developing countries enhanced action commitments e.g. renewable energy standards; niche market zero-carbon building standards and supply chain creation;

- setting international standards and regulation (multilateral or plurilateral) to provide large and certain markets for innovative products and drive down costs;

- innovation in globally competitive carbon intensive sectors such as steel, cement and aluminium where high efficiency and low carbon solutions, including CCS, need direct support for development and deployment.

In many of the key markets for mitigation and adaptation the public sector is a vital actor in driving patterns of consumption, either through regulation or public procurement; for example, infrastructure, buildings, vehicle standards and public transportation. Public sector purchasing agreements are a vital tool to accelerate innovation and diffusion in these key sectors, but have not been used that widely to date.

The need for tailored approaches to accelerate individual low carbon and climate resilient technologies in particular markets argues for a flexible approach to including these in the Copenhagen framework. Bilateral and regional cooperation agreements should be "registered" in the UNFCCC framework if they conform to agreed criteria, rather than an overly centralised approach where all cooperation passes through a UN process which will become a bottleneck for action and potentially inhibit innovation.

A failure to constructively tackle IPR and competitiveness issues will limit the pace of innovation and diffusion and potentially poison the international climate negotiations

In addition to market issues, technology specific IPR related factors (such as the ratio of R&D to total costs, ease of copying and IPR enforcement; and patent application standards and processes) also affect the rate of innovation and diffusion. The vast majority of patents are held by private firms; on average business enterprises held nearly 80% of patents over the period 2003-2005. Climate technologies and systems will provide significant high value-added industries to the countries that gain a comparative advantage in their development and production. There is a clear – and already apparent – tension between the desire to secure these economic benefits and the need to maximise technology diffusion to protect the global climate; as shown by the discussions over whether to include projects in developing countries inside the proposed EU CCS demonstration financing instrument.

It is also clear that without effective returns from intellectual property the private sector will not continue increasing its investment in low carbon technology; with estimates of up to $9 billion just in venture capital financing as of mid-2008 (up over 30% from 2007).[10] As a proportion of global venture capital investment, it has grown up from just 1.6% of total investment in 2003 to 11% in 2008.

There is a need to explicitly revisit the balance of incentives for private innovation

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[10] The Financial (2007); Environmental Finance (2008)

with those for maximising public benefit; to develop an appropriate and effective "social contract" around low carbon and climate resilient innovation. The tendency in the global climate negotiations to reduce this to the issues of transferring or purchasing IPR polarises the interests of Parties and prevents creative solutions emerging; this could have serious consequences for progress of the overall agreement.

Research carried out for this report showed that there are very few well founded empirical studies examining the role of IPR in the diffusion of particular low carbon technologies. Extensive interviews with technology experts and companies showed that most views were guided by anecdote and assumption, rather than evidence. Therefore, there is currently no sound basis for any definitive statements that IPR is - or is not - a barrier to low carbon technology diffusion across the range of key technologies. Primary research is still ongoing to provide better evidence in some low carbon sectors.

From the available evidence some conclusions can be drawn on how IPR protection may impact diffusion across different technologies, and why a flexible approach should be taken when dealing with climate related innovation and diffusion. For example, in pharmaceuticals IPR is absolutely central to the industry's business models as a single patent or copyright can capture the majority of returns for the innovator; this type of case may be relevant for biofuel catalysts, GM crops and advanced materials in turbines and fuel cells. However, in other sectors the importance of IPR may be limited either through the ease of reverse engineering processes (e.g. in information technology) or because competitive advantage is concentrated in tacit knowledge associated with its production; many complex power plant technologies seem to exhibit this structure. A final case is where a large number of small patents are used in a process, often referred to as a 'patent thicket'. Where a single company holds the majority of the patents this can create significant access issues; these cases are often seen in vehicle sector associated with pollution control technologies.[11]

Though concerns are often raised over the cost of IPR limiting access to technology in developing countries, this barrier may only apply to a small number of low carbon technologies such as catalysts. From interviews with technology companies, a more prevalent barrier to diffusion in low carbon technologies seems to come from companies restricting licensing of advanced technologies in developing countries through fears they will lose control of IPR and face export competition in home markets. This may occur even when agreements have been signed to prevent this; as has been seen on some pollution control equipment licences in China. However, while genuine risks exist, in some cases companies also seem to have strategically withheld or delayed technology from certain markets in order to maximise profits. This is not a sustainable strategy for addressing climate change as manufacturing of low carbon

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[11] Barton, 2008a

technologies must be widely spread into developing countries if required rapid diffusion rates are to be achieved.

Action is required to break the deadlock between developed and developing countries over intellectual property. There is no firm evidence of how IPR impacts diffusion across climate technologies, and available case studies show a wide range of different scenarios. Despite disputes over issues like compulsory licensing at the UNFCCC, in reality all countries already employ a variety of contractual and legal structures to ensure the diffusion of beneficial innovation; especially when R&D has benefited from public financing and public goods are involved. For example, the EU has strict requirements on the diffusion of IPR when companies receive State Aids subsidies.[12] There is no absolute system of IPR protection in any country and historically compulsory licensing has been most prevalent in countries such as the US and Canada.

A rebalancing of the system under the UNFCCC could be based on the principles of 'protect and share'. Where IPR would be protected from unauthorised use by strengthening implementation of IPR protection systems; while balancing this with a clear framework requiring different forms of sharing through, for example licensing and parallel markets and "pay to play" agreements to meet the climate challenge. Access to international R&D funding and credit for national R&D programmes for all Parties could be made conditional on implementation of these agreed principles for protecting and sharing IPR.

Finally, although ensuring future innovation is very important, the urgency of moving to a global low carbon economy within a very limited timeframe requires that the balance of the global innovation system must be to maximise the rate of diffusion. Any potential disincentives to technology developers which could result should be balanced by targeted public incentives for continued R&D and segmented markets for new innovations. Markets must be designed to give greater incentives for continued innovation rather than to continue reaping earnings from past inventions.

Proposals for action: a new institutional framework for low carbon innovation

The analysis in this report points to critical features needed in the UNFCCC system:

- A focus on increasing absolute levels of both innovation and diffusion for adaptation and mitigation, through outcome based strategic approaches based on mitigation pathways and worst case scenarios of climate responses and impacts;

- The need for action both within the UNFCCC framework and outside it to ensure

[12] For example see the Norwegian Ministry of Petroleum and Energy, 2006 and EFTA Surveillance Authority, 2008

healthy diversity, and encourage continued work on innovative approaches at the regional and national level;

- The importance of developing overall innovation systems for low carbon development and the use of sectoral approaches to engage all stages of the innovation chain to accelerate technology development and deployment;

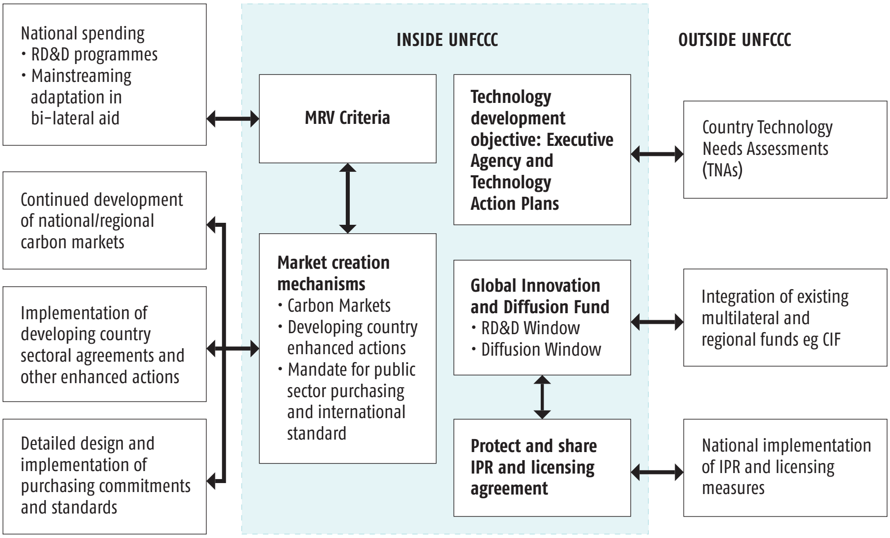
- The importance of supporting developing countries and international institutions in driving appropriate innovation in areas vital for developing economies;

- The need to explicitly rebalance the incentives for innovation and diffusion, including around the use of intellectual property rights, inside the UNFCCC.

The report below sets out a comprehensive set of proposals for action within the UNFCCC that builds on existing policies and measures to produce a framework for transforming innovation systems and delivering a 2°C world.

Given the weakness of current international cooperation in this area, and the lack of an existing competent multilateral body, the analysis also implies that new institutional structures will need to be established under the UNFCCC in order to organise and administer such an ambitious programme; especially on priority areas for international technology development and regional diffusion programmes.

Figure ES1: Breakdown of proposed action within and outside of the UNFCCC



Within the UNFCCC we recommend five key actions:

1. **Agreement to a Technology Development Objective:** The technology development objective would establish a set of critical climate change technologies (for both mitigation and adaptation) which must be developed to meet the goals of the agreement. The achievement of the technology development objective would be supported by a set of Technology Action Plans (TAPs) for each identified technology and a Technology Development Executive. The role of the Executive would be to monitor global efforts to deliver a portfolio of critical technologies – including public and private efforts - and propose complementary support and activity at the multilateral level needed to deliver agreed technology outcomes.

2. **Establish criteria for measurable, reportable, verifiable (MRV) action:** The MRV criteria should set out the conditions under which national R&D and development spending by developed countries – including on sectoral agreements – would qualify as a contribution to their UNFCCC commitments on technology, financing and capacity building support. These conditions would need to be carefully negotiated but could contain the following main elements: additionality to existing ODA and R&D spending; reciprocal knowledge sharing with other related R&D programmes; demonstrable link to a developing country's low carbon development plan; meeting criteria for enhanced developing country access to new technology; increasing developing countries' capacity to innovate and adapt; and climate proofing ODA.

3. **Market creation mechanisms:** Market creation mechanisms could include: technology-led sectoral agreements for developing country enhanced actions; international standards agreements; and public sector purchasing commitments. These may be developed inside or outside the UNFCCC system, but must be guided by its principles and procedures if they are to count towards Parties' commitments.

4. **A new multilateral Global Innovation and Diffusion Fund:** In order to implement the Technology Action Plans the Copenhagen Agreement should establish a new Global Innovation and Diffusion Fund. This fund could integrate existing activity (e.g. the World Bank Climate Investment Funds) through two windows under the new Technology Development Executive described above:

    - **The Research, Development and Demonstration (RD&D) Window:** This would be responsible for the development of new technologies with a focus on applied research and demonstration to push new technologies down the innovation chain, adapt them for use in developing countries and address orphan innovation areas;

- **The Diffusion Window:** This would be responsible for wide-scale uptake of new technologies including direct financing; patent buy-outs; and capacity building to ensure developing countries have the supporting systems necessary to use new technologies.

5. **A 'Protect and Share' agreement for IPR and licensing:** The agreement would provide government-to-government commitments to 'protect and share' low carbon technologies and encourage joint-ventures and public-private partnerships. Support would be made available under the Fund to strengthen IPR protection measures in developing countries, consistent with their existing international commitments under WIPO and WTO. Enhanced IPR protection would be balanced by a Framework Agreement for the accelerated sharing and licensing of low carbon technology to ensure rapid diffusion. This could consist of a range of standardised agreements covering five main areas:

   - Segmented/Parallel markets: to provide free licensing in certain developing country markets but prevent re-importation to developed countries for a limited period of time so innovators can earn a fair rate of return;

   - Public sector buy-out: to provide advanced purchase commitments under the Global Technology Innovation and Diffusion Fund for 'orphan' areas of research to guarantee a return to innovators and swift deployment of technology;

   - "Use it or lose it" agreements (compulsory licensing): to allow countries to take legal steps for the compulsory licensing of technology if innovators withhold technology from the market after a certain time period;

   - Pay to license: to provide direct subsidies or risk guarantees to increase licensing, and to ensure access when public funds are used to develop technology;

   - Global commons: to allow countries to provide open access to IPR where they have control of patents.

Countries that were found not to robustly protect low carbon IPR would risk having their access to the diffusion and RD&D funds blocked. Countries failing to ensure enhanced sharing of IPR and cooperative R&D spending would also be blocked from international funding and lose "MRV credit" in the agreement for their relevant technology programme.

1 Reframing the Low-Carbon Innovation Challenge

Technology urgency

Innovation and technology will be crucial for achieving low carbon stabilisation. Achieving 2°C will require a rapid increase in the scale and speed of both the development and deployment of low carbon innovation and supporting systems.

The Intergovernmental Panel on Climate Change (IPCC) has presented compelling evidence that climate change presents very serious global risks and demands an urgent global response. The science of climate change is complex, but in recent years there has been growing confidence in the relationship between the impact of emissions on the global temperature. The table below shows the established relationship between carbon emissions and climate change as put forward by the IPCC (Table 1.1; see also Figure 1.1):

Table 1.1: The relation between emissions and climate change

Temperature increase (°C)	CO_2 (ppm CO_2) 2005 = 379 ppm	All GHGs (ppm CO_2 eq.) 2005 = 375 ppm-eq	CO_2 emissions reduction 2050 (% of 2000 emissions)	$GtCO_2$ - eq/year in 2050*
2.0 – 2.4	350 – 400	445 – 490	-85 to -50	6.7 to 22.5
2.4 – 2.8	400 – 440	490 – 535	-60 to -30	18 to 35
2.8 – 3.2	440 – 485	535 – 590	-30 to +5	35 to 47
3.2 – 4.0	485 – 570	590 – 710	+10 to +60	49.5 to 72

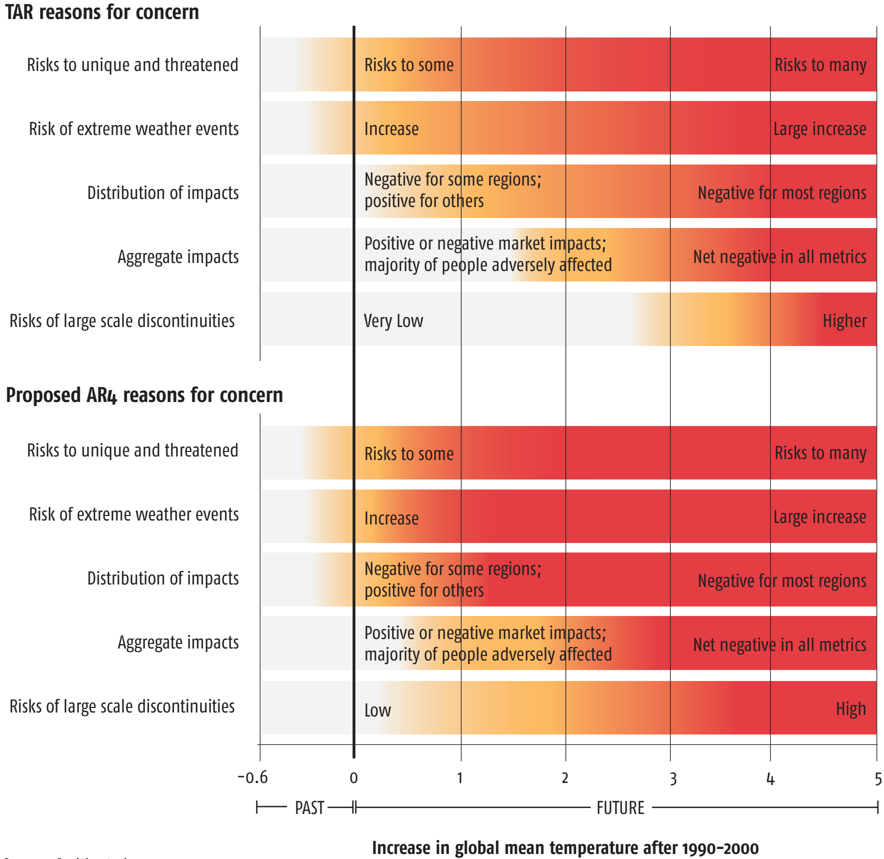
* Total GHG emissions in 2000 were 44.7 $GtCO_2$ - eq/year (IPCC, 2007a, Figure SPM3, p: 5)

Source: Modified from IPCC, 2007a (Table SPM6, p:20)

In 2005, energy-related CO_2 emissions were 27 Gt per year. Under business as usual (BAU) scenarios this would lead to total global energy-related CO_2 emissions in the order of 42 and 62 Gt in 2030 and 2050, respectively (Figure 1.4). Emissions of this scale would lead to a total atmospheric concentration of around 550 ppm by 2050, resulting in a global mean temperature increase of 2.8 – 3.2°C (Table 1.1).

Increases in global temperature will have serious implications for the stability of global ecosystems and human society. Figure 1.1 (above) from the IPCC shows that the

Figure 1.1: IPCC AR4 Finds Greater Risk

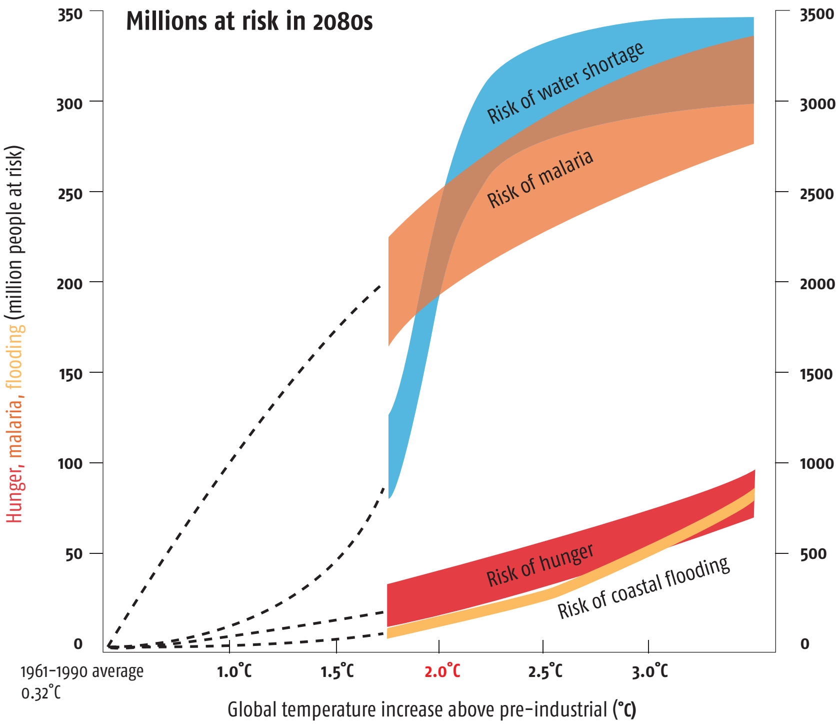


Source: Smith et al., 2007

most potentially damaging impacts from climate change, represented in red, are likely to occur with just a slight increase in temperature. Comparing the same assessment from the 3rd and 4th IPPC Assessment Reports shows a marked increase in the risk of serious impacts at each potential temperature increase. This illustrates a general shift to higher estimates of climate impacts since the Kyoto Protocol was agreed in 1997, and has led to a progressive lowering of estimates of long term acceptable atmospheric concentrations of greenhouse gases and earlier dates for when global emissions must peak. There is no reason to assume that these estimates will not continue shifting in future IPCC assessments, and the probability of the need for more aggressive action to stabilise GHG emissions should be included in future scenarios.

Figure 1.2 below shows the extent of potential impacts as temperature increases. Estimates of the impacts show that there seems to be a threshold effect around 2°C above which a very large increase in impacts, up to several hundred percent, will occur

Figure 1.2: Millions at Risk



Source: Parry et al., 2001

with dramatic humanitarian consequences on the proportion of the human population exposed to water scarcity, coastal flooding, and food security and public health risks. Developing countries, owing to their geographic location and relatively weak infrastructure, will be affected first and most severely by climate change. Potential impacts highlighted by the Stern Review include:[13]

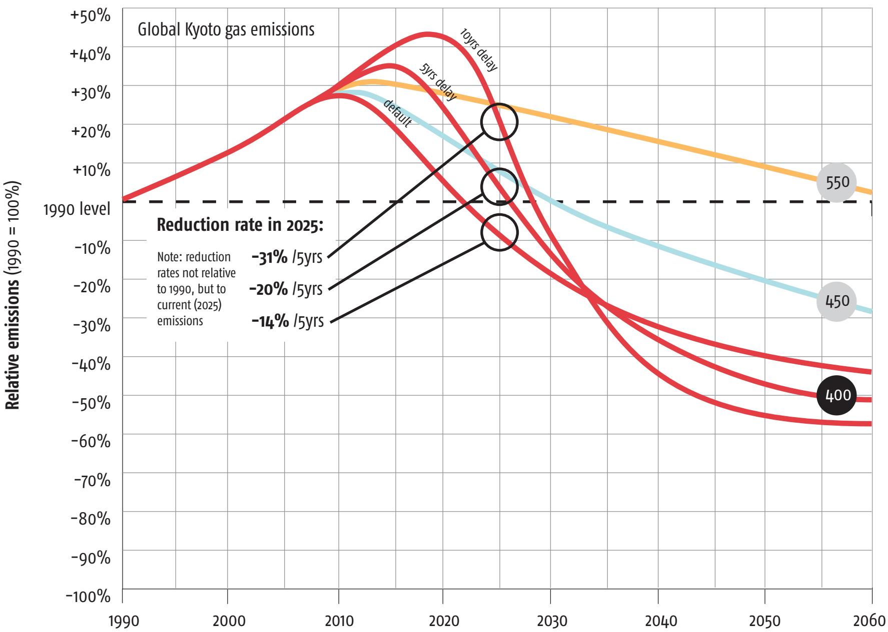
- Rapidly reduced water availability affecting hundreds of millions in Africa and Asia
- 15%-35% reduction in agricultural yields in Africa
- Up to 80m more people exposed to malaria in Africa
- Up to 300m more people affected by coastal flooding

In order to keep global temperature changes below 2°C emissions will need to peak in the next 10-15 years, and then decline. Delaying action will require much faster rates of reduction later in order to reach a concentration of 400-450 ppm (broadly consistent with 2°C). This is highlighted in Figure 1.3 which shows that if there is a 10

[13] Impacts shown in relation to a 4 degree temperature rise relative to pre-industrial levels, Stern Review, 2006, Chapter 3, p:56

year delay in reducing emissions then the rate of cuts required increases, over a five year period, from 14% to 31% (6% per year). Such rates of emissions cuts will be extremely expensive, highly disruptive and difficult to achieve without major advances in technology.

Figure 1.3: Emission reduction rates



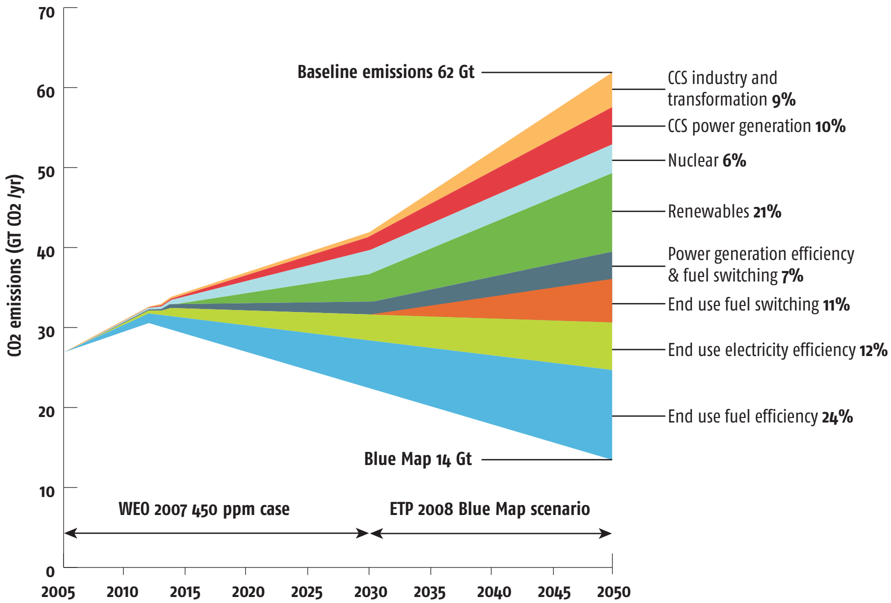
Source: Meinshausen, 2005

Achieving these emissions reductions will require a rapid increase in the development and deployment of low carbon innovations and their supporting systems. This will need to cover all of the major emitting sectors: energy, transport, industry, infrastructure and buildings. While this is undoubtedly an immense global challenge, the basic economic and technical systems exist to deliver the necessary advances. The International Energy Agency's (IEA) recent technology roadmaps of 17 key technologies suggest that these could deliver 87% of energy-related carbon emissions reductions by 2050 in the 450 ppm scenario[14]. Overall supply, end-use efficiency and fuel switching (54%), renewables (21%) and CCS (19%) provide the bulk of reduction options (Figure 1.4). Rapid deployment will be required in both developed and developing countries.

The need to deliver low-carbon innovation within a specific timeframe makes it a unique global challenge. In other areas, such as health and defence, although we want

[14] IEA, 2008a

Figure 1.4: Contribution of energy-related emission reduction options, 2005-2050



Source: IEA, 2008a

the maximum amount of innovation possible there is not a specific time period in which new innovations must be delivered before irreversible change occurs. The hard constraints which the global ecosystem imposes mean that we should reassess the balance of policies and measures used to promote low carbon innovation.

Avoiding lock-in to carbon intensive development pathways

Major investment in currently carbon intensive sectors will be made over the coming decades. Both developed and developing countries have critical interests in moving to low carbon development pathways to avoid lock-in for their economies.

Without rapid action to shift the world's economies onto low carbon pathways we will become 'locked-in' to carbon intensive development. The choices we make today will have significant implications for the future. Major capital investments are being made now the results of which will last for many decades, potentially leading to path dependency issues where future choices may be restricted because of decisions taken in the past. IEA BAU suggests that some $22 trillion of investment in supply infrastructure is needed to meet projected global energy demand between 2006 and 2030.[15] Of this, the power sector requires $11.6 trillion of capital expenditure, accounting for more than half of all total energy-supply investments.

Different stabilisation levels suggest different investments in the share of energy-efficiency and power generation. For example, in the 450 stabilisation scenario, CCS accounts for a fifth of cumulative power generation investment needs between 2006 and 2030. Similarly, renewables' share doubles compared to the reference scenario. There is currently a significant gap between the steps that need to be taken based on IEA reference scenarios and what is actually occurring. For example, there is no commercial scale CCS demonstration plants planned to be in operation before 2015, and renewable energy currently accounts for just 3.4% of global electricity production.[16]

In contrast to the need to curb emissions, concerns over resource scarcity are currently driving defensive investments in high carbon technologies because of the short-term security of supply benefits they bring. This is particularly true in rapidly industrialising transition economies but is also an increasing consideration in the US and Europe. Europe and China each will build more than 800 and 1000 GW, respectively, of new power capacity by 2030[17]. Furthermore, coal accounts for 70% of the anticipated installed capacity in China in 2030[18]. If all the planned fossil fuel power plants in India, China, US and Europe are built by 2030, their lifetime emissions will exceed all previous emissions from all sources (Figure 1.5). IEA projections[19] suggest that in order to limit emissions from the power sector to 6.3 Gt CO_2 by 2030, which would be in line with the 450 ppm equivalent stabilisation target, some 15% of the fossil-fuel generating capacity – around 350 GW – would need to be retired early between 2012 and 2030 before the end of their economic lifetime and any new capacity added would need to be carbon neutral. There are similar issues in all major emitting sectors: energy, transport, industry, infrastructure and buildings.[20]

While these scenarios require only an 18% increase in investment over business as usual, they imply a huge investment shift from high to low carbon technologies.[21] Transport is particularly important and accounts for the largest single area of investment in all the scenarios. A significant amount of the additional $45 trillion investment needed to 2050, around 70%, will occur in this sector as it shifts to more expensive low carbon vehicles with lower fuel costs. According to the BLUE Map

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15 IEA, 2007

16 REN21, 2008, p:9

17 IEA, 2006

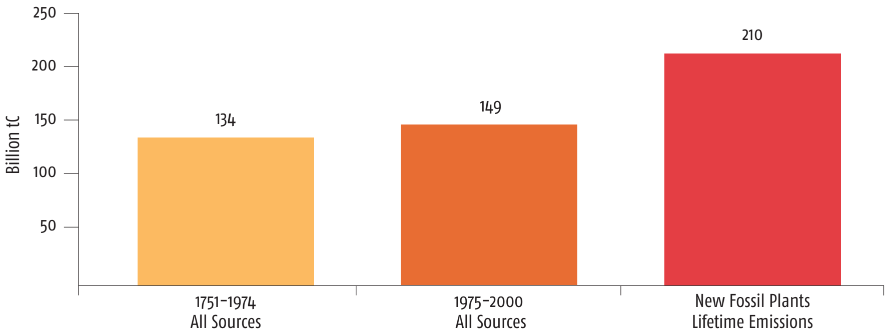
18 Lee et al., 2007, p:22

19 IEA, 2007, WEO, p:211

20 IEA, 2008a

21 IEA's BLUE Map Scenario in IEA (2008a)

Figure 1.5: CO_2 Emissions from New Fossil Fuel Plants



Source: CDIAC Database (Oak Ridge National Laboratory)[22]; IEA, 2004

scenario nearly one billion electric and fuel cell vehicles need to be on the road by 2050, which, making optimistic assumptions about technology growth, will still cost $6,500 more per unit than conventional vehicles.

Avoiding carbon lock-in will require countries to adopt low carbon development pathways and invest in existing and new technologies which can simultaneously provide emissions reductions while enhancing security of supply. It will also be important to plan ahead, for example by making new fossil fuel plants carbon-capture ready, so that retrofitting can occur when appropriate technologies are developed.

Countries which fail to innovate and avoid carbon lock-in may face heavy burdens in the future as they struggle to compete in a carbon constrained world. Thus innovation support for developing countries should focus on enhancing their capacity to innovate and adapt new technologies for use in their economies.

What types of innovation do we need?

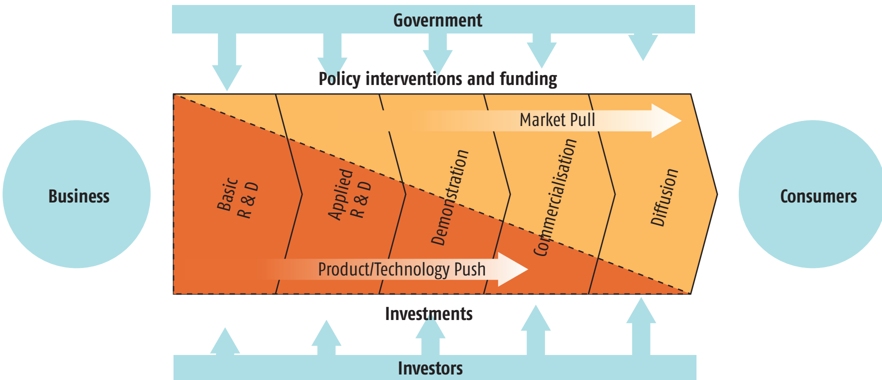
Innovation requires a balance between 'push' and 'pull' factors along the innovation chain. Tackling climate change will require a combination of adaptive, incremental and disruptive innovations which has implications for market regulation and structure.

Successful innovation requires a balance between 'push' and 'pull' factors along the innovation chain, with varying levels of public-private finance and policy interventions at different stages (Figure 1.6).

[22] For more information, visit http://cdiac.ornl.gov/trends/emis/meth_reg.html

The private sector already engages in significant technology joint ventures. The process of innovation tends to take place largely through private business investment which is increasingly international in nature.[23] Private sector spending accounts for 60% of global R&D expenditure in 2006 (i.e. $525 billion);[24] however government cooperation will be crucial to create the conditions to scale up the current rate of innovation and diffusion. **A key consideration for governments, therefore, should be creating the right balance of risk and reward in innovation markets to leverage private sector activity.**

Figure 1.6: Innovation Chain



Source: Adapted from Grubb, 2004

Delivering a 2ºC world will require many different types of innovation. Three different forms of innovation are particularly relevant to the current climate debate: incremental innovation, disruptive innovation and adaptive innovation (Figure 1.7).

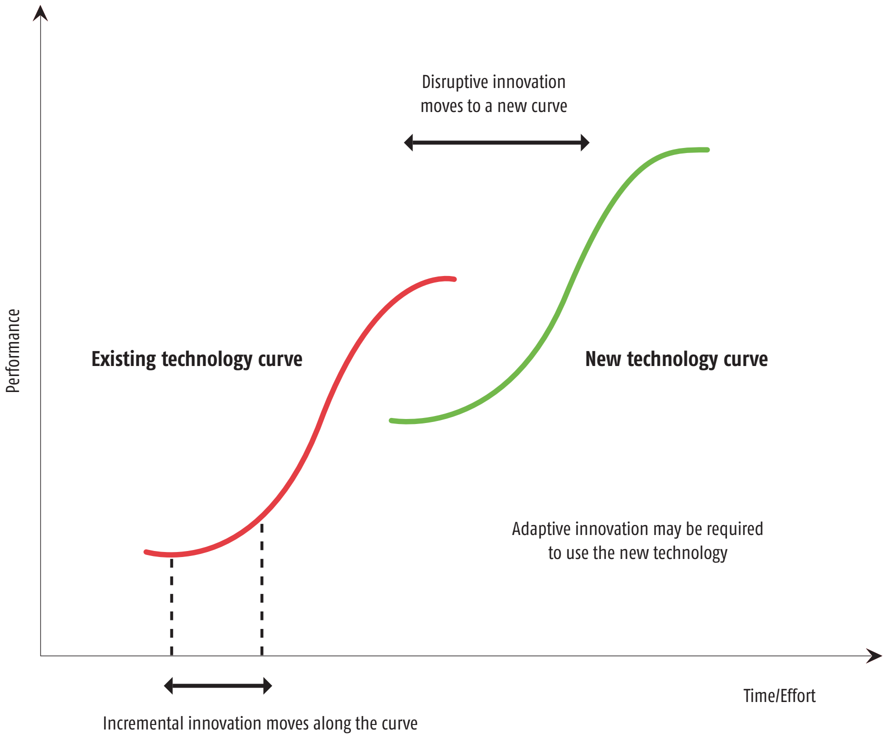
Incremental innovation improves existing technologies and systems, moving the technology along the performance curve as shown in the figure above. Examples of incremental innovation include improved fuel efficiency of vehicles or improvements in existing wind and solar power generation making them more competitive with fossil fuel alternatives. Incremental innovation will be vital to improve the currently available suite of technologies to deliver mitigation and adaptation efforts. Current modelling of mitigation pathways tend to be based on learning curve approaches and thus emphasise the importance of incremental innovation of existing technologies in reaching global targets.

In contrast *disruptive innovation* is the development of an entirely new technology represented above by the movement to a new performance curve. Examples of

[23] OECD, 2007

[24] Duga and Studt, 2007

Figure 1.7: Technology evolution S-curves



Source: Adapted from Foster, 1986, p: 88–111.

disruptive innovation would be switch to electric or hydrogen powered vehicles, or new distributed power generation technology such as thin-film solar cells. Disruptive innovation has the potential to make a massive contribution to mitigation and adaptation efforts, but because there is much greater uncertainty as to when it will be delivered at a large scale it is not emphasised as strongly in many mitigation models, and is obviously intrinsically harder to model. However, few technologies are intrinsically disruptive or sustaining in character on their own. It is often the changes to strategy and business models which new technologies allow that leads to truly disruptive impacts in the market.[25]

The ability for disruptive innovations to penetrate the market is significantly influenced by market structure and regulations. Restrictive regulations and markets dominated by large incumbents or network monopolies (e.g. power grids) can make it difficult for disruptive innovations to be successful, and can deter potential innovators from investing in these areas. These market issues are particularly apparent in

[25] Christensen and Raynor, 2003

many of the sectors most important for climate mitigation such as power, transport, infrastructure and buildings. These sectors tend to have high levels of market concentration and a lack of effective regulation, which can protect incumbents and act as barriers to new entry. The role of competition policy and innovative network regulation will be critical in driving disruptive low carbon innovation in these areas.

In addition to incremental and disruptive innovation, *adaptive innovation* will be required on a large scale in order to successfully deploy new and existing technologies across different markets. Variations in national circumstance and supporting infrastructure mean that a technology developed in one country may not immediately be applied to another. This is often particularly acute in developing countries where a lack of adaptive capacity may severely inhibit the diffusion of technology. An example of adaptive innovation would be ensuring CCS plants and storage systems work with local fuel sources and geological storage options.

A key issue relevant to innovation types involves 'orphan' areas of research, where developed markets provide few incentives for innovation. Examples are drought resistant African crops or small scale desalination – advances which can bring significant benefits to developing countries that are highly dependent on agricultural production or lack easy access to fresh water. Orphan research areas can fall under any of the three types of innovation; however, it is particularly relevant for adaptive innovation owing to the low ability to pay for new technologies in many developing countries.

Low carbon innovation is a global public good

National policies alone do not capture the global public good nature of low carbon innovation, leading to a global undersupply of investment. Action is required at the multilateral level to build on national actions and correct market failures.

Low carbon knowledge and innovation have the classic elements of a global public good (GPG) as, at a fundamental level, the benefits of low carbon innovation are non-excludable and non-rivalrous in consumption across national borders. That is to say that the use of new low carbon knowledge and innovation by one country does not prevent others benefiting from it, and when one country decarbonises all will gain from reduced global emissions. This means that in the absence of additional multilateral action, private markets will under-invest in low carbon innovations relative to the global social optimum.

In addition there are three specific cross-border coordination issues for delivering low carbon innovation: intellectual property rules relating to specific products and technologies under the Trade Related Aspects of Intellectual Property Rights (TRIPS) agreement; networks and connectivity relating to the supporting infrastructure and human capital necessary to use a new technology; and risk management relating to the regulatory environment and business models used to develop and transfer ideas and technology.

Although there is already significant public and private investment in low carbon innovation in high income countries, this is often done with a view to creating national competitive advantage (see policy failures section below). Competition is a crucial factor in driving innovation but it does not fully capture all of the global public good aspects of low carbon technologies. Therefore additional effort is required by the global community to create an innovation system that takes risks to develop new, disruptive technologies that are appropriate for both developed and developing country economies; that encourages innovation in supporting networks (business models and institutions) alongside new technology; and that allows for rapid diffusion of new ideas and technologies after they are developed.

Multilateral action should help correct policy failure at the national level

There is significant policy failure in national R&D programmes. Currently multilateral institutions do not sufficiently address cross-border issues of risk management and networks of innovation. Action is required to create a new balance of risk and reward to drive innovation forward.

R&D spending figures are notoriously difficult to compare since there are significant differences between studies in terms of data collected and countries included. Public spending in energy-related R&D and demonstration in IEA countries is about half the level it was about 25 years ago, estimated at approximately $10 billion a year in 2006.[26] Figure 1.8 below shows that public spending in R&D has significantly decreased in G7 countries for most energy technologies since the mid-1980s. There is also a strong bias towards certain technologies. In particular, nuclear power (both fission and fusion) has received over half of all state R&D budgets from the G7 countries over the last two decades, more than five times the combined energy efficiency budgets. Over the same timeframe energy RD&D as a share of total RD&D in OECD countries has declined from 11% in 1985 to 3% in 2005.[27]

Global R&D investment in non-energy sectors is mostly undertaken in the private

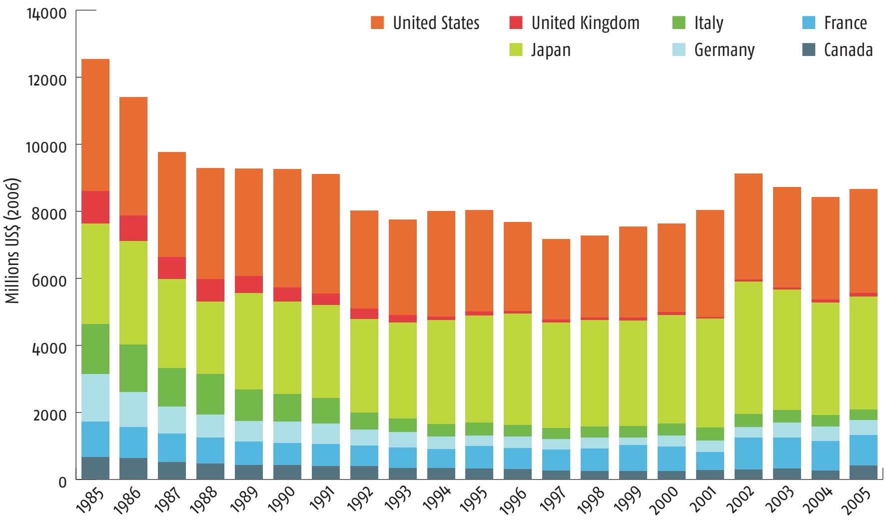
[26] IEA, 2008a

[27] Ibid.

sector, and is increasingly global in nature.[28] Energy R&D, however, is mainly financed by governments and around 40-60% of government energy R&D expenditure is used to subsidise private R&D investment.[29] The public sector spent $9 billion in 2004 on energy R&D, whilst private industry spent $4.5 billion in 2003.

Public policy has important implications for low carbon innovation. Public support to capture the public good nature of R&D and to overcome other market failures is critical for bringing new technologies to market. The crucial issue is ensuring the right policy frameworks and incentives to use innovative capacity to solve multiple climate change, energy security and climate resilience problems. Given the scale of private sector contribution in overall R&D, as mentioned above, government action should seek to leverage the power of private markets to solve low carbon innovation challenges. The World Business Council for Sustainable Development (WBCSD)[30] argues for major changes in investment frameworks, and suggests that "in the absence of strong policy support mechanisms and incentives, and while fossil fuels are cheap and readily available, public and private funds are unlikely to deliver the necessary technologies at a cost and scale necessary to address climate change".

Figure 1.8: Public energy-related R&D spending in G-7 countries, 1985-2005



Source: IEA database of R&D (IEA, 2008b)

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[28] Government and non-governmental organisations spent around $350 billion per year on R&D globally in 2006 (40% of the total). Private sector spent the rest 60% ($525 billion per year). (Duga and Studt, 2007 cited in Office of Climate Change, 2008).

[29] Doornbosch and Upton (2006)

[30] World Business Council for Sustainable Development, 2007, p:5

Innovation is increasingly becoming international both in terms of finance and actual research. The average R&D intensity of affiliates under foreign control is higher than the R&D intensity of domestically controlled firms in most countries. This is the case in Japan, Sweden, the United States and the United Kingdom and confirms "the increasingly global dispersion of R&D activities as they move closer to markets and to sources of knowledge (poles of excellence)".[31]

Major emerging economies are increasingly prioritising innovation and pursuing the ambition of becoming competitive knowledge-based economies. In 2005, China became the third largest R&D spender world wide (in purchasing power parity terms) after the United States and Japan, with a growth of more than 18% a year between 2000 and 2005. Emerging economy firms are also increasingly investing in developed countries. A recent study showed that Chinese firms alone set up 37 R&D units abroad of which 26 are based in developed countries (11 in the USA and 11 in the EU).[32] Emerging economy firms have also acquired developed country firms in order to gain access to their intellectual property and markets. A leading Indian wind turbine manufacturer, Suzlon Energy, recently acquired majority control of several wind turbine technology and components suppliers, including Hansen and REpower.[33] Similarly, Brazil has been very successful in its national Ethanol Programme, and is a leader in the global biofuel sector.

However, one of the main barriers to optimal innovation provision is that it is largely dealt with at the national level and tends to be viewed as an extension of R&D policy.[34] This has led to tensions within the current policy system of many states:

- Competing rationales: individual policy domains such as R&D and industrial policy have their own communities. This can lead to competition for resources both within and between different countries;

- Short-termism in resource allocation: resources are often invested with a view to generating short-term results rather than long-term solutions;

- Different imperatives for innovation policy: typically national economic imperatives dominate which can lead to difficulty when it needs to be coordinated with environmental or development policy;

- Fragmentation and segmentation: There is increasing fragmentation in national policy responses to innovation at a time when greater coordination is required;

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31 OECD, 2007, page: 17

32 von Zedtwitz, 2005 cited in OECD, 2008a

33 Lewis, 2008

34 OECD, 2005a

- Competition and rival ambition: competition and turf wars between policy officials/departments can skew R&D investment producing sub-optimal results.

In an increasingly globalised world these policy failures can significantly undermine incentives to develop new low carbon innovations.

At the moment collaborative R&D is very weak, outside long term areas such as nuclear fusion (e.g. ITER). Current national innovation strategies work against effective cooperation as they are fundamentally designed around national competitiveness priorities, not to produce global public goods. For example, under the EU's Framework 6 research programme, 209 joint research projects, worth €1.3 billion, have been signed with Chinese participation; however of this only €35 million was allocated to Chinese researchers.[35] Public R&D collaboration is little better between developed countries in the energy area despite many cooperative agreements at the IEA (i.e. Implementing Agreements).

Action at the multilateral level should seek to build and enhance national efforts, rather than replace them, and increase incentives for effective cooperation.

Key Conclusions

- While the science behind climate change is complex, there is widespread agreement that atmospheric CO_2 concentration should stabilise at 400-450 ppm by 2050 in order to ensure a temperature increase below 2°C and thus limit the most serious environmental and humanitarian consequences;

- Major investment in currently carbon intensive sectors will be made over the coming decades. Rapid action is therefore required to avoid carbon lock-in and ensure global emissions peak and reduce in the next 10-15 years. This will require increased levels of innovation and diffusion to switch countries onto low carbon development pathways;

- Innovation requires a balance between 'push' and 'pull' factors along the innovation chain. Tackling climate change will require a combination of adaptive, incremental and disruptive innovations which has implications for market regulation and structure. Steps will also be required to ensure that 'orphan' areas of research are supported;

- There is significant policy failure in national R&D programmes. Currently multilateral institutions do not sufficiently address cross-border issues of risk management and networks of innovation;

[35] Vialatte, 2008

- Action is therefore required at the multilateral level to build on national efforts and correct market failures to fully capture the global public good aspects of low carbon innovation.

2 Scale of the challenge – delivering a 2°C world

2°C stabilisation will require rapid development and deployment of low/zero carbon technologies in both developed and developing countries. Mitigation scenarios provide examples of the technology mix and investment cost required to achieve this; however, effective risk management will require a broad portfolio approach which accounts for the possibility of technology and investment failure.

The challenge of delivering a 2°C world is considerable. Never before has the world faced such an imperative to deliver radical improvements in both innovation and diffusion within a given timescale. However, the ability of the global economy to deliver such transformative solutions is equally formidable. History has shown that in a variety of different fields, from the space race to the pharmaceuticals industry, concerted effort can deliver immense results. **Meeting this challenge requires the large-scale delivery of new clean technologies and massive shifts in investment on a global scale inside a given timeframe, and well above current spending levels.**

The test for the international community is to deliver a framework which can harness the transformative power of the global economy and channel it in an effective manner. As discussed in the previous chapter doing so will require cooperative action at the multilateral level in order to fully capture the global public good aspect of low carbon innovation. Therefore, the important questions to be answered are: what are the technological options that could be employed in climate mitigation; how exactly would they contribute to lowering of CO_2 emissions; how rapidly they can be introduced; and what are the financial or investment dynamics required?

A variety of mitigation models have been put forward which describe scenarios for future energy policy and highlight the technology roadmaps, investment shifts, and timeframe across a variety of different target CO_2 levels. By analyzing the core elements of these different models it is possible to draw out the implications for innovation, diffusion and investment.

Table 2.1 provides an overall summary of the main mitigation models highlighting their timeframes, CO_2 target, types of technologies needed, and investment figures. The scenarios provide a varied view of the possible energy future based on policy decisions and investment in incremental and disruptive technologies. **It is important to note that scenarios are not predictions; they are analyses of least-cost pathways to meet energy policy objectives, based on a set of technology assumptions**. They do not address the likelihood of outcomes or climate policy instruments that could help them achieve their objectives, and it is important to note that the optimism of the scenarios means that they can only be met with global participation. The logistics needed to achieve this are not addressed.[36]

The relationship between CO_2 concentration targets and temperature change is complex: using probability statistics synthesised from related research, the IPCC has demonstrated that it is necessary to stabilise atmospheric concentrations of greenhouse gases at around 450 ppm-eq to prevent a temperature increase of over 2°C above pre industrial levels.[37] The chances of reaching this target decrease as atmospheric concentrations of greenhouse gases increase. Failure to meet the innovation and investment targets put forward by these mitigation scenarios will result in much of the world becoming locked-in to carbon intensive development and the risk of experiencing catastrophic climate change on a global level.

The scenarios which present the most aggressive emissions reduction targets include the IEA World Energy Outlook 2007 450 ppm Stabilisation Scenario; the IEA Energy Technology Perspectives 2008 BLUE Map Scenarios; a Scenario presented by the Stern Review Economics of Climate Change which combines IPCC climate data with financial analysis on technology investment; a scenario presented by Shell which analyses progressive policy changes entitled Blueprints; and a study by the Princeton Climate Mitigation Institute Stabilisation Wedges Scenario.[38]

All of the aggressive scenarios that focus on concentration levels between 450 and 550 ppm require the urgent acceleration of technology development and deployment from business as usual projections. Fundamental elements for all of these scenarios are increased energy efficiency across all sectors, introduction of renewable energy and biofuels as diversified energy sources, and large-scale CCS. The timing for deployment of these technologies varies slightly, but quick deployment and diversification of energy sources are emphasised throughout. In terms of investment, these scenarios propose immediate scale-up for existing clean technologies and energy efficiency, as well as a massive shift in investment in the medium and long term for incremental and disruptive technologies.

The terminology used to describe activities varies by scenario and can cause confusion. For the purposes of this report we make a distinction between early and late

[36] IEA, 2008a

[37] IPCC, 2007b, Chapter 10; see also Table 1.1 in Chapter I.

[38] Pacala and Socolow, 2004

Table 2.1: List of policy, exploratory and technology climate mitigation scenarios[39]

Source	Scenario	Description	Time frame	CO_2 target	Technology Mix	Investment Figures
International Energy Agency	IEA WEO 2007 Reference Scenario	Provides a baseline vision of how global energy markets are likely to evolve if Governments do nothing more to affect underlying trends in energy demand and supply	2030	885 – 1130 ppm CO_2-eq (660 – 790 ppm CO_2)	• Fossil fuels – oil, coal, natural gas • Efficient power generation technologies	$22 trillion to meet fuel demand (cumulative investment in energy-supply infrastructure). $5.7 trillion in power generation sector
	IEA WEO 2007 Alternative Policy Scenario	A reflection and global compilation of current government policies aimed at addressing the growth of energy demand, energy security, and environmental sustainability.	2030	550 ppm	• Energy efficient technologies • Second generation biofuels • Renewables • CCS	Shift in investment by consumers in energy efficient appliances and equipment. Net investment is $21.6 trillion, and $5.5 trillion in the power sector
	IEA WEO 2007 High Growth Scenario	Tests the sensitivity of India and China's energy demand to higher economic growth rates and the implications for global energy trade and energy-related greenhouse-gas emissions.	2030	885 – 1130 ppm CO_2-eq (660 – 790 ppm CO_2)	• Fossil fuels • Nuclear • Renewables	$2 trillion over the Reference Scenario ($24 trillion)
	IEA WEO 2007 450 ppm Stabilisation Scenario	Identifies a combination of technological changes that would allow the long-term stabilisation of atmospheric greenhouse-gas concentrations at 450 ppm.	2030	450 ppm	• Efficiency in fossil fuel use in industry, buildings and transport • Nuclear • Renewables • CCS (strong emphasis) • Quick deployment of clean technologies	Cumulative investment in power generation sector is $7.5 trillion. Early retirement of fossil fuel capacity will cost $1 trillion. No estimates for cumulative overall investment.
	IEA ETP 2008 Baseline Scenario	Global CO_2 emissions grow rapidly, oil and gas prices are high, energy security is a major concern	2050	550 ppm	Fossil fuels and current energy mix	Total cumulative investment between 2005 and 2050 = 254 trillion

[39] For more detailed information on individual scenarios, visit the E3G website where a technical annex can be found; www.e3g.org.

Source	Scenario	Description	Time frame	CO_2 target	Technology Mix	Investment Figures
International Energy Agency	IEA ETP 2008 ACT map Scenario	Existing or developing technologies bring global CO_2 emissions back to current levels by 2050	2050 Decarbonisation by 2100	485 ppm (stabilisation at 520 ppm long term)	• Energy efficiency (buildings, appliances, transport, industry, power generation) • Renewables • Nuclear • CCS at fossil fuel plants	Additional investment in energy sector = 17 trillion to 2050 Deployment = 2.8 trillion. Total undiscounted fuel costs savings for coal, oil and gas over 50 yrs are greater than the additional investment required.
	IEA ETP 2008 BLUE Map Scenario	Reduce CO_2 emissions by 50% (from current levels) by 2050 through deployment of a mix of technologies, including though still under development	2050 Decarbonisation by 2100	450 ppm	Energy efficiency and emission reduction in power sector. Same technologies as ACT Map scenario	More investment in RD&D. Additional investment = 45 trillion. (to 2050) Deployment costs = 7 trillion. Total undiscounted fuel costs savings for coal, oil and gas over 50 yrs are greater than the additional investment required.
Stern	Stern & IPCC Scenario	Cutting global emissions by half by 2050 by investing in incremental and disruptive low carbon technologies through immediate global action and policy change	2050	450 – 550 ppm	• Current low carbon technologies • Disruptive technology • CCS • Solar • Second generation biofuels	1.0% of global GDP by 2050 (450 ppm is 3 times higher) This is in addition to BAU investment. Total investment for existing tech in 2050 is $1,136 billion and total for emerging tech in 2050 is $228 billion. ($1,364 total)
Shell	Shell Scramble Scenario	Attention given to energy efficiency and alternative technologies only when supplies are tight and climate shocks start to appear.	2050	550 ppm +	• Coal (+ unconventional fossil fuels) • Biofuels • Renewables • Little or no nuclear or CCS	Late investment in clean technologies (post 2050) at high levels. This combines with high energy prices in earlier periods.
	Shell Blueprint Scenario	Local actions promote emission reductions and clean technology (market drives) developments which leads to positive impacts on economic development energy security and environmental pollution	2050	450 – 550 ppm	Increased efficiency, wind, solar, biomass + waste, nuclear, gas, oil, other renewables and coal with CCS (after 2020)	Investment is balanced with certainty in markets due to global nature and participation.
Princeton Environment Institute	Princeton Stabwedges Scenario	Range of existing technologies designed to prevent doubling of emission from pre-industrial levels by stabilisation at current levels over 50 years	2050	Maintain at 380 ppm; keep under 570 ppm	• Efficiency & conservation • Fossil fuel based strategies (includes CCS) • Nuclear energy • Renewables & biostorage	Depends on tech mix – figures available for individual technologies

phase activities on the innovation chain. Early phase activity consists of research (both basic materials research and applied research), development and demonstration of a technology, abbreviated as RD&D. Late phase activity consists of the widespread deployment and diffusion of technology up to the point of full commercialisation.

Action for emissions reductions in these scenarios is needed in the next decade, and investments in this period need to be the subject of early replacement or refurbishment to meet targets. For example in the BLUE Map Scenario, 350 GW of coal-fired power is to be replaced before the end of its lifespan, inefficient housing is to be replaced and most importantly transport infrastructure is to be changed - the scale of this issue is discussed later in this chapter. This will require action on the part of government policymakers and industry leaders to implement CO_2 emissions reduction policies to help avoid significant supply challenges in the future. Across all aggressive scenarios, end-use sectors need to apply fuel-switching and CCS in combination with energy-efficiency measures in the immediate term.

Although the above scenarios provide good examples of required technologies, investment needs, and the associated timeframes, they do not effectively account for unforeseen risks such as technology and market failure or enhanced climate sensitivity. For example, the IEA BLUE Map Scenario which this report uses as its most aggressive Scenario is based on the IEA 450 ppm Stabilisation Scenario to 2030 from the 2007 World Economic Outlook. This Scenario estimates that stabilising concentrations in the range of 445-490 ppm of CO_2-equivalent would require energy-related CO_2 emissions to be reduced to around 23 Gt in 2030. They also note, however that "in 2030, the estimated range of CO_2 emissions compatible with stabilisation of CO_2-equivalent at 445-490 ppm is 10 to 29 Gt. [They] decided to use 23 Gt as an illustrative target, allowing for up to 6 Gt of CO_2 from non-energy-related sources, notably land use, land-use changes and forestry".[40] The likelihood of achieving large emission reductions from these non-energy sources is dependent on a range of highly uncertain factors including global food prices, population growth, land use policy reform and improved local governance. Targeting at this 'top range' is most likely to stabilise atmospheric concentrations at 490 ppm-eq, and is therefore not aggressive enough to avoid predicted climate tipping points above a 2°C temperature increase.

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[40] IEA, 2007

Scenario timeframes

The different timeframes of the scenarios have important implications for their recommendations. However, in all cases overall climate stabilisation will require continued decarbonisation beyond the time horizons considered here, and long term targets should not deter action on emission reductions being taken in the immediate term.

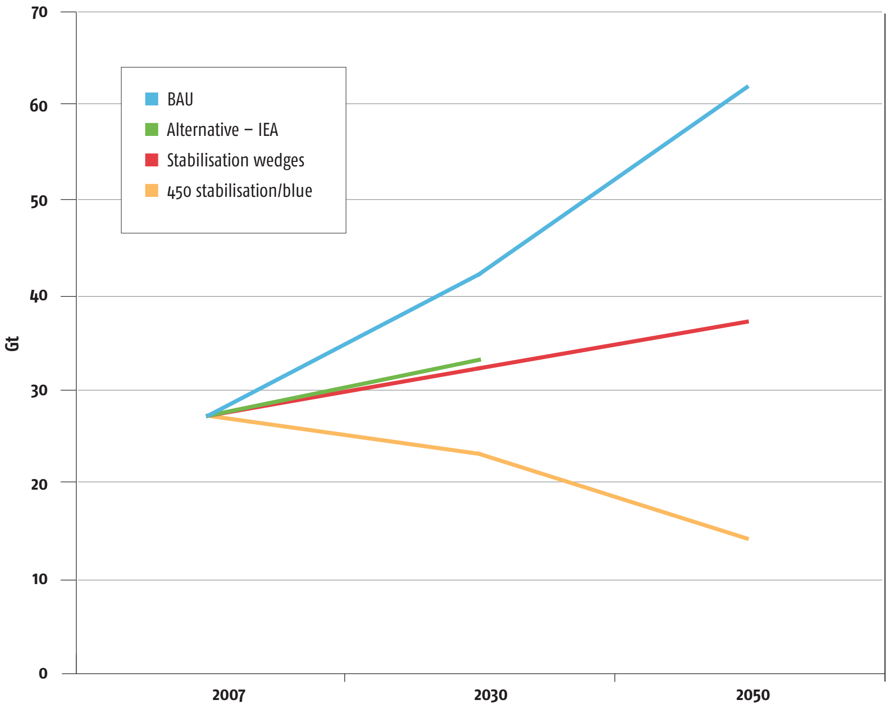
The timeframe over which a scenario is based has a material impact on its conclusions. Shorter timeframes do not necessarily allow for radical changes in energy infrastructure and consumption patterns. Combined with the use of learning curve approaches this can lead the shorter-term scenarios to emphasise incremental innovation in existing technologies rather than the entry of new and disruptive technologies. However, given the inherent uncertainty of disruptive innovation it is extremely challenging to try and include these in formal models. Therefore while these scenarios can provide a useful guide for innovation, policy makers should also ensure that investment and regulatory frameworks allow for a diversity of new entrants to come forward into the market. For example, while many studies include CCS as a emission control technology in the cement sector, they mostly do not include more radical zero emission cement technologies currently under development, or model potential for a progressive reduction in cement use through use of new timber laminates, high performance steel and advanced reduced material design.

Timeframes also matter with regard to overall climate stabilisation. A longer timeframe is needed for atmospheric concentrations of CO_2 to stabilise and reach levels which have a good chance of avoiding a temperature increase of more than 2°C. For instance, the IEA's ACT Map and BLUE Map Scenarios provide analysis on the timing of technology deployment and energy mix to 2050, but indicate that long term stabilisation of atmospheric concentrations of CO_2 will occur after 2050, with decarbonisation by 2100. The figure 2.1 below highlights the significantly different outcomes for CO_2 emissions across the different scenarios, showing global emissions in the stabilisation scenarios as one quarter of that in the BAU in 2050.

Important to note, is the danger of placing long term timeframes and targets on issues where urgent action is required. **Although concerted effort to reduce emissions must continue over the long term, it should be emphasised that action is required immediately to encourage diffusion of existing and breakthrough technologies to begin reducing emissions.**

As demonstrated in Chapter I, our understanding of risks and climate tipping points improves as science progresses. Scenarios with long timeframes cannot account for as yet unknown risks and therefore it is necessary to do more now to mitigate against these risks than the Scenarios illustrate.

Figure 2.1: Comparison of CO_2 emission targets of different scenarios



Source: Adapted from IEA, 2007, 2008a and Pacala and Socolow, 2004.

Technology Options

Under all Scenarios there is an urgent need to simultaneously scale-up the use of existing technologies and research and development for new technologies. Energy efficiency, changes in the transport sector and CCS solutions are particularly important for focus in the immediate term. Deployment needs to occur simultaneously in the developed and developing world, and will require large investment shifts. The public sector needs to act to effectively manage risk and plan for the long term.

The scenarios which are consistent with limiting future temperature increases to 2°C share similarities at the high level in terms of which technologies they recommend, and when they are deployed. For all scenarios, increases in energy efficiency and the use and implementation of new and emerging technologies are important features in their abilities to reach CO_2 targets under 550 ppm. Table 2.2 shows the most aggressive six mitigation scenarios technology mixes and the associated timeframes.

Table 2.2: High level analysis of technology mixes for selected mitigation scenarios

	2010	2020	2030	2050
IEA 450	• Immediate deployment of clean technology Deployment of existing and new clean technologies including CCS		• 4% second generation biofuels • 19% renewables in power sector • 16% nuclear • 21% CCS • Improved efficiency in fossil fuel use in industry and buildings account for ¼ of total avoided CO2 emission (compared to Alternative Policy)	N/A
IEA ACT Map	• Increased energy efficiency	Deployment of renewables, nuclear, CCS at fossil fuel plants and additional RD&D		
IEA BLUE Map	• Immediate deployment of clean technologies • Increased energy efficiency Deployment of renewables, nuclear, CCS at fossil fuel plants and additional RD&D			• 19% CCS (all) • 6% nuclear • 21% renewables • 54% energy efficiency (all sectors) including end-use fuel switching
Stern & IPCC	• Diffuse existing low carbon technology to 2030	• Near commercial technology development • CCS • Solar • Second generation biofuels to 2030	Deployment of breakthrough technologies	
Shell Blueprint	• Efficient infrastructure development • Congestion management • CHP at the local level • Energy efficiency	• Increased fuel efficiency CCS deployed commercially	• Renewables • Nuclear • Partial CCS	• 90% of OECD and 50% of non-OECD coal and gas-fired power stations fitted with CCS technology
Princeton Stabwedges	• Immediate scale-up of existing clean technology strategies Efficiency & conservation, nuclear energy, renewables & biostorage, fossil fuel based strategies (CCS)			

All of the scenarios require an immediate scale-up of the deployment of existing clean technologies and significant increases in energy efficiency, e.g. the IEA BLUE Map Scenario suggests energy efficiency across all sectors in 2050 will make up 54% of CO_2 savings compared to the Baseline Scenario. In addition to this, diversification of energy sources tends to follow with a mix of renewable technologies (wind, solar, biofuels and biostorage) and an emphasis on developing new clean technologies to reduce the reliance on conventional fuel sources. CCS is an integral part of the technology mix; with development and demonstration beginning within 5 years, and progressing to widespread deployment and utilisation in fossil fuel plants by 2030 – 2050.

Also emphasised is the importance of national and local level actions and policy changes which have the power to achieve immediate action and results, whilst influencing critical policy on the international stage. Policy changes in the immediate term are critical to affecting action in emissions reductions which can lead to long term greenhouse gas stabilisation.

IEA BLUE Map Scenario technology mix

The IEA utilises technology roadmaps to demonstrate the range of innovations on both the supply and demand side needed to reach ambitious CO_2 emissions reduction targets[41]. Table 2.3 shows the variety of technologies recommended for both its ACT Map and BLUE Map Scenarios.

Table 2.3: Key roadmaps used in the ETP study

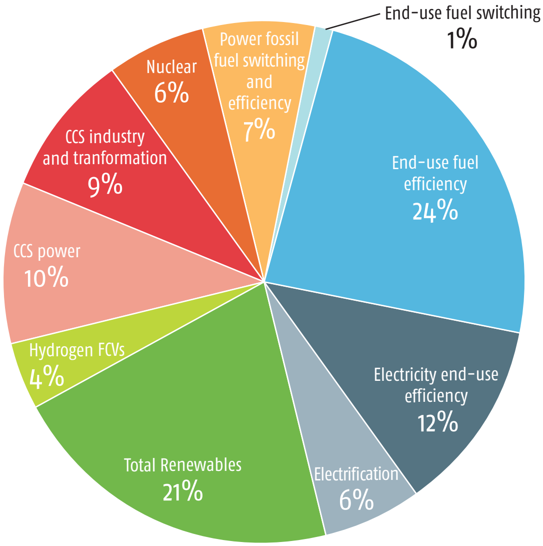
Supply Side	Demand Side
• CCS fossil fuel power generation • Nuclear power plants • Onshore and offshore wind • Biomass integrated-gasification combined-cycle and co-combustion • Photovoltaic systems • Concentrating solar power • Coal: integrated-gasification combined-cycle • Coal: ultra-supercritical • Second-generation biofuels	• Energy efficiency in buildings and appliances • Heat pumps • Solar space and water heating • Energy efficiency in transport • Electric and plug-in vehicles • H_2 fuel cell vehicles • CCS in industry, H_2 and fuel transformation • Industrial motor systems

Source: IEA, 2008a

[41] Roadmaps are highly dependant on policy targets and they can only be achieved if policy makers and industry leaders agree to: create policies that eliminate barriers to technological advancement; create market and financial incentives to allow the development and deployment of clean energy technologies; and engage the power of the marketplace to drive future technology breakthroughs (IEA, 2008a).

In order to achieve its target of reducing global greenhouse gas emissions to 50% of current levels by 2050, the BLUE Map Scenario uses the following technology mix.

Figure 2.2: Reduction in CO_2 Emissions from the Baseline Scenarios in the BLUE Map Scenario by Technology Area, 2050



Source: IEA, 2008a, p:65

It is important to note reductions in emissions through technologies such as end-use energy efficiency at 37%, CCS at 19%, renewable technologies at 21% and nuclear energy at 6%. In this scenario, the rate of energy efficiency improvement increases to 1.7% per year from 0.9% in the Baseline Scenario, with final energy intensity falling by 2.5% per year. The energy savings attributed to this scenario amount to 33% of baseline energy consumption by 2050.

Key technologies: CCS, energy efficiency and transport

High level analysis suggests the importance of CCS in future technology mixes as a tool on the critical path to reaching a 2°C goal; however it remains a controversial option. This can partly be attributed to the current lack of operational experience - in 2007 there were only four large-scale CO_2 capture and storage projects in operation globally. As a result it has yet to receive global support in terms of policy and implementation. While private and public initiatives are underway internationally to develop and promote this technology, the limited timescale for widespread implementation to effect real changes in emission reductions and avoid dangerous tipping points makes this an urgent issue. Investment, information sharing, and international cooperation for enabling CCS technologies are needed to meet aggressive mitigation targets set by the IEA and others, which include the deployment of CCS.

The conditions needed for large-scale deployment of CCS include:

- The removal of legal and regulatory barriers;
- Creation by local governments of enabling infrastructure;

- Creation of a global market that puts a value on CO2;

- International mechanisms to provide economic incentives for national governments and energy corporations;

- Demonstration of capture systems at commercial scale and reliability levels;

- Public awareness and support.

Recent support for CCS technology has been shown in legislation under discussion in the EU in 2008 as part of an overall Energy and Climate Package. This package includes a comprehensive legal framework for transportation and long term storage of carbon dioxide, and potentially a financing instrument to support the construction of 12 large-scale demonstration plants in Europe by 2015, including some projects in key developing countries.[42] The EU also has research programmes to support the use of CCS in the steel and cement sectors.

While energy efficiency measures make up a large part of abatement in this Scenario and others, in reality there is a high level of uncertainty in measuring and evaluating savings - they are hard to capture and policies often fail. Energy efficiency (in buildings, appliances, transport, industry and power generation) represents the largest and least costly savings in terms of clean technology investments, but the results are unreliable and hard to implement in practice as they are dependant on a variety of factors including the right mix of efficiency technologies and appropriate policy and standards. Subjectivity of results, difficulty in developing international standards and barriers such as market failures can add to the uncertainty of savings through energy efficiency.[43]

Transport can be viewed as a critical sector on the path to 2°C as it currently accounts for more than half of oil used worldwide and 25% of energy-related CO_2 emissions. In addition to this, CO_2 emissions from the transport sector have increased by 36% since 1990, and baseline predictions estimate transport energy use and emissions to increase by more than 50% by 2030 and more than double by 2050. Main areas of growth include air travel, road freight and light-duty vehicle travel – with the developing world experiencing the highest levels of growth. Changes to this sector need to occur by developing supporting infrastructure, creating fuel efficiency regulations, and investing in ongoing R&D in fuel storage systems and other innovations to decrease investment costs.

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[42] European Commission, 2008b

[43] Vine et al., 2003

Mitigation of future risks

The major risks associated with technology mixes and targets set by these scenarios include the following:

Policy failure – emissions reductions attributed to energy efficiency, infrastructure for emerging technologies, and reduced emissions from deforestation and degradation (REDD) are assumed in the above scenarios but in reality are hard to achieve and they face challenging policy delivery environments. To mitigate against this risk other technologies may have to be scaled up in other areas to compensate;

Enhanced climate sensitivity – evidence from the IPCC and others suggests a significant probability that climate sensitivity to greenhouse gases may continue to worsen, increasing the rate of emission reductions needed to meet stabilisation targets proposed by the above scenarios. This will mean acting faster than currently anticipated by scaling up existing clean technologies and investing in R&D for disruptive technologies to avoid reaching climate tipping points;

Technology failure – key technologies in the scenarios, such as second generation biofuels, may not be viable due to technological failure or public acceptance issues. For example in the case of biofuels land-use issues in relation to other activities such as food production may limit their effectiveness. As a result a larger range of low carbon energy alternative technologies – especially in power generation and transport – which are as yet not far enough along the innovation chain will need to be scaled up and deployed quicker than the scenarios suggest. This will have implications for research, development, and demonstration.

In the balancing of these risks the tendency is to do too little; while the opposite is needed. **Managing these risks suggests an increased focus on delivering a comprehensive portfolio of technology innovation and diffusion sooner rather than later.** Failure to incorporate these risks into future mitigation plans will lower the likelihood of climate stabilisation.

Shifting Investment

> *Achieving a 2°C future will require massive shifts in investment to accelerate innovation and diffusion, including supporting infrastructure. This will require increased public sector spending and action to leverage private sector investment. Investments need to scale-up in the immediate term, and take into account future risks.*

Although reliable figures for long term cumulative and net technology investment do not exist for all the mitigation scenarios, it is possible to make assumptions on the areas and scale of investment based on in-depth analysis from the IEA, IPCC, and Stern Review. A review of the investment figures and pace is provided in Table 2.4 below and presents a high level overview of investment projections for the six selected scenarios.[44]

Table 2.4: High level analysis of investment figures for selected mitigation scenarios

	2010	2020	2030	2050
IEA 450	Immediate policy action on clean technology deployment leads to high initial investment costs	Early retirement of fossil fuel generating capacity makes up • $1 trillion of additional investment required.	Cumulative investment (to 2030) in the power generation sector is • $7.5 trillion.	N/A
IEA ACT Map		Investment in RD&D		• Additional investment in the energy sector USD 17 trillion • 0.4% global GDP per year • Deployment costs make up $2.8 trillion to 2050
IEA BLUE Map	Investment in RD&D			• Additional investment USD 45 trillion • 1.1% global GDP per year to 2050 • Deployment costs make up $7 trillion to 2050
Stern & IPCC		• Invest in near commercial technology • 0.3% GDP • $173 billion p/a	• Invest in break-through technology • 0.7% GDP • $484 billion p/a	• 1.0% GDP • $1,364 billion p/a
Shell Blueprint	Clean technology investment begins in developing countries	Global participation in emissions trading schemes leads to investment in new energy technologies Emergence of new financial, insurance and financial markets to help finance major investments (CCS)		
Princeton Stabwedges	Immediate investment in existing clean technologies	Investment in deployment of disruptive technologies (CCS)		

44 Detailed investment figures vary by scenario and so these descriptions should be treated as illustrative.

These scenarios recommend immediate investment and policy action on near-commercial technologies such as some renewable energy sources, and second generation biofuels as well as investments supporting increased energy efficiency. A heavy emphasis is placed on investment in research development and demonstration (RD&D) as soon as possible to begin diversification of energy sources, and speed up the deployment of fossil fuel based technologies such as CCS.

The IEA 450 ppm Stabilisation Scenario notes that high costs will be associated with the immediate scale-up of investment in clean technologies and incremental technologies, relating directly to deployment. For several of the scenarios timing for investment in R&D begins in the mid 2010s, continues to 2030 and focuses on disruptive technologies. It is also noted that developing countries need to begin investing in clean technologies in the immediate term, and that global participation in energy, financial, insurance and carbon markets will become more widespread by 2020 - 2030.

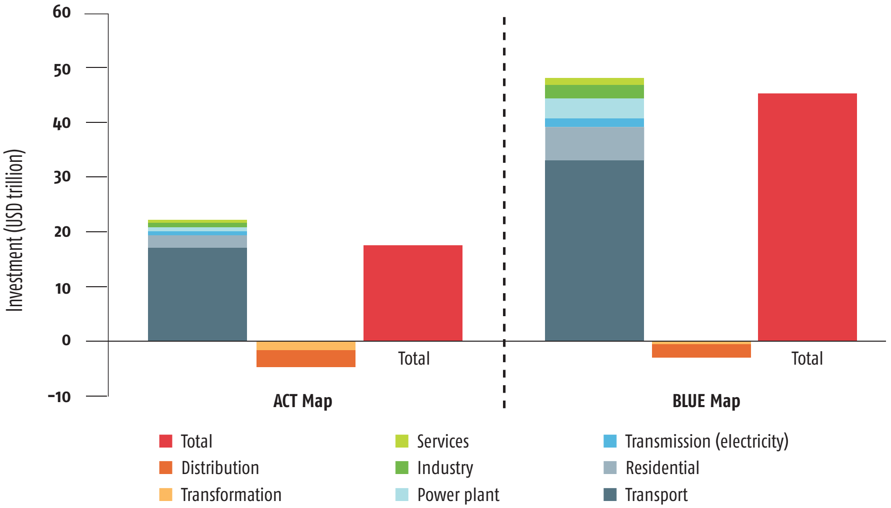
IEA BLUE Map Scenario investment needs

A closer look into investment figures as they relate to the IEA ETP BLUE Map Scenario gives an indication of the financing that is required to keep atmospheric greenhouse gas concentrations stabilised at 450 ppm-eq, with a greater chance of keeping temperature increases between 2 - 3°C above pre-industrial levels.

Additional investment costs for this Scenario amount to a total $45 trillion – an 18% increase over total baseline investment figures and representing an increase that is equivalent to 1.1% of cumulative GDP between 2005 and 2050. Although fuel savings incorporating switching and efficiency would amount to $50.6 trillion undiscounted and an actual difference in savings would amount to $5.6 trillion, it is clear that massive amounts of investment funds will need to be leveraged in order to achieve ambitious emissions reductions targets. The additional investment needs in clean energy technologies and energy efficiency is 18 times the current level of investment in this area.

Figure 2.3 indicates the additional investment required in both the ACT and BLUE Map Scenarios as compared to the baseline for 2005 – 2050. What is striking is that the figures are dominated by the high cost of decarbonising the transport sector.

Figure 2.3: Additional investment in the ACT Map and BLUE Map Scenarios compared to the Baseline Scenario, 2005 - 2050



Source: IEA, 2008a, p:225

Investment in the transport sector

The transport sector represents a critical area on the path to 2°C. High costs associated with decarbonising this sector (70% of overall additional investment needs in the BLUE Map Scenario) are due to the growing sales of transport vehicles and their high unit costs. Much of this investment will be increased levels of RD&D in the next 15 years into energy storage systems, fuel cell systems and advanced biofuel systems. This investment is critical for lowering long-term costs of CO_2 reductions in this sector.

Huge challenges exist for this sector as fuel sources diversify and new technologies that are critical to emissions reductions such as fuel cells and on-board energy storage are not yet viable or cost-effective. Investments are needed in R&D and infrastructure development for several areas including public transit and rail, aviation and shipping, and light-duty vehicles. Current costs of some transport technologies associated with fuel switching are high and will continue to remain so without strong policy support in the immediate term. Incentives for low carbon vehicles, fuel efficiency regulations, changes in infrastructure and ongoing R&D are necessary to bring technologies into the market and work toward lowering their costs.

One of the key uses of scenario modelling is to highlight areas such as transport where current estimates of incremental innovation are not sufficient to radically lower costs, even by 2050. In the Blue map scenario the need to aggressively decarbonise the transport sector raises the marginal cost of abatement from around $200 per tonne CO_2 to between $400-500 per tonne. Analysis of this sort should inform the prioritisation of cooperative global RD&D efforts to bring forward critical mitigation technologies.

Mitigation of future risks

The major risks related to investment figures for the above scenarios include the following:

- Failure to shift investment - investment shifts are not automatic and will require significant public action and clear policy signals. Both market size and certainty for low carbon and adaptive innovations will be important, including the eventual linking of national and regional systems;

- Global nature of investment – there is a need to shift patterns of investment both across sectors and countries as evidenced by the above scenarios which will require changes to investment regimes in some countries;

- Gap between investment and innovation - system lags between investment and the delivery of innovation mean that urgent action is required to ensure innovation funding is increased as soon as possible and adequate funding for demonstration to avoid "valley of death" problems in key technologies.

Future investment estimates need to take into consideration the need for a wider portfolio of technologies to provide adequate risk management. The market will not automatically bring technologies forward at the pace required, and will not account for future risks such as climate sensitivity or policy failure. Mitigating against these risks by investing early and in a wider portfolio of low carbon technologies will work toward achieving climate stabilisation.

An additional example of future risks can be seen through fluctuating oil prices. The implications of high fossil fuel prices on decarbonisation are not well covered in existing models. A long-term oil price of $100-$200 per barrel would potentially make decarbonisation considerably cheaper but also stimulate further investment in high carbon fuels such as oil sands; further work is necessary to understand the full net implications of such prices on emissions, investment and innovation (Box 2.1).

Box 2.1: Impact of Increasing Energy Prices

The International Energy Agency (IEA) have assessed that the total additional investment cost of halving current emissions by 2050 to be in the order of $50 trillion. In order to arrive at this figure they have made assumptions about the cost of different technologies over the coming decades.

Given the current stage of development and deployment of some of these technologies, for example, CCS, which has still to have operational experience of large scale facilities, the timescales involved and the uncertainties around the price of traditional fossil fuels, the price forecasts must be treated with caution. In addition the IEA takes optimistic construction costs for its nuclear scenarios, 2,100 USD/kW, when current experience – in Finland – is providing a range of 4,600 and 5,730 USD/kW.[45]

In their carbon abatement curves the IEA makes an assumption that the most expensive technologies will be those associated with CCS and those related to transport fuels. Under normal conditions these technologies have carbon abatement costs in the order of $500 per tonne of CO_2, but under technologically pessimistic costs up to $800 per tonne. This is significantly higher than the current ($32 per tonne[46]), or in fact, the highest market price for carbon dioxide.

However, it is also important to consider that higher fossil energy prices, particularly oil, will also impact upon the viability of some zero carbon technologies. According to the ETP report a $200 per tonne increase in the price of CO_2 is equivalent to an $80 per barrel increase in the price of oil. This would imply that a $200 per barrel increase in the price of oil is equivalent to $500 per tonne of Co_2. There are a number of oil experts that suggest that the price of oil could reach as high as $200 per barrel in the near future.[47] This could significantly affect the investment needs and additional cost estimates associated with decarbonisation but will also drive investment into high carbon fuels such as oil sands and coal-to-liquids. At present high fossil fuel price scenarios are not well covered in the existing models and further work is necessary to unpick their full impacts on emissions, innovation and investment.

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45 Pierre Gadonneix, CEO of EDF suggests that investment cost for building four EPR will be around €20-25 billion (De Monicault, 2008).

46 €25 per tonne (1 Euro~1.27 USD)

47 Subrahmaniyan, N., 2008 on Arjun N. Murti led report of Goldman Sachs.

Support for R&D, demonstration and deployment

There are a variety of estimates for the scale of additional support necessary for low carbon research, development, demonstration and deployment. However, significant gaps in our understanding still exist, especially with regard to adaptation innovations. Based on current estimates we suggest that over the next 10-15 years global public support should increase from current levels by a minimum of $15-$20bn per annum for research development and demonstration at least . The scale-up in required public spending is not unprecedented and is likely to be similar in both size and profile to other international challenges such as the War on Terror and the Apollo programme.

Research, development and demonstration (RD&D)

In addition to scaling up the use of existing clean technologies, significant additional investment will need to be made into new and emerging technologies which will include research, development and demonstration. A range of different estimates for the scale of additional RD&D exist (Figure 2.4). The Stern Review estimates that globally the public sector spends around $10 billion per year on energy R&D, half the level it was 25 years ago.[48]

Given the scale of the problem, The Stern Review and UNFCCC recommended a doubling of public investment in R&D[49] to a total of $20 billion per year. This requires an additional $10 billion per year over the next 15-20 years. Other studies suggest increases of between two and ten times current levels. For example, in order to stabilise at 450 ppm (not equivalent), Bosetti et al.[50] suggest global energy R&D double to $20 billion in 2020, and increase rapidly to around $70 billion in 2050 and $165 billion in 2100. Similarly, based on previous estimates of optimal levels of public energy R&D spending, Kammen and Nemet[51] suggest that US public energy R&D should increase 5 to 10 times of its current level to around $15-30 billion per year[52] between 2005 and 2015. However, this would be sufficient to stabilise CO_2 concentrations at double pre-industrial levels only.

[48] Stern, 2006; IEA, 2008a cites this number for R&D and demonstration.

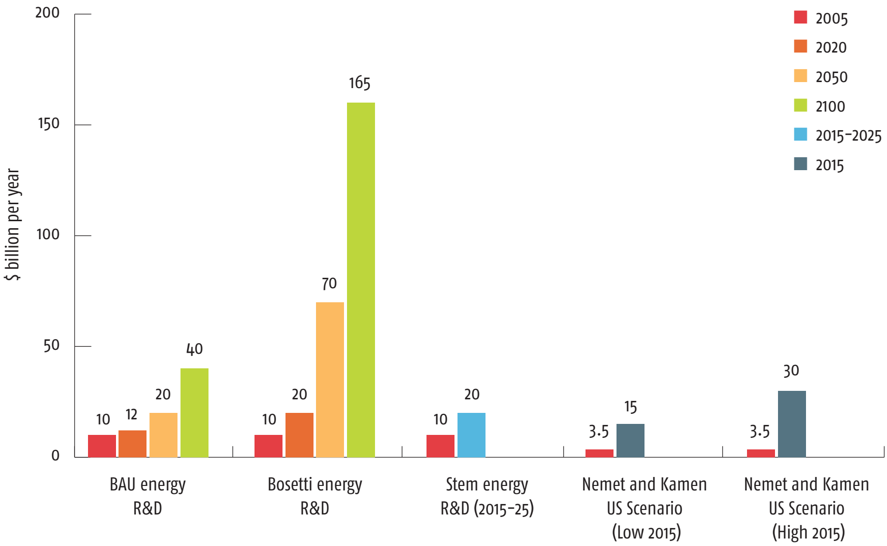
[49] Stern, 2006

[50] Bosetti et al., 2007

[51] Kammen and Nemet, 2007

[52] 2002 US dollars

Figure 2.4: Estimated scale of current and necessary global public R&D support



It is acknowledged that these estimates are highly uncertain. Taking into account the need for a wider portfolio of technologies to give adequate risk management and funding to accelerate the demonstration of critical technologies, **an additional $15-$20 billion per annum over and above the current level of $10 billion per annum for global public energy RD&D support would seem a more adequate average over the next 10 - 15 years.**

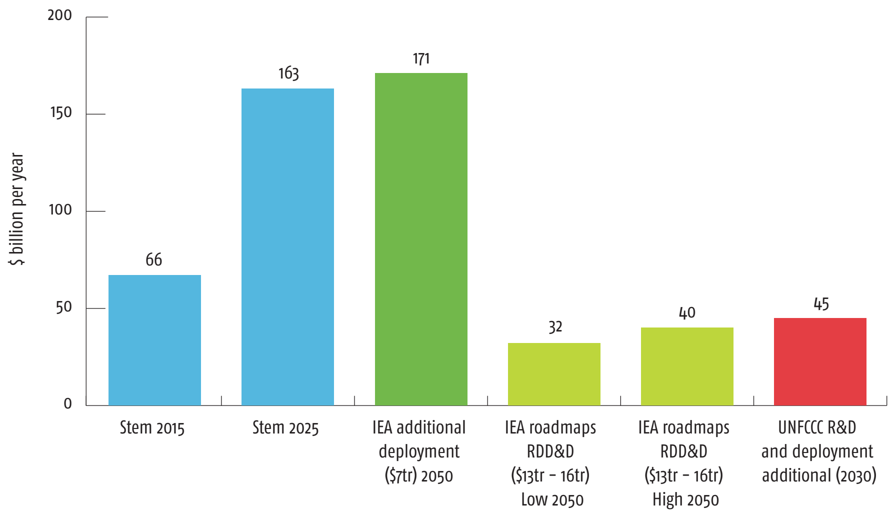
Deployment and diffusion

The Stern Review estimates that globally the public sector spends around $33 billion on deployment support. Figure 2.5 below compares various estimates of deployment support. Stern suggests an increase in public support to around $66 billion per year in 2015 and $163 billion per year in 2025 is needed; therefore, an additional $33 billion/per year in 2015 and $130 billion/per year in 2025 globally. A large proportion of this could be met through the carbon market. However, as the Stern Review targets stabilisation at 550 ppm equivalent (giving a very small probability of staying below 2°C) the balance of risk suggests that even greater levels may be required to avoid irreversible climate impacts. The UNFCCC suggested doubling both R&D and deployment by 2030. This requires $35 – 45 billion of additional R&D and deployment investment.[53]

[53] In 2030 to return to global GHG emissions to 26 GtCO2

The IEA Blue Map Scenario estimates that $7 trillion of public and private investment (Approximately $171 billion/year if distributed equally) needs to be spent between now and 2050 globally as the additional costs (i.e. above market value) of deploying new energy technologies. It does not specify a public versus private contribution to this cost. However, it calls for governments to enhance their deployment programmes. Another estimate from IEA on RDD&D investment costs of the development and roll-out of 17 key technologies is around $13-16 trillion up to 2050. This covers all R&D, demonstration and deployment costs of these key technologies as opposed to the deployment cost only. Transport has the biggest share due to the high investment cost of electric and plug-in vehicles, and hydrogen fuel cell vehicles. It accounts for about 60% of the total RDD&D investment cost (i.e. $7.6-9.2 trillion).[54] The IEA says that the need for public contribution to these costs will vary depending on the specific technology, but does not suggest a particular ratio.

Figure 2.5: Estimated scale of current and necessary global deployment support[55]



Adaptation RD&D and deployment

Our knowledge on adaptation needs is even more limited. The World Bank and Stern Review estimated the additional costs necessary for adaptation investments at $40 billion per annum, with a range of $10 – 100 billion. Using an expanded methodology the UNDP Human Development Report suggested $86 billion per year[56] by 2015. However, both the World Bank and UNDP reports do not detail what fraction

[54] IEA, 2008a, p:132

[55] Stern and UNFCCC numbers are for public sector support. IEA does not specify the level of public contribution; this is an overall investment cost.

of this cost should be spent on innovation. The UNFCCC estimates $49-171 billion will be needed in 2030 for adaptation,[57] which is in line with the World Bank and Stern estimates. Of this, it suggests approximately $3 billion will be needed for research and development (R&D) and extension activities in adapting agriculture, forestry and fisheries (AFF). Based on current trends, public sources of funding are expected to cover a large part of this additional need. **Given the limited analysis and extreme importance of adaptation technologies, we suggest immediate further research and evaluation of these issues.**

The required scale-up of public spending has been achieved before

The scale-up in required public spending is not unprecedented and is likely to be similar in both size and profile to other international challenges. However, this does not necessarily mean that it will be easy to achieve and significant effort is required by the international community to achieve success. The additional investment required is relatively modest in comparison with overall energy investment. The IEA estimates that total levels of investment on energy supply infrastructure is $20 trillion up to 2030,[58] and the existing level of fossil fuel subsidies worldwide is estimated at $150-250 billion per year.[59]

The scale-up of support is likely to be similar to meeting other major investment challenges. Nemet and Kamen also compare their estimates of energy investment in the US with other public programmes (Figure 2.6). A ten-fold expansion of federal energy R&D spending would be analogous to the Apollo Programme ($20bn in 2002 prices), while five-fold increase to War on Terror spending ($12bn).

In order to deliver the development, deployment and diffusion of low carbon technologies government support is needed to balance the risk and reward incentives faced by the private sector, and encourage further development of a diverse portfolio of these technologies. Private sector investment is the primary facilitator of technology deployment and diffusion, and therefore mobilising this type of investment is one of the keys to accelerating energy technology innovation. However, achieving this will require a significant scaling up of public sector spending to correct market failures and leverage private sector activity.

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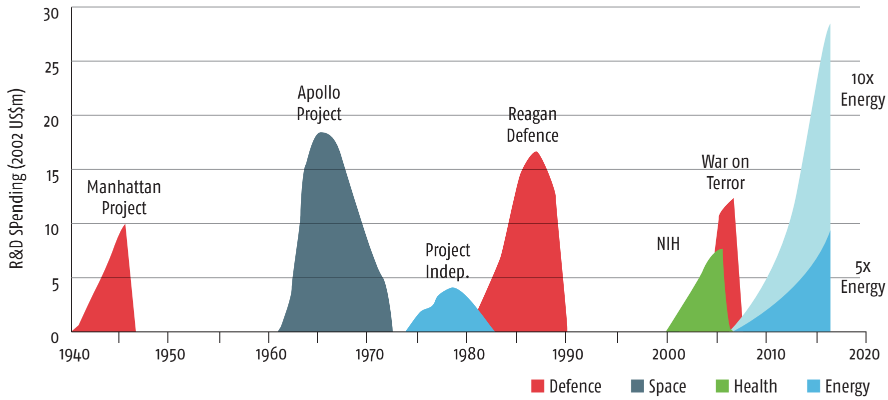
[56] World Bank, 2006; United Nations Development Programme, 2007

[57] UNFCCC, 2007b

[58] IEA, 2006 cited in Stern, 2006 Chapter 16, p:370

[59] Stern, 2006

Figure 2.6: Major US Public R&D Programmes



Source: Nemet and Kamen, 2007

Key Conclusions

- All of the major climate scenarios show that 2°C stabilisation will require rapid development and deployment of low/zero carbon technologies in both developed and developing countries;

- Supply and demand side efficiency provide about 50% of the total emissions savings by 2050 and will reduce the cost of introducing new low carbon supply options;

- A range of different supply innovations will be required but energy efficiency, renewables and CCS solutions are particularly important. Major cost reductions could be achieved by accelerating investment in transport RD&D which dominates marginal abatement costs and investment needs in more aggressive abatement scenarios. Action should also be taken to ensure that future disruptive innovations, which may not be covered by the current models, can enter the market;

- Evidence from selected scenarios shows that by acting in the immediate term to encourage deployment of low carbon technologies and shift investments, it is possible to mitigate against any unforeseen risks such as policy and technology failure, and increased climate sensitivity;

- Accelerating diffusion and R&D into new technologies will require a significant increase in both the size and direction of current investment flows. Action by both, the public and private sectors, will be key to achieving this. Based on current estimates we suggest that over the next 10-15 years global public support should increase from current levels by a minimum of $15-$20bn per annum for research development and demonstration.

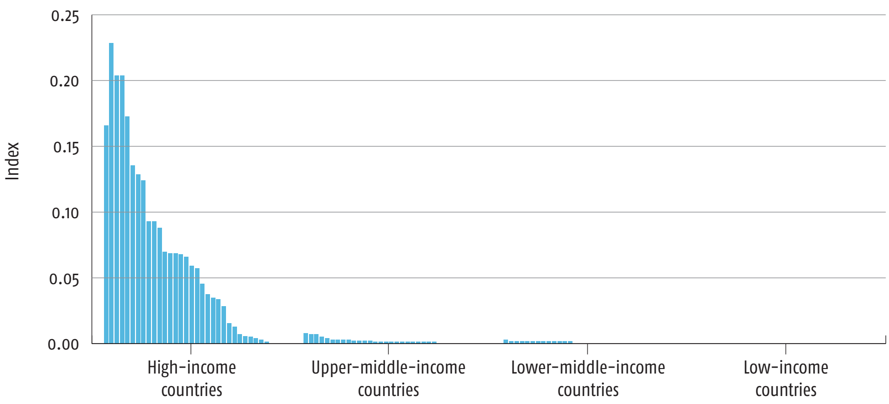
3 Innovation and diffusion in developing countries

Innovation capacity is concentrated in high income countries

Innovation and invention is overwhelmingly a high income country activity. Efforts should focus on building or strengthening adaptive and disruptive innovation capacity in developing countries, and particular attention should be paid to potential 'orphan' areas of research. Developing countries should be supported to undertake their Technology Needs Assessments (TNA) and align them with their poverty reduction strategies for effective multilateral action.

At present the global frontier in technology invention and innovation is dominated by the developed world. The number of patents and scientific journals is highly correlated with GDP per capita in high income countries, but there is very little or no activity in other income groups (Figure 3.1). Core technologies are mainly imported from developed countries. China estimates that over 85% of patents in many of its core high tech economic sectors are owned by developed country companies (see Chapter IV China case study for further details) .[60]

Figure 3.1: Scientific innovation and invention



Source: World Bank 2008b, p:3

[60] Liu, 2007

Market demand is also concentrated in high-income and transition economies. As such the private sector has a strong incentive to only develop innovations which are suitable for those markets (e.g. markets with large industrial population centres with existing power transmission and distribution infrastructure). Developing countries' (particularly the lower middle and lower income countries) lack of innovative capacity may severely limit their ability to engage in effective decarbonisation and adaptation. Similarly, lack of market incentives has led to the creation of 'orphan' areas of research, especially in relation to adaptation technologies (e.g. drought resistant crops).

As highlighted in Chapter I developing countries' ability to engage and use adaptive and disruptive innovation alongside incremental improvements is crucial. This has three important implications for innovation in developing countries:

- Firstly, creating enabling market structures and regulations which will facilitate the penetration of new technologies into the market; supporting new business models which might have a disruptive impact through the development of new technologies;

- Secondly, ensuring that countries have the capacity to adapt innovations to suit their local circumstances;

- Thirdly, ensuring that 'orphan' areas of research are covered by international action.

Disruptive innovation – New technologies can have a disruptive impact in developing countries and speed up the move to more advanced technologies (see Chapter I, particularly Figure 1.7). However, these need to be accompanied by new business models that can be implemented in developing countries. Joint projects between developed and developing countries can be useful for developing and testing different approaches. For example, initiatives such as Near-Zero Emission Coal (NZEC) project between China and UK are developing new approaches to technology and industrial cooperation. Proposed Low-Carbon Zones (LCZs)[61] in China, where large regions (above 20 million population) at different levels of development would commit to innovative low carbon development plans and be supported by focused outside assistance, could give a focus for transformational change and cooperation.

Adaptive innovation – As noted in Chapter I new and existing technologies will need to be adapted for use in different countries. This could involve factors as diverse as coping with different physical environments (e.g. hot and cold climates), different

61 For more information on Low-Carbon Zones (LCZ), see Chatham House and E3G (2008) Low Carbon Zones: A Transformational Agenda for China and Europe (forthcoming).

regulatory environments and the availability of different local skills and other resources. Innovation to adapt technologies is non-trivial and requires concerted effort and investment to be effective. For example, Integrated Gasification Combined Cycle (IGCC) clean coal technology, still remains to be demonstrated to work with varying qualities of coal, particularly lower quality coal in India.[62]

Similarly, in the biofuel sector, because of the possibility of having different feedstocks, developing country needs would be different than those of developed countries.[63] The IEA World Energy Outlook[64] suggests that transport will contribute "roughly a fifth of the increase in global emissions to 2030 in all of its three scenarios, consolidating its position as the second-largest sector for CO_2 emissions worldwide. Most of the increase in transport emissions comes from developing countries, where car ownership and freight transport are expected to grow rapidly".[65] This clearly highlights the need for investment in adaptive research which will suit developing countries' needs. It is evident that there will be other areas and sectors where the differing needs of developed and developing countries might require additional R&D and demonstration capacity to fill this gap.

'Orphan' areas of research – Agriculture remains the main livelihood of the poor in developing countries. Increased climatic stress will affect the performance of the crops, wild species, livestock and other natural resources within the agrosystems they are being managed. The Consultative Group on International Agricultural Research (CGIAR) suggests that to increase the resilience of those dependent on agriculture, serious efforts should be made to adopt stress-tolerant crop varieties and animal breeds as well as better crop management systems.[66] There are world-wide partnerships to develop climate-resilient varieties of a number of essential crops, including drought-tolerant maize, drought-escaping and waterproof rice for the tropics. In addition to extensive R&D and demonstration, strong market incentives, competent institutions, and supportive policies would quicken the pace of change and heighten the chance for success.

The need for adaptive innovation and research in 'orphan' areas emphasises the role technology needs assessments (TNAs) could play. **In order to guide action effectively at the multilateral level, it is critical that developing countries undertake TNAs to identify orphan areas of research and critical areas where adaptive capacity is needed**. Detailed guidelines for undertaking TNAs already exist but developing countries may require administrative and technical support to fully undertake them. To be effective, the TNAs should be linked with

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62 Ockwell et al., 2007

63 Barton, 2008a

64 IEA, 2007

65 IEA, 2007, p:196

66 CGIAR, 2008

poverty reduction strategy papers (PRSPs) and other development planning tools to generate low carbon development pathways. This would be a crucial input to the Copenhagen Agreement and existing aid agencies should prioritise action to assist developing countries in completing these assessments.

Moving beyond traditional concepts of technology transfer

Diffusion of new innovations is as much about the institutions, structures and organisations in a country as it is about narrow funding support to access specific technologies. Achieving this will require a broad approach to capacity building to enable developing countries to generate their own innovation systems, not just a narrow focus on technology transfer.

Chapter I emphasised the importance of countries moving beyond a narrow national competitiveness focus to capture the global public good aspects of low carbon innovation. International collaboration will be vital to achieve the necessary commercial scale for low carbon innovations. **Therefore, developing countries require support to build effective innovation systems rather than a narrow focus on technology transfer.**

Innovation in the global economy is a dynamic non-linear process involving a diverse range of different actors, both public and private. Traditional concepts of technology transfer have followed a relatively narrow approach with limited funding and capacity building support which is unlikely to transform the way technologies are diffused to developing countries.

Globally, the pace at which technology spreads between countries is accelerating. The World Bank notes that while "a new technology in the 1800s could take as long as 100 years to reach 80 percent of the world's countries, for a new technology to reach 80 percent of the world's countries now takes less than 20 years [...] Ultimately, however, what matters most for technological achievement is the speed with which technology spreads within a country" .[67] Although, the pace of internal diffusion has also increased, there is a widespread divergence across countries even between those at similar income groups.

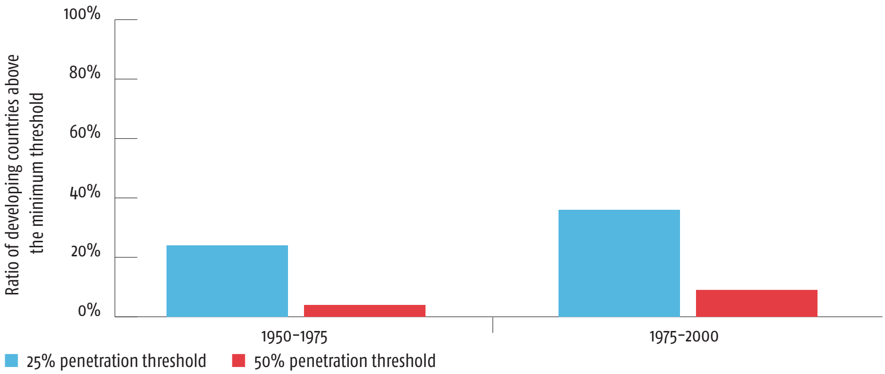
Evidence suggests that new technologies still have a very slow rate of diffusion in developing countries.[68] This means many developing countries never reach high levels of technology penetration as shown below (Figure 3.2). Between 1975 and 2000, only

[67] World Bank, 2008b, p:53

[68] World Bank, 2008b

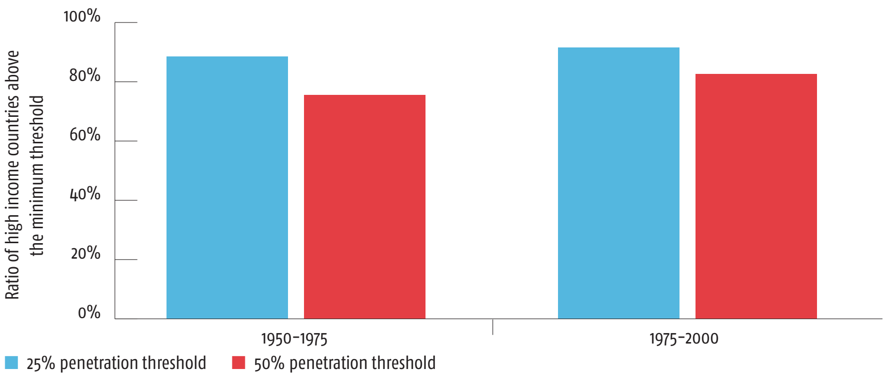
9% of developing countries who had a minimum level of technology diffusion (5%) were able to reach a 50% technology penetration threshold, compared to 82% for high income countries (Figure 3.2. and 3.3). Furthermore, between 1975 and 2000 almost all developing countries that reached a 25-50% threshold of technology diffusion were upper-middle income countries. This has two potential implications for the diffusion of low carbon technologies in developing countries. Most of the developing countries with higher technology penetration rates are upper-middle income countries. Therefore, there is a real danger that the currently low/middle-income and low-income countries with fast growing economies will become locked into carbon intensive development pathways. Secondly, despite the World Bank data, our knowledge of how diffusion operates is still relatively weak. Managing the risk around this uncertainty would emphasise doing even more to accelerate diffusion rates to hedge against policy failure.

Figure 3.2: Technology penetration rates in developing countries



Source: Adapted from World Bank, 2008b, p: 7 and 90

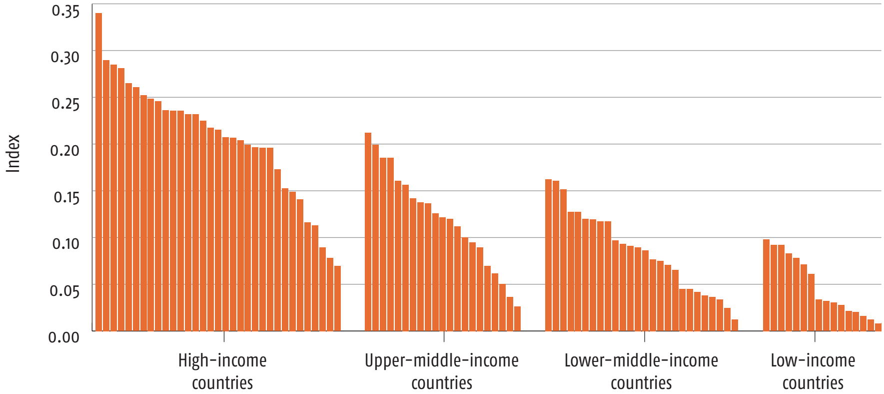
Figure 3.3: Technology penetration rates in high income countries



Source: Adapted from World Bank, 2008b, p: 7 and 90

Further research shows that the take-up of older technologies[69] depends on more than just income. Although there is a clear correlation between income and penetration of technologies, as shown in the chart below, there is considerable variation of technology penetration within each income group (Figure 3.4). For older technologies the highest utilisation levels tend to have rates that match the average of the next highest income group. On the other hand, newer technologies' (e.g. ratio of internet and personal computer users, digital mainlines) penetration was more strongly correlated with income. **Therefore, although ability to pay is clearly an important issue for technology diffusion, it may not be sufficient in isolation.**

Figure 3.4: Diffusion of older technologies in different income group countries, 2000-03



Source: Modified from World Bank, 2008b, p: 5

Although the factors that impeded the diffusion of older and newer technologies seem to differ qualitatively, the study highlights regulatory reforms as playing an important overall role and a variety of other critical system factors. It suggests, overall, increased openness to trade, FDI and Diaspora contacts have boosted technological diffusion. A more detailed look at the best and worst performing countries[70] within each income group allowed interesting comparisons when other factors were taken into account. It showed that there is a relationship between ease of doing trade and tertiary education and the diffusion of older technologies among countries (Figure 3.5; 3.6; 3.7).

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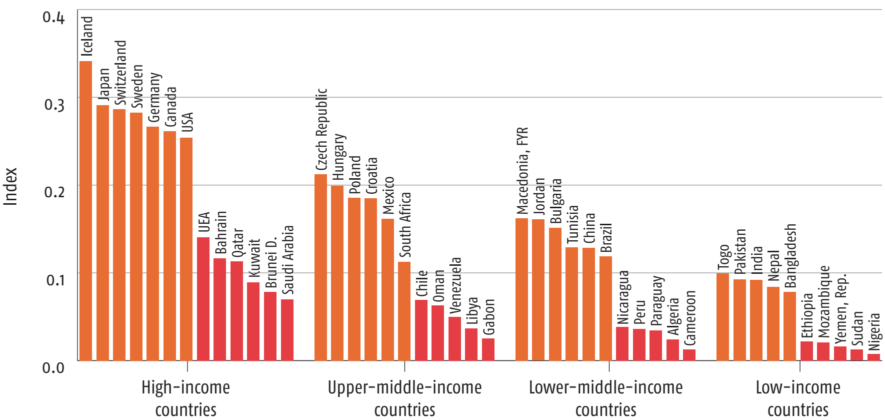
[69] World Bank technology index includes factors such as electric power consumption, agricultural machinery, international outgoing telephone traffic etc.

[70] In this particular analysis, we cropped the World Bank dataset (provided by the Global Economic Prospects team) in order to compare the five top and bottom performers in more detail. However, for high income countries, we cropped the six top and bottom countries instead of five. South Africa and Brazil were also included into the dataset (the former ranked moderately within upper-middle income country category; Brazil ranked very close to the top range) given our particular interest in the performance of major developing countries.

The World Bank emphasises that given the highly varied diffusion of older technologies in the same income groups, "the efficiency of the regulatory environment and the diffusion of basic skills within countries [seems to be] more important than incomes in determining the actual level of diffusion of these technologies".[71] In accordance with our observation, the level of diffusion tends to be higher for countries of the former Soviet bloc than for other countries at the same income levels. On the other hand, Latin American and Caribbean upper-middle and lower- middle income countries had lower levels of diffusion than other countries at similar income levels. This difference between Eastern European high performers and Latin America-Caribbean low performers has been attributed to "more equal access to education combined with greater government investment in infrastructure, which facilitated more rapid diffusion of technologies than in Latin America and the Caribbean".[72]

The analysis presented here has significant implications for the way we conceptualise technology transfer. Diffusion is as much about the institutions and organisations in a country (i.e. having a well-functioning market, legal and regulatory framework etc.) as it is about narrow funding support to access specific technologies. **Therefore, accelerating the transfer and diffusion of new and existing technologies successfully to developing countries will require focusing on system-wide approaches that enhance overall innovative capacity**. Cross-country and sectoral experiences suggest that policy measures can be effective, and success does not entirely depend on income. However, achieving this will require significant policy reform and targeted capacity-building support in critical areas.

Figure 3.5: Penetration of Old Innovations – Top and Bottom Countries (2000-03)



Source: World Bank; Note: Orange represent high performers whilst red represent low performers.

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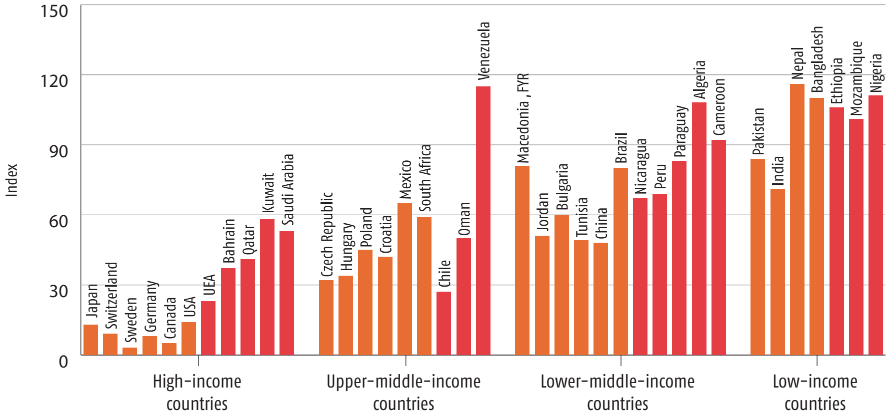
[71] World Bank, 2008b, p:70

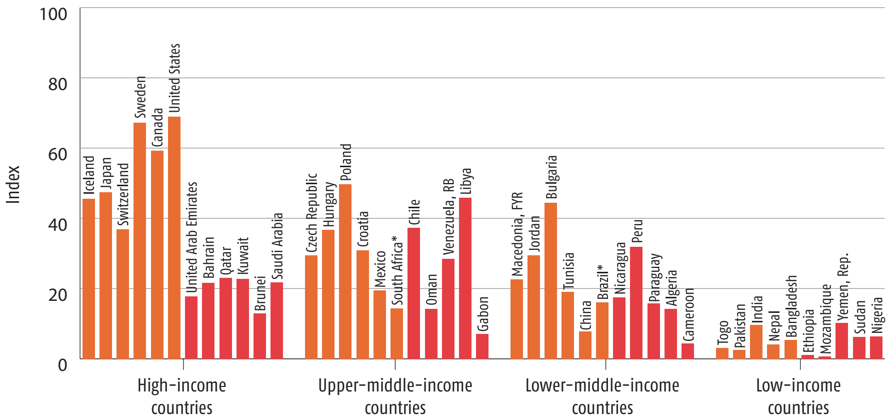
[72] Maloney, 2006 cited in World Bank, 2008b, p:70

Figure 3.6: Enabling trade index, 2008



Source: World Economic Forum, 2008

Figure 3.7: Gross tertiary education enrolment ratios, 2000



Source: World Bank, 2008d, EdStats Database

Innovation systems are dynamic, they respond to dynamic conditions such as incentives (or lack of incentives), existing capabilities, and the business and governance environment. International action should incentivise both public and private actors to deliver the three important types of innovation (i.e. disruptive, adaptive innovation and 'orphan' areas of research), which were elaborated above, to tackle the challenge.

Enhancing the capacity of developing countries to innovate will bring significant benefits to other countries by providing new markets for firms and investors and increasing the overall rate of global innovation. Major developing countries already have the ambition to build towards a knowledge-base economy. Brazil, China, India, South Africa and Malaysia – among others - have significant domestic capacity to innovate. For example, China's R&D intensity (gross R&D expenditure relative to GDP) has more than doubled between 1995 and 2005, from 0.6 to 1.3%.[73] They are expected to play a critical role in undertaking innovation in climate related areas individually but also in North-South and South-South co-operations. Similarly, commercialisation of new technologies at scale will be possible only by early deployment in major developing economies. Therefore, by acting as pathfinders for new technologies with wide application in developing countries and consistent with poverty reduction objectives, they could lay the ground for future mitigation and adaptation action.

While the role of emerging economies is very important, other developing countries should also be encouraged and supported to build their innovation systems in line with their low-carbon development plans. **The Copenhagen agreement must provide incentives for developing country innovation, cooperation and sharing, not just technology transfer.**

Key Conclusions

- Invention and innovation is mainly a high-income country activity. Support is required for the developing countries to adapt technologies to suit local circumstances, to provide incentives to invest in 'orphan' areas of research, and enable disruptive innovation takes place;

- Diffusion of new innovations is as much about the institutions, structures and organisations in a country as it is about narrow funding support to access specific technologies;

- Although income is important, it is not sufficient in isolation; policies and measures can create a radical change in the way technology is deployed and diffused in developing countries. A new approach to technology transfer is required which emphasises system-wide capacity building to enable developing countries to develop their own innovation systems;

- Developing countries might need administrative and technical support to fully undertake TNAs. To be effective the TNAs should be linked with poverty reduction strategy papers (PRSPs) and in line with their low-carbon development and adaptation plans;

- International support should create incentives for developing country innovation, cooperation and sharing.

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[73] OECD, 2007, p:25

4 Delivering innovation faster and to scale

Fundamentally low-carbon innovation will reach new markets when companies are presented with the right balance of risk and reward. These incentives are affected by a variety of market factors and action is required to both increase the size and certainty of markets and overcome other market failures to drive private investment.

While action is required to address barriers to innovation caused by R&D funding issues and IPR protection, there must also be a focus on issues related to market creation and regulation which are at least as important in driving change. Fundamentally low carbon innovation will reach new markets when companies are presented with the right balance of risk and reward.

Innovation and diffusion are affected by various market factors (Table 4.1). Market factors shape the external conditions and incentives that innovators face. IPR is also an important element shaping innovation and diffusion and this is covered in the next chapter. Together they have a significant impact on the overall incentives to engage in innovation and the speed and scale with which technologies are able to penetrate markets.

Past initiatives in other sectors have successfully addressed some of these market barriers. Government support through direct grants and purchasing has long been a key factor in driving innovations in the military and space industries. Issues with market size and certainty have also been overcome through the creation of funds to reward innovation, or through regulation and standards. Many of the lessons from these initiatives can be successfully applied to low carbon and adaptation innovations.

Table 4.1: Key Market Related Factors Affecting Innovation

Size and certainty of the market
• Total market size would affect the level of effort devoted to innovation in that area (e.g. the case of 'orphan' drugs) • Market uncertainty, such as that which surrounds the end of the Kyoto commitment period, can have strong negative incentives on innovation • Market location (e.g. in LDCs) may have additional challenges relating to the availability of supporting infrastructure, human capital etc.
Size and profile of R&D investment
• The ease with which private sector investment in innovation can be generated will be influenced by the total size and time profile of expected R&D investment. Large, lumpy projects may struggle to generate sufficient private funding
Rate of turnover
• Rate of technology turnover will affect the potential speed of diffusion from new innovations. Markets with slow turnover offer reduced gains from new product development • The rate of turnover may also affect the speed with which a new innovation becomes obsolete, affecting incentives for new technology development
Public sector engagement
• Direct public R&D plays an important role in pushing technology through it's early research stages and supporting deployment costs • Regulatory measures (e.g. standards) can favour low-carbon technologies over carbon intensive ones, and therefore provide incentives for further innovation and deployment • Government purchasing policy, especially where it has a high degree of monopsony power, would affect the incentives for innovation and diffusion
Number and profile of competitors
• Firm size might determine the level of its R&D investment. While large firms may invest more in R&D, small firms may struggle to raise capital • High levels of market concentration can increase barriers to entry and limit the ability of new disruptive technologies to penetrate the market, preventing Schumpeterian 'creative destruction'

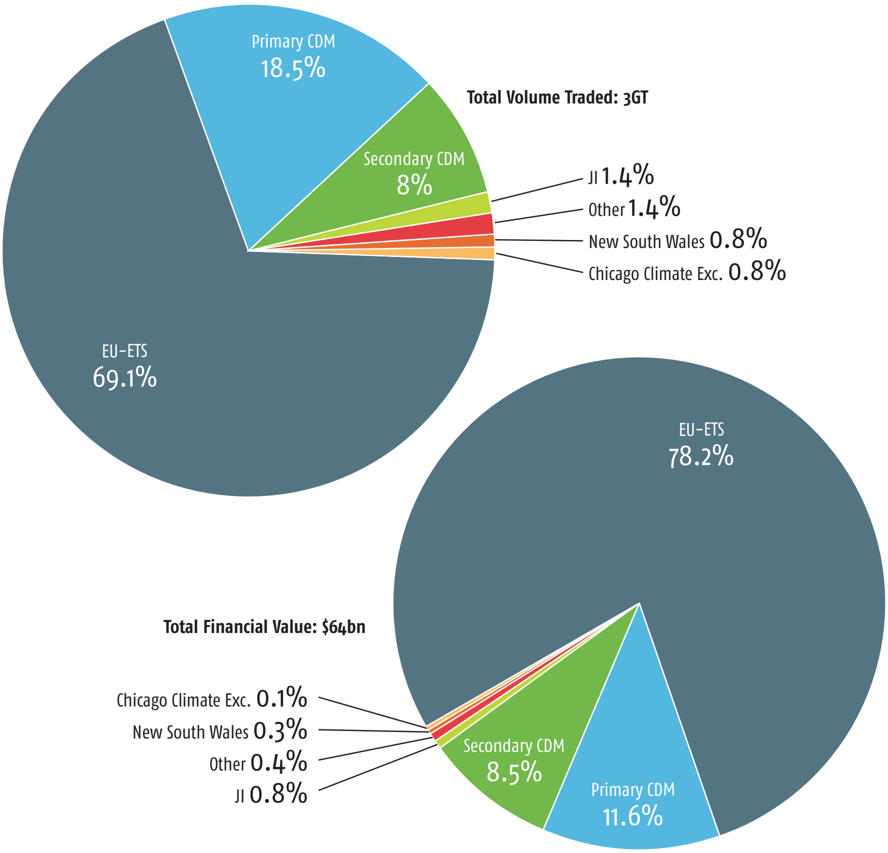
Using markets to drive innovation

Increasing the size and certainty of the global carbon market will be essential to pull technologies down the innovation chain. However, the carbon market alone will not be sufficient and so other mechanisms, such as sectoral agreements, international standards and public sector purchasing, should also be considered. In particular, lack of ability to pay may undermine incentives for private firms to invest in adaptation innovations; creating an adaptation technology market is of vital importance.

Increasing the size and certainty of markets for low carbon technologies will be vital to spur private sector activity and drive innovation forward. **The agreement of a new UNFCCC commitment period with ambitious, binding targets for mitigation in industrialised countries and an indicative target for long-term action will be key to achieving this.**

In 2007, the global carbon market was worth about $64bn, more than doubling from $31bn in 2006[74] (Figure 4.1). Early reports suggest this trend is continuing, as the market has reached $87bn through the first 9 months of 2008 and is likely to top $100bn and even reach to $116 bn by the end of the year.[75] If we are to meet the innovation challenge it will be vital that the carbon market continues to grow. This is unlikely to be a smooth process: establishing new markets and linking existing ones will always generate considerable volatility. In the first phase of EU-ETS, EU emissions allowances (EUAs) lost two thirds of their value after having soared at one time to over €30 in April 2006 (Figure 4.2). The inability to "bank" unused allowances from Phase I to Phase II contributed to making EUAs almost worthless at the close of Phase I.[76]

Figure 4.1: Carbon market at a glance, Volumes & Values in 2007



Source: World Bank, 2008a

[74] World Bank, 2008a

[75] New Carbon Finance, 2008

[76] World Bank, 2008a

Unlike the EU ETS, where the value of Phase I EUAs saw significant volatility, Certified Emissions Reduction (CER) prices within the Clean Development Mechanism (CDM) saw remarkable stability over 2006. Average CER prices for the whole year were only slightly lower than the US$11.10 per tCO_2e in the first quarter of 2006 (€8.50).[77] However, unless market certainty is provided through the signature of a successor to the Kyoto Protocol, projections suggest the value of new projects under the CDM will barely grow in 2008, halve next year, and shrink to almost zero by 2010.[78]

Figure 4.2: Spot (Phase I) and Dec'08 (Phase II) Prices for EUAs 2006-Q1'07

Source: World Bank, 2007, p:12

The need to maintain confidence and drive investment decisions as the global carbon market evolves makes political commitments to market certainty even more important. Investors are used to coping with market risk and volatility issues, but as long as carbon market decisions remain closely tied to the political cycle they will be wary of making long-term investment decisions. Thus it is crucial that a Copenhagen agreement sends a clear signal not only about the future size of the carbon market, but also makes a credible commitment that it will exist long into the future so as to ensure investors factor this into their current decisions.

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77 Ibid., p:21

78 The Economist, 2008

In developing the global carbon market it is important to learn the lessons from existing structures such as the Clean Development Mechanism (CDM). To date the CDM has initiated projects with a total traded value of $13bn and prompted investments of $59bn between 2002 and 2007 across fifty countries.[79] However, there are a number of factors that should be considered when evaluating the performance of the CDM. To-date, only 76% of the forecast number of credits have actually been issued.[80] This results from a high rejection rate for projects and an overestimation of the carbon reduction potential. The high rejection rate is significantly linked to the CDM governance structures and a failure to demonstrate additionality. Host countries, in theory, have significant leeway in defining how projects meet the dual aims of reducing emissions and delivering sustainable development benefits. However, measuring the latter often does not include quantifiable indicators.[81] This has led to significant concerns over the extent of emissions reductions, as well as sustainable development contributions, which will be achieved by the CDM. For example, the share of renewable projects has been low in the market share of certified emission reductions (CERs) compared to large scale, non-CO_2 emission reduction projects such as NO_2 and HFC-23.[82] Around 35% of CDM credits in the pipeline come from just 15 projects for industrial gases rather than renewable energy projects. These types of CDM projects have so far satisfied market demand for CERs, and they are not likely to trigger technology transfer in the early stages of technology development.[83]

Another important lesson from the CDM is that market mechanisms will not necessarily deliver benefits to the poorest countries. Private financing will flow to the areas where it is cheapest and most cost-effective to make investments. Transition economies have a significant advantage over many low-income countries owing to their higher levels of supporting infrastructure and systems (e.g. transport networks, banking facilities etc.). This has resulted in a concentration of CDM projects in transition economies such as India, China, Brazil and Mexico to the exclusion of low income countries in Africa and elsewhere (Figure 4.3). Efforts should be made in future to ensure that low income countries can gain access to, and benefit from, the flow of funds generated by carbon markets.

The development of the global carbon market will be central to pull new innovations down the innovation chain. However, the presence of other market failures and the time it will take for the global market to evolve mean that it is vital that other policies and measures are developed.

[79] UNFCCC, 2008

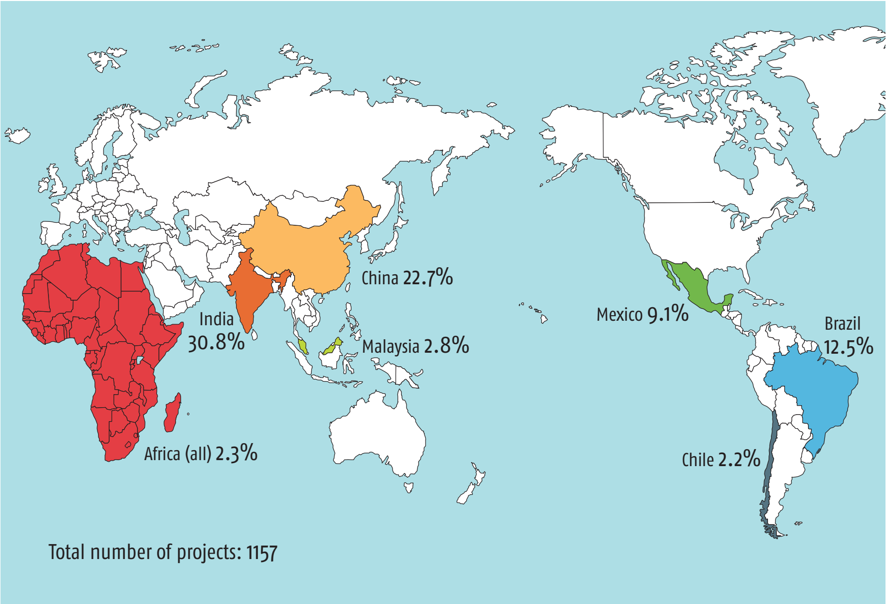
[80] Castro and Michaleowa, 2008

[81] Ibid.

[82] de Coninck et al., 2007

[83] World Business Council for Sustainable Development (WBCSD), 2007, p:9

Figure 4.3: Global Map of CDM Projects



Source: UNFCCC, 2008

While there is no one size fits all solution, there are a limited set of factors which can be considered in order to create a robust and effective low carbon innovation policy.

- Sectoral agreements: At present the global carbon market is fragmented and dominated by the EU (Figure 4.1). Even with a post-2012 agreement it will take time for a patchwork of existing national and regional initiatives for private carbon trading (as opposed to State to State trading) to be linked in order to deliver a single global market, with a single price for carbon. As this could take many years to achieve and other measures, such as sectoral agreements should also be pursued. Technology-driven sectoral agreements will be especially important as part of developing countries enhanced action commitments at Copenhagen.

- International Standards: Additional policies and measures such as international standards will also help drive innovation, especially if they set dynamic standards which increase predictably over time. Many existing energy efficiency investments are not taken up despite offering significant net positive returns. This is often a result of other market failures such as high transactions costs which carbon market expansion will not address. Well-conceived policies and regulations have proved very effective in creating markets, and hence, speeding up deployment and diffusion of new technologies.

- Public Procurement: The public sector is a vital actor in driving patterns of consumption,in sectors such as infrastructure, buildings, vehicle standards and public transportation. Public sector purchasing agreements are a vital tool to accelerate innovation in these key sectors.

Sectoral agreements and public sector purchasing can also help creating markets for adaptation technologies. Our understanding of driving investments in adaptation technologies is much more limited than in the area of mitigation. Market failures for adaptation innovation are potentially large with a lack of ability to pay in many developing countries, undermining incentives for private firms to invest in adaptation innovations. Thus public sector support through sectoral agreements, public purchasing and other measures will be vital to successfully develop markets for adaptation technologies and support direct financing through systems such as the proposed multilateral Adaptation Fund.

Creating sectoral agreements to deliver enhanced actions

Technology-driven sectoral agreements can be used to catalyze action both as part of developing countries enhanced action commitments and in globally competitive carbon intensive sectors.

The evolution of a deep and mature global carbon market will take many years. However, faster action can be catalyzed in key sectors through the use of sectoral agreements of various types. This would expand both market size and certainty, ensuring investors factor climate impacts into long-term investment decisions (see Box 4.1 for successful sectoral approach examples).

Developing countries could take individual technology-driven sectoral agreements as part of their enhanced actions under the Bali Road Map. These would cover mainly sectors for where there are no carbon finance incentives at present, e.g. zero carbon building standards. These enhanced actions would be linked to measurable, reportable and verifiable (MRV) support through funding and technology cooperation.[84] Sectoral agreements have the advantage of allowing enabling actions to be taken along the full innovation chain, so multiple barriers can be addressed.

However, it is important to note that proposals for some types of sectoral agreements are treated with extreme caution by many developing countries, which are concerned

[84] The Bali Action Plan (Decision 1/CP.13) supports "nationally appropriate mitigation actions by developing country Parties in the context of sustainable development, supported and enabled by technology, financing and capacity building, in a measurable, reportable and verifiable manner." (UNFCCC, 2007a).

that sectoral targets might mean a 'substitute' for tougher emission reduction targets for developed countries. At the Sino-Japanese bilateral talks in 2008, China expressed a view that "sectoral approaches in fighting climate change are an important method", but stopped short of a full endorsement.[85] Developing countries, particularly emerging economies such as China and India, having less energy efficient industries on average, are likely to face higher incremental cost (relative to their GDP) to decarbonise these sectors. However, many developing countries also have some of the most modern and efficient production plants compared to the OECD.

Technology focused sectoral agreements are likely to be less contentious than ones aimed at meeting emission benchmarks or standards. The technology components of sectoral enhanced actions would need to be treated in a different way to other commitments. Agreements aiming to reduce the maximum amount of carbon emissions would focus on diffusing mature technologies in high intensity sectors; in this way sectoral approaches would mirror the distributional focus of CDM projects described above. In order to provide a focus on incentivising more innovative – and by definition risky – technologies and approaches would require specific agreements based on long term analysis of country decarbonisation paths. This emphasises the need for increased capacity building support for developing low carbon development path analysis – and associated TNAs - as a basis for concluding ambitious and transformational sectoral agreements in the Copenhagen process.

Sectoral agreements could be critical to drive innovation in carbon intensive sectors (e.g. steel, cement and aluminium) where high efficiency and low carbon solutions, including CCS, need direct support for development and deployment. Heavy industry is a large source of global emissions, and IEA scenarios expect around half of emission reductions from CCS to come from these sectors in 2050.[86] Technological innovation is particularly important because these sectors are expected to grow in importance in the shift to a low carbon economy; as high efficiency building and infrastructure will require larger quantities of steel and cement. Developing countries also have very high domestic demand for these commodities as they enter their rapid urbanisation phase of development. China with 5% of global GDP (10% at PPP) is at the peak of this cycle and currently produces 50% of world cement production and 37% of global steel production, mostly for domestic use.[87]

In the cement sector, incremental sectoral agreements have the potential to increase efficiency all along the value chain from clinker to final service.[88] Similarly, in the steel sector, diffusion of best available techniques has great potential, although

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[85] Graham-Harrison, 2008

[86] IEA, 2008a

[87] van Oss (2008) and World Steel Association (2008)

[88] Tubiana, 2008.

national circumstances matter in making investment decisions (electricity price etc.).[89] However, fundamental physical processes restrict the incremental carbon reductions possible in the steel and cement sector to the order of 20% from current levels (aluminium has greater potential as it can run on zero-emission electricity); this will not be enough to offset future demand growth. In the medium term, decarbonisation of electricity use and CCS on industrial plants provides a possible solution to reduce both process and energy emissions.[90] However, more radical solutions are also in development to produce virtually zero carbon production in both sectors by changing the nature of the production process; however, industry bodies do not expect these new technologies to enter widespread use before 2030-40.[91]

To achieve the 2°C target it is critical to have faster development of low carbon technologies in the high energy using sectors. Given that the fastest growth in demand lies in developing countries much of the technological development activity should also take place in these markets. This should go beyond advanced process and energy technologies, and include demand side innovation in low carbon substitutes in the automotive, construction and chemical sectors; this could be achieved through the use of different materials or redesign of demand systems e.g. substitution of oil based chemicals for biological feedstocks; reduced material design in buildings and infrastructure.

Box 4.1: Successful sectoral approaches

Two successful examples of sectoral approaches illustrate the potential of such agreements: **Montreal Protocol's mandatory sector-led phase-out of CFCs and HCFCs and subsequent EU Directive for phasing-down HCFCs.**

The Montreal Protocol is an international treaty designed to protect the ozone layer by phasing-out ozone-depleting substances (ODS) such as CFCs and HCFCs. It managed to reach 95% of global production and consumption targets in just 20 years, and the ozone layer is on path to recover by mid-century.[92] Its mandatory sector-led approach for the phase-out of CFCs and HCFCs was supported by Technical Options Committees (TOCs) for different sectors (e.g. refrigeration and air-conditioning, foam, medical

[89] Ibid.

[90] For example, see plans for a large scale CCS demonstration plant by the European Steel Technology Platform (ESTEP) Ultra Low CO_2 Steelmaking research programme.

[91] For steel industry views on R&D see http://www.worldsteel.org/index.php?action=storypages&id=306

[92] Gonzalez, 2007

aerosols, methyl bromide, etc.). These committees comprising members from the business community, government and academia, report on the availability of CFCs and HCFCs substitutes as well as the status of transition within the different sectors. "Based upon these reports, the Parties to the Montreal Protocol determine the timetable for the phase-out of production and consumption".[93] For example, the European Union established a sector-based phase-down schedule for HCFCs under Directive EC 2037/2000. "As a sector, the fluorocarbon production industry developed both a voluntary data reporting initiative (through the Fluorocarbon Programme Panel (FPP) and, subsequently, the Alternative Fluorocarbons Environmental Assessment Study (AFEAS) as well as an initiative to jointly evaluate the environmental and toxicological aspects of alternatives to CFCs".[94]

CFC control measures created market for substitutes, and many businesses complied at no cost or at a profit (it's important to note that substitutes were already available). Meanwhile, its financial assistance component – the Multilateral Fund- was introduced to assist developing countries (Article 5 countries) to comply with the control measures of the Protocol. Financial mechanism covered incremental costs of phasing-out and acted as a tool to deliver common but differentiated responsibilities. Whilst started with a project-based approach, it has since moved to a sector-based approach to complete the CFC phase-out process.

Defining new international standards for products and energy efficiency

The carbon market will not necessarily deliver energy efficiency improvements owing to significant market failures. Setting International standards and regulation (both multilateral and plurilateral) will provide large and certain markets for innovative products and drive down costs.

Developing new international standards and regulations for energy efficiency could play a key part in creating demand to support the innovation and diffusion of more efficient end-user products. **Many energy efficiency investments are already 'economic' in a narrow sense** (i.e. offering a positive rate of return under standard economic assumptions). However, most of these investments are not taken up because

93 Stigson et al., 2008, p:22-23

94 Ibid.

of other market failures. Often energy efficiency investments have high transaction costs associated with them (e.g. the disruption involved in improving home insulation or replacing an old boiler). These additional transaction costs can prevent people making investments which would likely bring positive financial returns. Market structure can also effect energy efficiency investments. For example, landlords may have an incentive to under-invest in energy efficiency home improvements as tenants have to bear the costs of higher fuel payments. In addition energy efficiency is often not the only criteria people care about when making a purchase. Other factors such as style and performance can outweigh energy efficiency criteria leading to the selection of less efficient products (e.g. non-energy efficient lights).

The expansion of the carbon market will not affect take-up of products which are already cost-effective but suffer from other market failures. Therefore other policies and measures should be considered to expand international standards in areas such as domestic appliances, transport and buildings. Many countries already have standards in several of these areas (see Box 4.2 below). The CAFE standards for vehicles in the US and Top Runner Programme of Japan are well-known examples of environmental standards. The EU is also in the process of drafting regulations for a number of energy using products under its Eco-Design Directive. There is, however, considerable scope for these to be improved, and particularly given the global value chain of many electric/electronic equipments, an international agreement would maximise returns to scale and reduce any potential negative competitiveness impacts from having higher standards than other countries (although in many cases these will be small). Ideally these standards should have a dynamic component which requires continual improvement in efficiency, providing an incentive for continual innovation and improvement.

Box 4.2: Standards are strong policy instruments and are effectively employed in many countries domestically and internationally

EcoDesign Directive of the European Union (EU)

EcoDesign Directive (2005) of the EU aims to set out efficiency standards for a number of Energy-using-Products (EuPs). Pursuant to the Directive, the European Commission has been given the mandate to prepare a regulation as an implementing measure. The first Regulatory Committee meeting has endorsed the draft regulation concerning the power consumption of household and office electric and electronic equipment when on standby/off modes.[95] By 2020, it is expected that electricity consumption in standby/off

[95] European Commission, 2008

mode will have risen to the equivalent of total electricity consumption of Greece (i.e. 49 TWh per year). The draft regulation proposes a staged implementation with increasing efficiency over a 1-4 year period, and is expected to lead to a reduction of 35 TWh of electricity per year in the EU by 2020. Spillover effects, hence additional savings, are also expected since some equipment categories are produced for the world market to identical specifications. The initiative has been discussed with many international stakeholder representatives, including bilateral meetings with delegations of Japan, China and Korea as well as in other platforms (i.e. EU-US Summit Process, IEA Implementing Agreement). This is due to the fact that the role of foreign manufacturer countries is significant since many electric and electronic types of equipment have global value chains. For example, since 2004, China is the world's largest exporter of ICT goods.[96] Second, it is important to ensure that eco-design requirements do not become *de facto* trade barriers, and standards are negotiated bilaterally or multilaterally. International cooperation has the potential to transform global markets. One of the cooperation examples is the China Market Transformation Programme in partnership with the UK. The programme aims to develop long-term strategies to foster the development of efficient appliances at lower cost. In theory, the project will enable the Chinese government to develop a more informed approach to product policy.[97]

The Corporate Average Fuel Economy Standards (CAFE)

In response to the 1973 oil embargo and in order to reduce US dependency on foreign oil, Congress passed the Energy Policy and Conservation Act in 1975 which established CAFE Standards for passenger cars. Standards are now applicable to light trucks.[98] Numerous studies explored how these standards might have affected car manufacturer behaviour in comparison with other economic factors. For example, Greene[99] found that for three big U.S. firms that faced a binding CAFE constraint, compliance with CAFE standards had roughly twice the impact on fuel economy as did fuel prices. On the other hand, for Japanese firms that did not face the same constraint, fuel prices had only a small effect. Interestingly, "luxury European manufacturers seemed to base their fuel efficiency largely on market demand and often exceeded CAFE requirements. For these firms, neither the standards nor prices seemed to have much effect".[100]

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96 Zhang, Gang, 2007

97 IEA, 2008c

98 Bamberger, 2003

99 Greene, 1990 cited in Jaffe et al., 2002

100 Jaffe et al., 2002, p.19

Japan's Top Runner Programme

Japan's rising concerns with energy supply-demand issues led to a concerted effort to improve efficiency. Instead of setting minimum efficiency standards like many other countries, Japan followed a different strategy. Recognizing the lack of incentives to develop energy efficient products the Top Runner Programme developed a benchmarking approach of best available technology by looking at the highest efficiency performance product models already in the market. The regulation is focused solely on the supply-side, hence, imposed only on manufacturers and importers and not end-users, although large parts of the cost were passed onto the customers.

The scope of the programme is setting product performance targets - not aggregated energy savings impact which, presumably, would eventually take place. Performance targets are continuously updated. Standards and mandatory targets are negotiated in a consensus-oriented way, and with close engagement with industry. Including an effective 'name and shame' system, they were able to achieve significant results (see below).

Table 4.2: Result of Achieving Standard Values

Product category	Energy efficiency improvement (result)	Energy efficiency improvement (initial expectation)
TV receivers (TV sets using CRTs)	25.7% (FY 1997 → FY 2003)	16.4%
VCRs	73.6% (FY 1997 → FY 2003)	58.7%
Air conditioners (room air conditioners)	67.8% (FY 1997 → 2004 freezing year)	66.1%
Electric refrigerators	55.2% (FY 1998 → FY 2004)	30.5%
Electric freezers	29.6% (FY 1998 → FY 2004)	22.9%
Gasoline passenger vehicles	22.8% (FY 1995 → FY 2005)	22.8% (FY 1995 → FY 2010)
Diesel freight vehicles	21.7% (FY 1995 → FY 2005)	6.5%
Vending machines	37.3% (FY 2000 → FY 2005)	33.9%
Computers	99.1% (FY 1997 → FY 2005)	83%
Magnetic disk units	98.2% (FY 1997 → FY 2005)	78%
Fluorescent lights	35.6% (FY 1997 → FY 2005)	16.6%

Source: Top Runner Programme, 2008, p:9[101]

101 For the product categories marked with *, energy efficiency standard values are defined by the energy consumption efficiency (e.g. km/l), while those without * are by the amount of energy consumption (e.g. kWh/year). In the above table, values of the "Energy efficiency improvement" indicate the rate of improvement calculated based on each standard. (Example: If 10 km/l is developed to be 15km/l, an improvement rate is calculated as 50%.

However, the programme has been criticised by many for its drawbacks: Lack of comprehensive data on its achievements of effectiveness and cost efficiency (difficulty of measuring energy savings and penetration rates); doubts about whether the targets for standards are too loose, therefore easy to achieve. Other criticism included that the programme encourages only incremental technical improvements, while innovations receive no incentives.

Although there is no information on how much the government spent specifically on Top Runner and related activities, it is argued that the implementation of the programme did not constitute a huge burden to total public budget for energy savings activities. The overall budget for all publicly financed energy efficiency measures was €880 million in 2002 with a 20% increase from the previous year.[102] In addition to the lack of public spending figures, the costs incurred by industry for the whole process or manufacturing costs of designing, producing, distributing and selling products that meet the targets set are not publicly known.[103]

Japan's Top Runner Programme delivers significant efficiency improvements with its fast performance standard update and its close engagement with the industry leading to consensus-based targets. Nordqvist[104] suggests more scrutiny is needed for the effectiveness of target setting procedures and additional information needs to be collected and synthesized for M&E (e.g. baselines, penetration/replacement data). The challenge energy and climate security sets ahead requires targets to be ambitious, realistic and measurable.

Setting new standards for public sector procurement and innovation

The public sector is an important player in many of the key markets for mitigation and adaptation. Public sector purchasing agreements can be used to accelerate innovation and diffusion in these key sectors.

Public sector purchasing can be utilised to rapidly expand the market for low carbon products and help pull new innovations forward. It is difficult to measure the size of public procurement markets. However, available statistics[105] suggest that the amounts involved

[102] Nordqvist, 2006
[103] Ibid.
[104] Ibid.
[105] OECD, 2005b

are very large: **the ratio of government procurement markets to Gross Domestic Product is estimated to be over 15%**,[106] and worldwide public procurement to be equivalent to 80% of world merchandise and commercial services exports in 1998.

It is not just national government purchasing that is important. The UN and Regional Development Banks procurement of goods and professional services during 2000 was over US$3 billion dollars.[107] At the international level the WTO Government Procurement Agreement (GPA) sets out its international legal and institutional framework for member countries. In the GPA, a separate Article governs special and differential treatment for developing countries, technical assistance and capacity building in which the need to take into account participants' development priorities was also highlighted by the Doha Mandate.

In most of the key sectors for both climate change mitigation and adaptation the public sector is a major purchaser and user of technologies (Table 4.3). For example, public sector plays a particularly strong role in driving technology push in the building and power sector. Public sector's market pull instruments in transport and power infrastructure are also very important.

Table 4.3: Key actors on innovation chain

KEY: ● Low importance ● Moderate importance ● High importance

		Push			Pull		
		Public sector	Industry	Venture Capitalists	Public sector	Industry	Consumers
Transport	Cars	Low	High	Low	Low	High	High
	Infrastructure	Moderate	High	Moderate	High	High	Low
	Fuels	Low	High	High	Low	High	High
Power	Generation	High	High	High	Low	High	High
	Infrastructure	High	High	Moderate	High	Moderate	Moderate
Building	Residential	High	High	Moderate	Moderate	Low	High
	Commercial	High	High	Moderate	Moderate	High	Low
	Construction/ Equipment	High	High	High	Moderate	High	Low
Industry		Moderate	High	High	Low	High	Low

[106] This ratio indicates the total government expenditure, including compensation for employees and defence-related expenditure. For further detail see "The Size of Government Procurement Markets, OECD, 2002", available at http://www.oecd.org/dataoecd/34/14/1845927.pdf

[107] Environmentally and Socially Responsible Procurement Working Group. Available at: http://www.sustainableprocurement.net/home3.html

Meeting the challenges of mitigation and adaptation will require significant innovation in the public sector as well as the private sector. New institutions and procedures must be developed to achieve this including in the area of public procurement. **The agreement of new and enhanced standards for public procurement could significantly expand the size of the carbon market and strongly signal government credibility and commitment to a low carbon future.** Such actions would build on existing proposals such as the European Commission plan to promote environmental technologies through public procurement by setting performance-based specifications[108] which are currently being prepared by the European standards organisation.[109]

Innovation in public procurement will also be required to handle risks associated with expanded action on adaptation and mitigation. Without proper controls and measures there is a significant risk that corruption associated with climate change spending could increase. The OECD warns that some sectors are more exposed to risk "due to the complex nature of the works and the vast amounts of the contracts that are involved". Similarly, "international public procurement, that often involves large contracts, can be an especially lucrative target for would-be wrongdoers".[110] It is likely that public procurement around many adaptation and mitigation projects may suffer from both of these factors. Thus early investment in transparency and good governance initiatives will be important, building on existing measures such as the Extractive Industries Transparency Initiative (EITI).[111]

The need for a flexible approach

The need for specific tailored approaches to accelerate individual low carbon and climate resilient technologies in particular markets argues for a flexible approach to including these in the Copenhagen Framework. Bilateral and regional cooperation should be registered in the UNFCCC framework if they conform to agreed criteria, rather than relying on an overly centralised approach where all cooperation passes through a UN process.

The UNFCCC has an essential role to play in helping to deliver innovation and diffusion faster and to scale. It is well-placed to address many of the market failures and

[108] European Commission, 2004

[109] Such as the European Committee for Standardisation (CEN), the European Committee for Electrotechnical Standardisation (Cenelec) and the European Telecommunications Standards Institute (ETSI)

[110] OECD, 2005b

[111] For more information, visit http://eitransparency.org/

other barriers to diffusion that currently exist. However, action by the UN alone is not sufficient given the extreme complexity of these issues. **Therefore it is also crucial that action taken by the UN should supplement and encourage other simultaneous actions on a multilateral, bilateral, or regional basis.** These 'extra'-UN activities are essential to addressing all aspects of what is an increasingly complex global innovation process, because they allow for greater degree of experimentation and more opportunities for innovation and diffusion to occur.

Rather than pushing for an overly centralised approach that forces cooperation exclusively through the UN, any new framework should allow for bilateral and regional cooperation to be recognised. The UNFCCC would need to agree to criteria for recognising these initiatives. Examples of such cooperation could include:

- The continued development of national/regional carbon markets;
- Detailed design and implementation of purchasing commitments and standards;
- Multilateral cooperation non RD&D programmes;
- Mainstreaming adaptation in bilateral aid;
- Technology Needs Assessments;
- Regional cooperation on IPR and licensing;
- Environmental Goods and Services Agreements to address tariff issues.

The need for rapid action to shift towards a low carbon economy argues for a flexible and diverse set of cooperation instruments, which overtime will become more standardised as successful models are copied and other approaches scaled back. The Copenhagen Framework must encourage such diversity while maintaining clear criteria for monitoring and assessing success, and ensuring fair treatment for all Parties.

Key Conclusions

- Innovation and diffusion is affected by a variety of market factors. Increasing the size and certainty of the global carbon market will be essential to pull technologies down the innovation chain. However, the carbon market alone will not be sufficient and so other mechanisms should also be considered;
- Technology-focused sectoral agreements can be used to catalyze action as part of developing countries enhanced action commitments, but will need to be designed to incentivise innovation. There is a particular need for enhanced international

cooperation with developing countries to develop new low carbon technologies in carbon intensive sectors such as steel, cement and chemicals;

- The carbon market will not necessarily deliver energy efficiency improvements as many of these investments are already ‘economic’. International standards are therefore required to drive innovation and diffusion for more efficient products;

- The public sector is an important player in many of the key markets for mitigation and adaptation. Public sector purchasing agreements can be used to accelerate innovation and diffusion in these key sectors;

- There should be a flexible approach within the UNFCCC framework allowing for bilateral and regional cooperation to be “registered” if they conform to a certain criteria, rather than having all cooperation passing through a UN process.

5 Intellectual Property Rights and competitiveness – a new balance to protect and share innovation

Reframing the politics and policy of IPR

In global climate change negotiations, IPR has become a lightning rod for wider competitiveness debates. Therefore, a failure to tackle IPR and competitiveness issues will potentially limit innovation and diffusion and potentially poison the international climate negotiations. It is important to ensure that there is a correct balance between protecting IPR and ensuring rapid diffusion of new technology to mitigate and adapt to climate change.

As noted in the previous chapter many different barriers exist around innovation and diffusion including: infrastructural constraints, capital shortfall, unstable investment conditions and low absorptive capacities. But none elicit the level of emotion and polarisation like issues around IPR. For the proponents of a patents-based innovation system, IPRs are the bedrock of societal innovation and the propeller of speedy diffusion. Others question the market distortions created by monopolistic rights accrued to patent-holders, especially when the knowledge or know-how is essential for promoting public policy goals like public health, food security as well as climate change.

However, above all, the hard time-constraint that the urgency around climate action dictates (more stringent than other global public goods such as health, food security or even national security) provides an imperative to rebalance the politics and policy around IPR and climate change. **A failure to tackle IPR and competitiveness issues will limit innovation and diffusion and potentially poison the international climate negotiations.**

In a knowledge-driven global economy, IPR is also increasingly associated with competitive advantages – both at the firm level and from national perspectives. In international negotiations on climate-related technology transfer, IPR is often cited by developing countries as the prime barrier to their access to key technologies and know-how. On the other side, developed countries emphasise their tied hands as it is often their companies, not their governments, who hold patents. Some also cite concerns over IPR infringement and theft that has led to a degree of corporate scepticism over rapid technology transfer to developing countries.

None of these arguments are new. They have been played out in different fora over the past decade, ever since the Trade-related Aspects of Intellectual Property Rights (TRIPS) became part of the single undertaking at the World Trade Negotiations. In global climate discussions, IPR has also become a lightning rod for wider competitiveness debates. Climate technologies and systems will provide significant high value-added industries to the countries that gain a comparative advantage in their development and production. However, the desire to secure these benefits should not prevent action to fully capture and diffuse the global public good benefits which these innovations will provide.

As mentioned in Chapter IV, we think IPR is an important element shaping the innovation and diffusion of technologies. Technology specific IPR factors reflect the inherent characteristics of different types of innovations, and can limit or enhance the diffusion of low carbon technologies (Table 5.1).

Table 5.1 Key technology specific factors shaping the importance of IPR

Ratio of R&D to total cost
As the ratio of R&D cost to total cost rises the importance of IPR protection also rises. This could limit development and diffusion of technologies to countries that are perceived as having weak IPR protection
Ease of IPR enforcement
Certain types of patents (e.g. method patents) are harder to enforce than others. This would influence how effective/useful patents are going to be in capturing returns to investment
Patent application standards and processes
Different standards and application processes might pose an impediment to further innovation and diffusion due to cost and length of time required for approval. Patent application standards are also crucial for determining the ability of holders to defend patents against breaches
Ease of copying
Access to the underlying knowledge is a key component for 'reverse-engineering'. For some technologies this will be easier than others, potentially reducing the incentives to innovate in the first place
Patent thickets
Some technologies require multiple patents. These 'patent thickets' may require cooperation from many different actors in order to successfully innovate, and can act as a barrier to diffusion
Tacit knowledge
Most advanced technologies involve a degree of tacit knowledge. This can act as a barrier to diffusion and further development even in situations where formal licensing agreements exist

There are also other significant market failures associated with global innovation. The global public good nature of basic and applied research means that further funding, both multilateral and unilateral, will be required to capture these benefits and push technologies down the innovation chain. It will be important to ensure that there is a correct balance between protecting IPR to ensure innovators can earn a fair return on their investment while also ensuring rapid diffusion of new technology to where it is most needed.

Patent ownership in a globalising world

Globalisation has led to a rise in cross-border ownership of intellectual property, increasing the role of multilateral action to ensure effective regulation. International cooperation in co-invention is also increasing. The vast majority of patents are held by private firms.

There has been a sharp rise in the globalisation of scientific and technological activities, including research. Cross-border ownership of inventions has increased, on average, from 13.7 to 15.7% of total patent applications filed under the Patent Cooperation Treaty (PCT)[112] between 1993-1995 and 2003-2005, respectively. The creation of alliances (to obtain synergies and complementarities) and the search for new knowledge competencies helped to drive this phenomenon.[113] Foreign ownership of domestic patents expresses the extent to which foreign firms control domestic inventions. This has increased by 50% between the start of the 1990s and the early 2000s; reflecting the increasing rate of multinational companies locating R&D labs in a country different from that of their headquarters.[114] For example, Philips invested $50 million in R&D in China and had 15 R&D labs in 2004.[115]

International co-operation is a particular aspect of the globalisation of research activities. It is expressed through the share of patents involving inventors with different countries of residence. The world share of patents involving international co-inventions increased from 5.8% in the mid-1990s to more than 7% in 2003-05 (Figure 5.1).[116] At the country level, for example, in Chinese Taipei, more than 50% of patents were invented with a foreign co-inventor. The OECD suggests that “on average, small and less developed countries engage more actively in inter-national collaboration, reflecting their need to over-come limitations due to the size of internal markets and/or a lack of necessary infrastructure to develop technology”.[117]

The vast majority of patents are currently held by private firms with lesser shares for both universities and governments (Figure 5.2). On average, nearly 80% of patents were owned by the business enterprise sector over 2003-2005.

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[112] OECD, 2008a; OECD explains this as the advent of global value chains, differences in R&D costs, increased flexibility in handling cross-border R&D projects (owing to ICT), and major policy changes (such as stronger intellectual property rights or the tax treatment of R&D) have all favoured this trend. (OECD, 2007).

[113] Ibid.

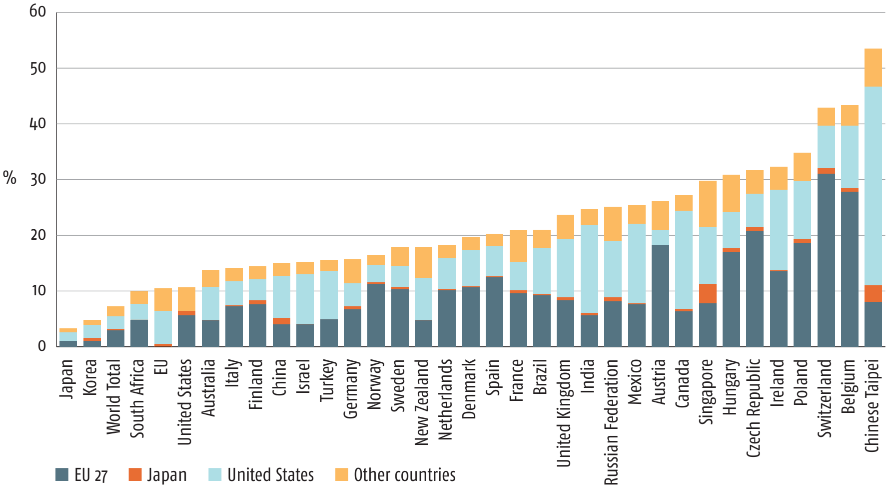
[114] OECD, 2007

[115] Philips, 2005

[116] OECD, 2008a, p:30

[117] Ibid.

Figure 5.1: Share of patents with foreign co-inventors, 2003-05



Source: OECD, 2008b

Note: Share of PCT filings with at least one foreign co-inventor in total patents invented domestically. Only countries/economies with more than 300 patents over the period are included in the graph. The EU is treated as one country; intra-EU co-operation is excluded.

The interplay between financing opportunities and ownership or access to patents has been raised as a critical issue for new entrants. Venture capital is increasingly investing in renewable energy technologies. Ernst & Young's study reveals that as a proportion of global venture capital investment, low carbon technologies has grown rapidly - increasing from just 1.6% of total investment in 2003 to 11% in 2008. As of June 2008 there were 549 private venture capital backed low carbon technology companies globally with US$8.9 billion in venture capital.[118] The venture capital firms prefer to invest in start-ups with strong proprietary position; thus patents are quite important to the start-ups for attracting the capital.[119] However, as described below, the private interests of venture capital firms will not necessarily lead to optimal rates of diffusion for new technologies, and in some areas there may be incentives to strategically withhold innovations from the market.

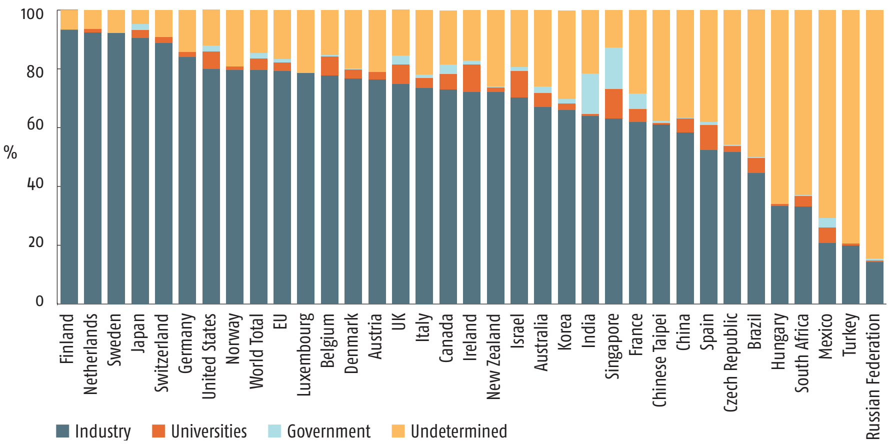
The increasingly international nature of research and patent ownership, particularly the private sector involvement, means that national government focus on protecting domestic R&D is increasingly outdated. In a global world research and innovation will flow to those places where it can most effectively be undertaken. National policies can influence this in a positive way (e.g. by offering tax incentives) but increasingly issues of competition and regulation should be dealt with at the multilateral rather than the national level.

[118] Ernst & Young's Venture Insights, 2007 cited in The Financial, 2007

[119] Barton, 2007

Climate technologies and systems will provide significant high value-added industries to the countries that gain a comparative advantage in their development and production. There is a clear – and already apparent – tension between the desire to secure these economic benefits and the needed to maximise technology diffusion to protect the global climate.

Figure 5.2: Share of patents owned by institutional sectors, 2003-05*



*Source: Adapted from OECD, 2008b. Patent applications filed under the PCT, at international phase, designating the EPO. Only countries with more than 300 PCT filings per period are included.

Note: There was a gap in patent ownership data which was quite significant in some countries, shown as 'undetermined'.

The balance between incentives for private innovation and those for maximising public benefit needs to be revisited explicitly. **An appropriate and effective "social contract" needs to be developed around low carbon and climate resilient innovation to balance public and private interests.** The tendency in the global climate negotiations to reduce this to the issue of transferring or purchasing IPR polarises the interests of Parties and prevents creative solutions emerging; this could have serious consequences for progress of the overall agreement.

IPR issues for low carbon innovation vary massively across technologies

Most views on the extent to which IPR is a barrier to low carbon technology diffusion across the range of key technologies are guided by anecdote and assumption, rather than evidence. The implications of IPR seem to vary massively across different technologies. Different business models and regulatory tools will be needed to drive innovation and diffusion depending on the significance of IPR.

Research carried out for this report showed that there are very few well founded empirical studies examining the role of IPR in the diffusion of particular low carbon technologies. Extensive interviews with technology experts and companies in key low carbon sectors showed that most views were guided by anecdote and assumption, rather than evidence. Therefore, there is currently no sound basis for any definitive statements that IPR is – or is not – a barrier to low carbon technology diffusion across the range of key technologies. Primary research is still ongoing to provide better evidence in some low carbon sectors.

In a patent-driven innovation system, the implications of IPR protection vary depending on the sector and the specific technology. For pharmaceuticals and entertainment, IPR is absolutely central to the industry's business models as a single patent or copyright represents the lion's share of benefits associated with the provision a good or service (e.g. the patent for a new drug or copyrights in the case of music recording), not least because the marginal cost of reproduction is low. However, in other sectors the importance of IPR may be limited either through the ease of reverse engineering processes (for example in the IT sector) or because competitive advantage is concentrated in tacit knowledge associated with its production. A final case is where a large number of small patents are used in a process, often referred to as a 'patent thicket'. Where a single company holds the majority of the patents this can create significant access issues.

In preliminary research a number of experts summarised the respective role of IP for a number of individual sectors in ways detailed below:

Pharmaceutical:[120]
- Patents core to the business model; the sector makes much more extensive use of patents than other industries;
- First mover advantage;
- Many work-alike products which are not socially desirable;
- Without violating IP rights, it has been possible to move companies to more licensing (Doha/TRIPS process).

Semi-conductors:[121]
- Capital, skill and R&D intensive (particularly the layout design of integrated circuits) but very easy to copy;
- Subject to a number of patents (contrary to fine chemicals, difficult to identify the patented product);
- Companies extracted rents through know-how, not through fast diffusion of basic discoveries;

[120] Boldrin and Levine, 2005

[121] Hall and Ham, 1999 cited in Niranjan Rao, 2004

- First mover advantage;
- Clusters of patents have important bargaining role in cross-licensing (i.e. patent portfolio race); problematic in tech transfer since developing countries may not have patents to cross-licence.

Solar PV:[122]
- Possible difficulties and barriers in obtaining most advanced technologies;
- Main concern is access to publicly-funded technologies; Standards.

Wind:[123]
- Possible difficulties in obtaining the most advanced technologies;
- Anti-competitive behaviour;
- Main concern is access to publicly-funded technologies; Standards.

LED:[124]
- Patent thickets (each process in manufacturing is patented);
- High investment cost for chip manufacturing and cost of resolving IPR issues;
- Numerous cases of litigation among the manufacturers over patents.

Biomass briquettes:[125]
- IPR, although not important in this sector, created friction;
- High potential for reverse-engineering, although usually lower quality.

Hybrid:[126]
- Strict IPR, yet potential problems with imitating patented hybrid drivetrains; Further investigation needed.

IGCC:[127]
- Possible difficulties in obtaining the most advanced high tech parts/products in advanced industrial gas turbines for IGCC.

Biofuel:[128]
- Possible barriers and delays over accessing new enzymes and converter organisms;
- Sector is already globalised, therefore more likely to license (more of a royalty issue);
- Global trade barriers in this sector (anti-competitive behaviour);
- Main concern over access to publicly-funded technologies; Standards.

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[122] Barton, 2007
[123] Barton, 2007, Lewis, 2007
[124] Ockwell et al., 2007
[125] Ibid.
[126] Ibid.
[127] Ibid.
[128] Barton, 2007, p:18; Barton, 2008a

As the significance of IP differs across different sectors, it is clear that different business models and regulatory tools will be needed to drive innovation and diffusion.

Competitiveness concerns do not have to limit diffusion

Concern over loss of IPR has limited companies willingness to license new technologies in developing countries. However, while genuine risks exist, in some cases companies may also have incentives to strategically withhold technology from the market to gain a competitive advantage. Action is required to strengthen IPR protection to reward innovation while also ensuring incentives exist for rapid diffusion. Government to Government agreements can be a useful tool for achieving this.

Different countries have followed different strategies to get hold of the most advanced technologies and underlying tacit knowledge in order to increase their innovative capacity. While some middle-income countries have implemented stronger IPR regimes to encourage greater FDI flows,[129] others encouraged joint ventures to maximise technology transfer instead of FDI. For example, Japan, in the 1950s and 60s, followed a protectionist strategy regarding FDI and instead encouraged multinationals to license to domestic firms.[130] China has followed a similar strategy. The World Bank argues that, "this strategy is likely to work only if the country has sufficient market power".[131]

A widely mentioned drawback has been that companies with fear of losing control of their IPR in their joint-venture deal reserved their best technologies and transferred only older ones.[132] A case study of Korean firms and R&D institutions shows that there were cases where the private firms and even public institutions of industrialised countries refused to license environmental technologies like HFC-134a, fuel cell and IGCC.[133] Even when agreements for segmented markets have been signed when the technologies were licensed to protect the owner's share in its domestic market, there have been concerns over licensee companies breaching this agreement; this has been the case with pollution control equipment in China. These obviously increase the risk for the technology owner and reduce willingness to transfer cutting edge technologies.

Nevertheless, Harvey and Morgan[134] suggest that companies that took a proactive stance

129 World Bank, 2008b

130 Pack and Saggi, 1997 cited in World Bank, 2008b

131 Pack and Saggi, 1997 cited in World Bank, 2008b, p.122

132 OECD, 2008a

133 UNCTAD, 1997 cited in IPCC, 2000

134 Harvey and Morgan, 2007

and invested in developing strong links within China were able to protect their IPR, and expose four common myths about IPR in China (see case study in the Box 5.1 below). While there may be some legitimate concerns among companies over IPR enforcement (although as the examples below will show in many cases these may be surmountable) companies can also use patents to distort competition and engage in rent-seeking behaviour. Companies may try to strategically withhold technologies from the market in order to gain a competitive advantage or refuse to license their technologies in order to ensure they do not create future competitors for themselves.[135] This can be especially problematic in sectors where patent thickets are prevalent, and so many different pieces of IPR must be used to produce a final product. Although grants of monopoly rights increase the incentive to innovate and raises the profit from innovation, it also increases the cost of future new ideas since the latter will be built on past ideas.[136]

In addition to motivations or concerns above, our interviews with utility supplier companies showed that direct investment was considerably more profitable than licensing which was a low risk/low return activity. Therefore, it has been argued that many power sector technology suppliers only license commercially uncompetitive technologies, and transfer their advanced technologies where direct investment is possible. However, a business model based only on direct investment for new technology will lead to slow rates of diffusion owing to capacity constraints (e.g. numbers of appropriately trained staff; overall financing limits and growth plans) in those companies.

If competitiveness issues are not addressed this will significantly undermine the roll out of low carbon technologies leading to carbon lock-in. However, concerns over competitiveness can be dealt with in other ways that encourage the swift diffusion of technology. Government action can be used to ease competitiveness fears. Bilateral agreements on IPR enforcement between governments can lead to foreign companies having greater confidence to invest in 'IPR-risky' markets. Government to Government agreements can also help deal with perceived competitiveness issues as well as concerns over breaching segmented market agreements as mentioned above. The Chinese government has signed a Memorandum of Understanding (MoU) on IPR issues with a number of countries:[137]

- China-USA, MoU on the Protection of Intellectual Property in 1992 and a framework for regular consultation mechanism on IP was established in 2000. Following various roundtable discussions, in 2004, the Intellectual Property Protection Working Group of the Joint Commission of Commerce and Trade (JCCT) of China and US was set up;

[135] Clark and Paolucci, 1997a, b; The Economist, 1999a, b cited in IPCC, 2000; Shaynneran, 1996; Ockwell et al., 2007

[136] Boldrin and Levine, 2005

[137] UNESCAP, 2006

- The EU and China have also been engaged extensively on IPR issues including the establishment of a working group in the EU-China Dialogue mechanism in 2005;
- China has also established bilateral or triangular dialogues and cooperation mechanisms on IP with Japan and South Korea, which included annual meetings between the commissioners of the respective patent offices since 2001 (i.e. Trilateral Policy Dialogue Meetings).

Similarly, other countries also increasingly engage on a bilateral basis on IPR issues. India signed a MoU with Japan on IPR cooperation in early 2007.[138]

Box 5.1: Innovation, IPR and competitiveness – a case study on China

Enhancing the capacity of developing countries to innovate will bring significant benefits to other countries by providing new markets for firms and investors and increasing the overall rate of global innovation. However, dealing with IPR and competitiveness issues will be key to realizing these benefits.

China provides an excellent case study for many of these issues. China's R&D intensity (gross R&D expenditure relative to GDP) has more than doubled between 1995 and 2005, from 0.6 to 1.3%.[139] Reflecting this ambition, China's Medium and Long-Term S&T plan for 2006-2020 aims to increase R&D intensity to 2% of GDP in 2010, and 2.5% by 2020. Another target of the plan is S&T and innovation to contribute to 60% of GDP growth.

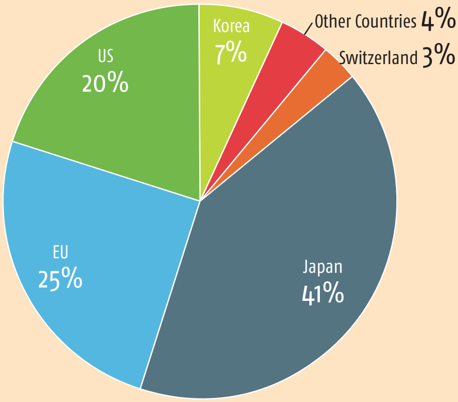
There has been a dramatic increase in the overall domestic patent applications in the last couple of decades, while foreign patent applications, though fewer in number than Chinese applications, grew even faster - more than five-fold. Japan, EU, and USA are the leading foreign patent owners in the Chinese Patent Office – SIPO (Figure 5.3). Japan is the major foreign patent owner in China with 41%, and followed by the EU (25%) and the USA (20%).

Foreign companies increasingly register their invention patents in China. Between 2000 and 2006, 76% of foreign patents granted were invention patent. On the other hand, patents granted to Chinese companies were mainly non-invention patents (i.e. utility model and design). Although total number of foreign patents granted is less than a quarter of domestic patents granted, foreign invention patents outnumber Chinese invention patents

[138] MOFCOM, 2007

[139] OECD, 2007, p:25

Figure 5.3: Patents granted by SIPO to foreign applicants, cumulative 1985-2006



in absolute terms as well (Figure 5.4). Similarly, high-tech inventions in some areas account approximately 85% of overall foreign patent applications (e.g. wireless transmission 93%, pharmaceuticals 69%). Not surprisingly, these constitute the majority of core technologies available in the country.

Currently, most core technologies are either imported or controlled by foreign companies. China is the 3rd largest global trade power, but its high-tech products independently created only account for 2% of its total foreign trade.[140] **Over 85% of patents in many of its core high tech economic sectors are owned by developed country companies.** The share of foreign ownership is significant in the following areas:

- Civil airplanes – **100%**
- Medical equipment – **mainly imported**
- Manufacturing equipment for semi-conductor, integrated circuits, laser fibre – **mainly imported**
- Petro-chemical equipment – **80%**
- Numerical controlled machine tool and advanced textile manufacturing – **70%**
- **Over 50%** core technologies of colour TV and cell phone.

China is ambitious in overcoming the challenges ahead. Its international competitiveness depends on building a strong capacity of science & technology innovation and increasing its share in developing IPR.

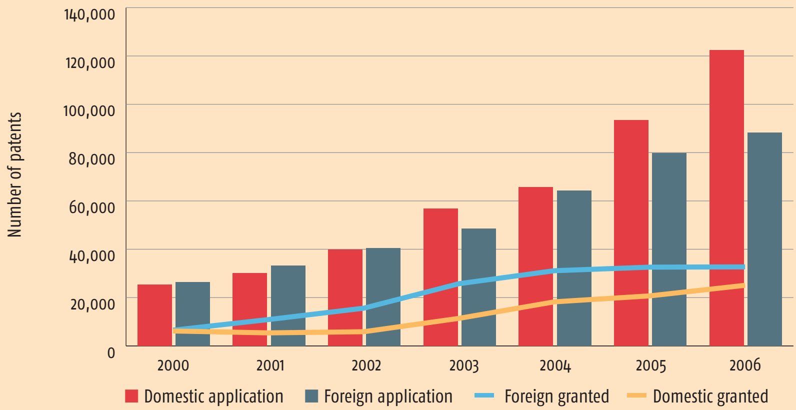
Despite these facts, there are substantial misunderstandings about the state of IPR regime and protection in China. Harvey and Morgan[141] expose four

[140] Liu, Jian, 2007

[141] Harvey and Morgan, 2007

common myths about IPR in China and discuss the real issues and problems which need to be explored further. One of the common myths is regarding the IP laws and enforcement favouring domestic interests. They argue that there is no bias in the laws or the judicial system. Cost of and time required for litigation is on par with, if not better than international standards.

Figure 5.4: Invention patents granted by SIPO, Chinese versus foreign



Source: SIPO database, 2008

However, they note that in lower courts judges have no formal training and are inexperienced in IP issues. In addition to that, there have been problems of corruption and local bias in less developed parts of China. Therefore, Chinese authorities have encouraged foreign companies to use the "federal" Supreme Court instead. In 2004, there was more patent litigation in China than in any other country of which only 2% involved foreign parties.

On the other hand, counterfeit goods remain a big issue particularly raised by European companies. Although the Chinese government is working toward increasing enforcement on this, these are still far from adequate. SIPO recognises that **"without IP protection, there could hardly be indigenous innovation**. IP protection is actually the most vital part of the whole chain of the IP system".

In summary, IP-related issues may stand in the way of rapid shift economies onto low carbon, climate resilient, development pathways. These could play themselves out in a few important ways. For patent holders, the system offers insufficient protection for the first movers, limiting their willingness to diffuse technologies. IP concerns may also encourage companies to strategically withhold key technologies from the market, especially for more risk-averse medium sized firms. On the other side of the coin, higher technological costs associated with monopolistic price-setting may limit the uptake due to the high incremental costs incurred. Patents may also raise the upfront cost of innovation activities. It goes without saying that all these different scenarios will stand in the way of rapid diffusion of low carbon technologies. Action at the multilateral level is imperative to rebalance the politics of IPR to re-shape and sharpen the incentives for scaling up both innovation and diffusion.

Creating the conditions to 'protect and share' innovations

Climate urgency requires the international community to break the deadlock between developed and developing countries over IP. Action to rebalance the current system to simultaneously strengthen protection while establishing a framework of options to support diffusion, such as the creation of segmented markets, advance purchase commitments, and compulsory licensing can provide a solution to this issue.

The stand-off between developed and developing countries on IP-related matters can be seen as a classic impasse. However, as outlined earlier, climate urgency means that the world must find a workable solution for this important issue. This report proposes to outline a set of conditions that will encourage the innovation and diffusion of technology for the international community along the principle of 'protect and share'. This centres on addressing the twin needs for strengthened IP protection for patent-holders on the one side, and the need for developing countries to access critical and much needed technologies on the other.

Strengthened government to government agreements, building on the example of Memorandums of Understanding (MoU) between China and other key economies as discussed in the preceding section, could be used to reinforce the importance of IPR protection and encourage joint-ventures. New innovations for adaptation and mitigation will require a range of different public and private actors to work together. In the private sector (especially amongst firms headquartered in OECD countries) joint-ventures on innovation are commonplace, and firms have well established practices for undertaking such activities. However, in the case of public-private ventures this can be a more difficult. Establishing what each party contributes to the venture and how the benefits (and risks of failure) will be shared out can be a costly and difficult legal process. This can be especially difficult for developing country governments who may not have strong capacity in this area.

However, despite the myriad of potential legal complexities there are a relatively small number of core models that can be used to undertake joint-ventures. For example, in the UK, following a government review,[142] a small set of model research collaboration contracts, also known as Lambert Model Agreements, were established to provide a voluntary and workable compromise for the universities and the sponsor companies around IPR ownership.[143] The international community could work to establish a framework laying out these core models to act as a basis for public-private joint-ventures on low carbon and adaptation innovations. These basic models would need to be adapted to suit each individual project, but could still dramatically reduce the transaction costs involved. In addition to establishing the framework for cooperation multilateral action should also stress the importance of protecting IPR agreements.

Despite disputes over issues like compulsory licensing at the UNFCCC, in reality all countries already employ a variety of contractual and legal structures to ensure the diffusion of beneficial innovation; especially when R&D has benefited from public financing and public goods are involved. For example, the EU has strict requirements on taking the diffusion of IPR into account when setting conditions over companies receiving State Aids subsidies. An example of how IPR is being managed in a low-carbon technology private-public partnership is the Mongstad CCS facility in Norway.[144] In 2007, the Norwegian authorities notified the intention of the Norwegian Government to invest in the company that would construct and own a test CCS facility in Mongstad. For this purpose, a company has been set up to manage the project. The State will own maximum of 80% of the Company, and StatoilHydro will participate with 20% as a shareholder. The State's share will be reduced according to the possible participation of the third parties. The Implementation Agreement notes that the partners of the Company will not develop new technology; instead they will accumulate know-how and experience in buying and testing such technology. The project will serve as a laboratory for testing and developing the technology solutions of the technology suppliers (i.e. Alstom). They will retain the ownership and marketing rights on the tested technologies. The regulator's assumption in approving the State subsidy is that equipment suppliers have an incentive to licence IPR generated on a fair basis, whereas a state funded company may have restricted access which would have been unacceptable to the public authorities.

To maintain the right balance between IPR protection and diffusion, international action should also establish mechanisms to accelerate the deployment of new innovations. It should be noted that not all of these actions will be appropriate for all technologies and so a flexible approach should be taken. However, three main mechanisms could be used to accelerate diffusion:

- Use of advance purchase commitments and pay to license agreements;

[142] Lambert Review of Business-University Collaboration of HM Treasury (Lambert, 2003)

[143] For more information visit http://www.innovation.gov.uk/lambertagreements/index.asp?lvl1=1&lvl2=0&lvl3=0&lvl4=0

[144] For more information see Norwegian Ministry of Petroleum and Energy, 2006 and EFTA Surveillance Authority, 2008

- The creation of segmented/parallel markets;
- Compulsory licensing.

Advance purchase commitments can help guarantee demand for a certain innovation/ product will be met if it meets certain defined environmental standards or criteria. These advance purchase commitment can either commit to purchase new technologies that meet pre-defined standards directly, or to pay patent holders to licence to a third party or to buy-out patents and put them in the public domain (this final option is often referred to as providing an innovation 'prize'). The most effective policy option will depend on the type of innovation required and so a combination of measures is likely to be the most effective. Advance purchase commitments can be used to encourage innovation in 'orphan' areas of research which the private sector would otherwise under-invest in. Such measures have already been used in relation to the Global Fund for HIV/AIDS, Malaria and TB as described in Box 5.2 below.

Box 5.2: The Global Fund for HIV/AIDS, Malaria and Tuberculosis

There has been considerable underinvestment in innovation for diseases (i.e. HIV/AIDS, Malaria, and Tuberculosis) prevalent in developing countries with a low ability to pay. In order to address these concerns the Global Fund was established in early 2002 as a global private-public health partnership of governments, private sector, NGOs, and technical partners.

It finances developing country grant applications on treatment, prevention and support by channelling donor funding to country partners. To date the fund has approved over $10bn of proposals making a considerable difference to both access to pharmaceuticals on the ground and the rewards available for those investing in new innovations. The governance model for the Global Fund provides for strong developing country representation which has been key to harmonise and align action

Figure 5.5: GF share of international financing for HIV/AIDS

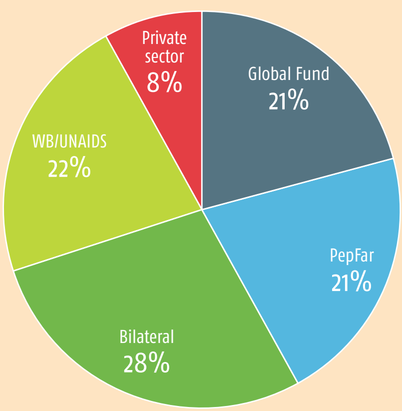


Figure 5.6: GF share of international financing for Tuberculosis

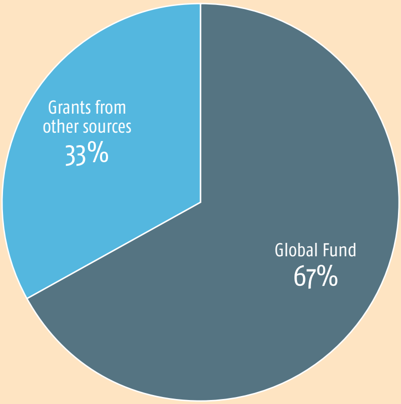
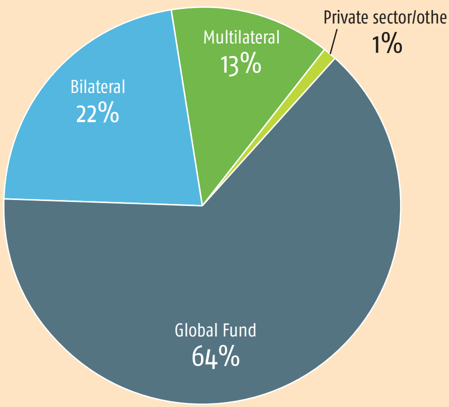


Figure 5.7: GF share of international financing for Malaria



within individual national contexts. The Fund uses a performance based funding model which has been successful at leveraging private sector action and rapidly scaling up resources in priority areas.

The Fund makes substantial contribution to international financial commitments,[145] particularly in tackling malaria and tuberculosis, which are prevalent diseases only in developing countries (Figure 5.5; 5.6; 5.7).

Between 2001 and 2006, the Global Fund has signed grant agreements worth $4 billion for 333 grants in 127 countries. In just over three years, the Global Fund has disbursed $2.26 billion to grant recipients.[146]

However, the fund faces several financial and operational problems.[147] In addition to its potential funding deficit, sources of financing are currently not diversified enough which creates more uncertainty over future funding. For instance, public finance accounted for 94% of the total amount paid between 2002 and mid-2008. In addition to that, recipient countries lack a proactive role for raising funds. This raises an important lesson for climate innovation funds where ensuring regular, sustainable financing will be critical for success.

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[145] The Global Fund to Fight AIDS, Tuberculosis and Malaria (2006)

[146] Ibid.

[147] Sidibe et al., 2006

Segmented/parallel markets work by establishing re-importation controls between different regions allowing for differentiated pricing. Establishing segmented markets between developed and low-income countries can allow patent holders to charge monopoly prices in rich economies, and thus earn a return on their investment, while allowing marginal cost pricing in developing countries ensuring rapid diffusion. For example, The European Commission adopted a regulation which supported the Doha Declaration, and prohibited re-importation of generic drugs into the EU once the export takes place (see Box 5.3 for details). For this to work it is essential that the re-importation controls are effective to limit third-party manufacturing undermining the patent holders' rights in developed country markets. For many energy technologies this may be somewhat easier to achieve than in other sectors. Small easily transported products, such as pharmaceuticals, are difficult to track and hence prevent re-importation. However, large scale energy technologies, such as carbon capture equipment, are much easier to monitor and hence enforce export controls. Segmented markets measures would also need to be reviewed over the medium-long term to ensure they were not creating a disincentive to local innovation. However, with appropriate targeting this could be an effective way to accelerate the diffusion of some key technologies.

Another important tool can be **compulsory licensing**. As described in Box 5.3 compulsory licensing compels a patent holder to grant a license to a third-party. This is not appropriate in all innovation cases but is a tool used by many private companies and governments to accelerate the diffusion of the latest technologies in many sectors beyond pharmaceuticals. This includes the enforcement of "use it or lose it agreements", whereby if the patent holder does not bring a technology to market they can be forced to licence to a third party to prevent strategically withholding key technologies. A recent example of the use of this type of compulsory licensing enabled Toyota to gain access to an important hybrid electric vehicle technology in the US (see Box 5.4 below).

Similarly, some suggested that patents may usefully be implemented as liability rules rather than as strong exclusive rights in areas where companies hold patents of different components of a technology, where technologies are needed to meet environmental standards, or where technological turnover is rapid.[148] Under this type of arrangement third parties would have the freedom to use patented invention, subject to compensation or remuneration.[149]

[148] Childs, 2008

[149] "According to Calabresi and Melamed (1972) a property rule confers the holder the right to exclude other individuals from consuming or using a good along with the power of alienating it at a chosen price. Thus a property rule prevents any non-consensual transfers of the right. By contrast, a liability rule permits non-holders to use the entitlement, even without the consent of the right holder, should it be the case by paying a price decided by the court or the legislator." Ghosh et al, 2005, p:4

Box 5.3: WTO-Doha Declaration on compulsory licensing of drugs

Compulsory licensing (CL), whereby a third party compels the patent holder to grant a license, occurs relatively frequently between private sector firms. However, the political implications of such licensing in sensitive areas, such as pharmaceuticals, are often very complex. The most important global norm of compulsory licensing is Article 31 of WTO – TRIPS agreement which defines it as uses of "patent without the authorisation of the right holder, including use by the government or third parties authorised by the government". The 2001 Doha Declaration and subsequent decisions set the conditions for the access of developing countries to cheaper generic drugs. It allows compulsory licenses to be issued in developed countries for the manufacture of patented drugs, provided they are exported to certain developing countries with public health problems.

Use of compulsory licenses can be combined with market segmentation to prevent re-importation to other markets. In the case of pharmaceuticals such segmentation allows developing countries to gain access to vital drugs at low prices, while ensuring innovators can still earn good returns on their investment in high income countries. Malaysia and Thailand recently issued CL for generic drug production to address the HIV/AIDS pandemic. The EC adopted the Regulation 816/2006 which supported the Doha Declaration, and prohibited re-importation into the EU once the export takes place.

Barton[150] argues that thanks to TRIPS flexibilities, **the price of antiretrovirals has dramatically reduced**. In low and middle-income countries, the average prices of most first-line medicines decreased by 30-64% from 2004 to 2007, making the treatment available in a wider scale with the exception of most Eastern European and Latin American countries.[151] On the other hand, prices for the second-line medicines remain high in both low and middle-income countries, where few or no pre-qualified generic alternatives are available. The most commonly used second-line treatment cost $1214 and $3306 in low and middle-income countries, respectively. The decline in the first-line medicine prices has been attributed to 'the scaling-up of treatment programmes, increased competition between a growing number of products pre-qualified by WTO, new pricing policies by pharmaceutical companies and successful negotiations between the W.J. Clinton Foundation and major generic manufacturers'.

[150] Barton, 2008b

[151] WHO, 2008

Compulsory licensing is not about giving anything way for free. Under compulsory licensing the patent holder receives compensation for granting the license. Another concern has been that this would inhibit innovation. However, in fact, there is no strong evidence suggesting that companies invest less in R&D under flexible IP regimes.[152] On the contrary, recent models trying to predict the relationship between market competition and R&D intensity suggest that all else being equal, firms' incentives to invest in R&D would be greater in oligopoly in an effort to 'escape-the-competition'.[153] Particularly in high-tech consumer markets, Oxera[154] argues that companies 'might be better off facing the market expanding competition than by seeking [monopoly] through, for example, by refusal to license an essential patent or through patent litigation".

In general developed countries are wary of advocating the use of compulsory licensing as tools for developing countries to access key technologies, though historically it has been used most frequently in the US and Canada. However there are some signs of movement by developed countries. In November 2007, the European Parliament adopted a text[155] on climate change and trade that called for action towards multilateral solutions. It has called for swift progress in WTO on the removal of tariff and non-tariff barriers to 'green' goods and services within the context of climate change. It has also called for "a study on possible amendments to the WTO Agreement on [TRIPS] in order to allow for the compulsory licensing of environmentally necessary technologies, within the framework of clear and stringent rules for the protection of intellectual property, and the strict monitoring of their implementation worldwide".

Box 5.4: Compulsory licensing case of Paice-Toyota

Courts in the US have approved considerable numbers of CL requests.[156] One of the very interesting CL cases involved Toyota-Paice patent decision. In August 2006, a court in the US granted Toyota a compulsory licence on three Paice patents which involved a hybrid electric vehicle improvement, for a royalty of $25 per automobile.[157] Because Paice, the patent owner, never practiced the patented invention, Paice fell within the definition of an NPE (non-practicing entities). NPEs are recently emerged "business entities focused solely on

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[152] Scherer, 1977 and Levin et al., 1987 cited in Fisher, 2001 both concluded that "compulsory licenses do not discourage spending on research and development and are not considered by managers significant limitations on the effectiveness of patents" (p:13).

[153] Oxera, 2007; Aghion et al., 2005.

[154] Oxera, 2007, p.4

[155] European Parliament, 2007

[156] Reichman with Hasenzahl, 2003.

[157] Paice LLC v. Toyota Motor Corporation, 2006 WL 2385139 (E.D.Tex. Aug 16, 2006) (NO. 2:04CV211DF).

acquiring under-valued patents and realizing the value of those patents through licensing and enforcement of the patent right, the right to exclude".[158] E-Bay v MercExchange case applied to NPE by the new standard approved by the Supreme Court meant that "if an NPE, as a patent owner, attempts to enforce a patent, a permanent injunction will not likely issue. Instead the court will set damages in the form of a reasonable royalty".[159] Unable to establish each of the prongs of the 4 factor test that the Supreme Court had set as a standard, the court decided in favour of Toyota. The court also noted that the contrary decision would also harm the burgeoning hybrid vehicle market. Jones argues that courts should not routinely deny NPEs permanent injunctive relief; "once a court determines that a patent is valid and infringed, denial of permanent injunctive relief should only occur in situations of the utmost exigency."

The use of compulsory licensing should not be done lightly and risks triggering trade-related retaliation. However, it remains a potentially important tool to meet the need for rapid diffusion of mitigation and adaptation innovations. Action at the international level should seek to establish the criteria for some form of automatic licensing to hasten climate diffusion. This would ensure that compulsory licensing is used sensibly and balances the needs to accelerate diffusion with ensuring incentives for future innovation remain.

Overall, a rebalancing of the system under the UNFCCC could be based on the principles of 'protect and share' where IPR would be protected from unauthorised use by strengthening implementation of the protection systems. This would be balanced with a clear framework requiring different forms of licensing and diffusion to meet the climate challenge such as parallel markets and "pay to play" agreements.

Finally, although ensuring future innovation is very important, the urgency of acting within given timeframe requires that the balance of the system must be to maximise the rate of diffusion. Any potential disincentives to technology developers could be balanced by public incentives for continued R&D and by segmented markets for new innovations. Markets must be designed to give greater incentives for continued innovation rather than reaping earnings from past inventions.

Access to international R&D funding and credit for national R&D programmes for all Parties, therefore, could be made conditional upon implementation of the agreed principles of 'protect and share'. The next chapter will lay out how the overall institutional architecture could look like to deliver the outcomes discussed.

158 Jones, 2007

159 Ibid.

Key conclusions

- A failure to tackle IPR and competitiveness issues will limit innovation and diffusion and potentially poison the international climate negotiations;

- The vast majority of patents are held by private firms. Globalisation has led to a rise in cross-border ownership increasing the role of multilateral action to ensure effective regulation. In the meanwhile, there is a clear tension between the desire to secure the national economic benefits of low carbon innovation and the need to maximise technology diffusion;

- The implications of IPR vary massively across different technologies and, at present, there is limited hard evidence on the precise impacts of IPR on diffusion. A flexible approach to IPR should therefore be taken when dealing with climate related innovations;

- Competitiveness concerns do not have to limit diffusion. Concern over loss of IPR has limited companies willingness to license new technologies in developing countries. However, while genuine risks exist, in some cases companies may also have incentives to strategically withhold technology from the market to gain a competitive advantage;

- Action is required to break the deadlock between developed and developing countries over IP. A system of 'protect and share' which provides government-to-government agreements on strengthening IP protection and a diffusion framework for the use of segmented markets, advance purchase commitments and compulsory licensing can achieve this.

6 Recommendations for action

The analysis in this report points to critical features needed in the UNFCCC system:

- A focus on increasing absolute levels of innovation and diffusion for a broad portfolio of adaptation and mitigation technologies, through outcome based strategic approaches based on mitigation pathways, and the need to manage the risks of worst case scenarios of climate responses and impacts;

- The need for action both within the UNFCCC framework and outside it to ensure healthy diversity of approaches, and encourage continued work on innovative approaches at the regional and national level;

- The importance of developing overall innovation systems for low carbon development and the use of sectoral approaches to engage all stages of the innovation chain to accelerate technology development and deployment;

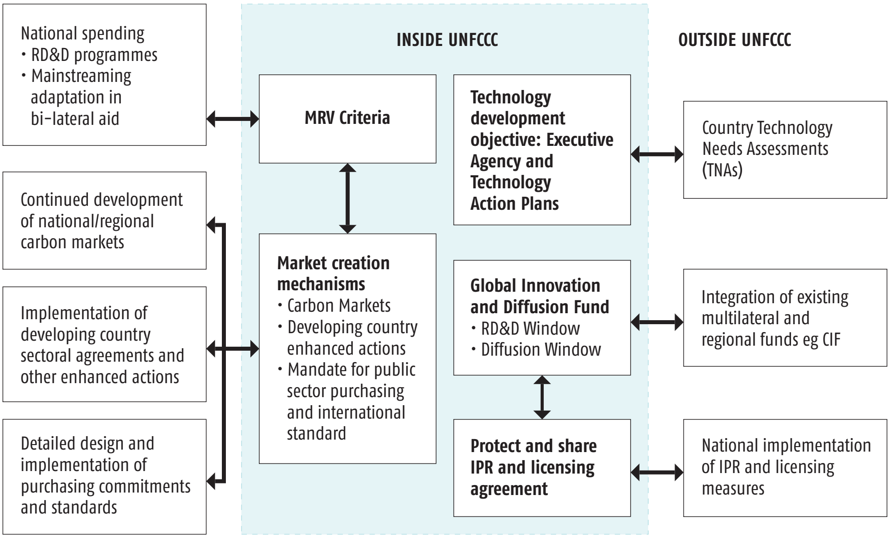
- The importance of supporting developing countries and international institutions in driving appropriate innovation in areas vital for developing economies;

- The need to explicitly rebalance the incentives for innovation and diffusion, including around the use of intellectual property rights, inside the UNFCCC.

The proposals below set out a comprehensive set of actions within the UNFCCC that builds on existing policies and measures to produce a framework for transforming innovation systems and delivering a 2°C world (Figure 6.1).

Given the weakness of current international cooperation in this area, and the lack of a competent multilateral body, the analysis also implies that new institutional structures will need to be established under the UNFCCC in order to organise and administer such an ambitious programme, especially on priority areas for international technology development and regional diffusion programmes.

Figure 6.1: Breakdown of proposed action within and outside of the UNFCCC



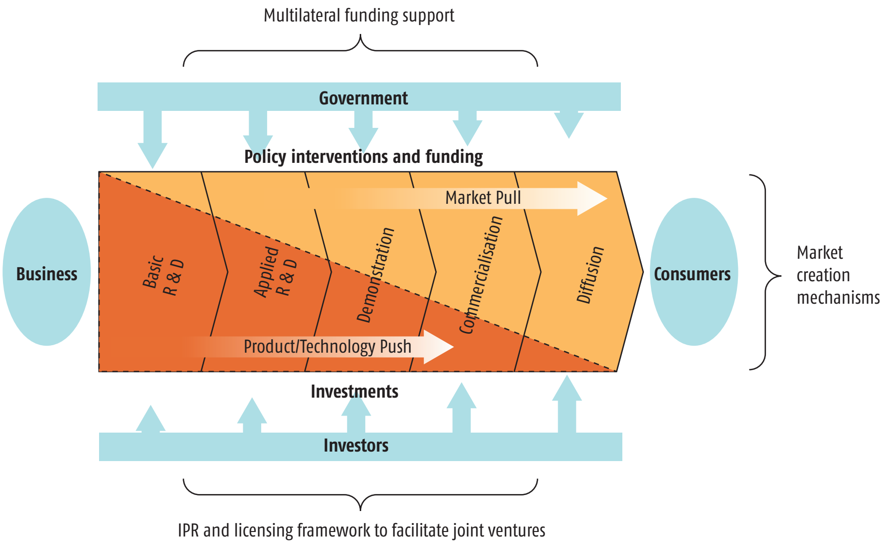
Proposals for Action inside the UNFCCC

In relation to innovation, the Copenhagen Agreement should provide five main actions: establishing a technology development objective; criteria for measurable, reportable, verifiable (MRV) action; market creation mechanisms; a new multilateral Global Innovation and Diffusion Fund; and a Protect and Share agreement for IPR and licensing.

We envisage that the Copenhagen Agreement will contain a substantial section on technology cooperation and development. Within this section we propose five main actions to be included inside the agreement: the establishment of a technology development objective and supporting action plans for priority technologies; the establishment of robust criteria for assessing measurable, reportable and verifiable (MRV) action; market creation mechanisms building on the agreement to a new ambitious commitment period; the creation of a new multilateral fund for RD&D and diffusion support; and the establishment of a framework for IPR and licensing cooperation (Figure 6.1). As Figure 6.2 illustrates, support will cover all stages of the innovation chain.

The implementation of these actions would be driven by a new technology development executive under the UNFCCC, and through new regional centres for innovation and diffusion.

Figure 6.2: Support covers all stages of the innovation chain



Source: Modified from Grubb, 2004

In order to effectively shift investment and avoid carbon lock-in, the high-level objectives for new multilateral instruments should be as follows:

- **Speed:** need to deliver product, business model and infrastructure innovation quickly enough to avoid carbon lock-in;

- **Scale:** need to ensure sufficient resources are invested in innovation in order to develop new ideas and technologies across the full range of sectors (power, heat, transport, infrastructure, buildings, industry);

- **Coverage:** need to deliver innovation in both developed and developing countries and across the full range of sectors;

- **Legitimacy:** new innovation systems have to be credible with both developed and developing country governments, civil society and the private sector.

Technology Development Objective and Action Plans

In order to drive innovation forward and establish clear priorities for action the Copenhagen Agreement should agree to a Technology Development Objective for key mitigation and adaptation technologies. This would be supported by Technology Action Plans (TAPs) for specific technologies and a Technology Development Executive to oversee action.

The Technology Development Objective would establish a set of critical climate change technologies – for both mitigation and adaptation – which must be developed to meet the goals of the agreement. The achievement of the technology development objective would be supported by a set of technology action plans and a technology development executive:

- **Technology Action Plans:** for a smaller set of technologies (perhaps up to 20 at any one time), Parties would agree a comprehensive Technology Action Plan (TAP) with a set of financing, regulatory and market creation elements to bring the technology to commercialisation inside a specific timescale;

- **Technology Development Executive:** development, implementation and monitoring of the TAPs would be devolved to an executive body, supported by expert groups. The Executive Body would be responsible for identifying the resources needed to deliver the Action Plan, and working with the Parties, private sector and research institutes to develop collaborative partnerships to deliver the critical elements. Members of the Executive would be independent specialists to ensure neutrality and provide the relevant technical experience.

Understanding of successful public and private sector programmes for technology development has greatly improved in the last decades moving policy approaches well beyond outdated caricatures of "picking winners". The core characteristics of effective innovation programmes include: clear outcome driven objectives; a balanced portfolio of technological options covering high-to-low risk options; a set of interventions tailored to each technology across the relevant parts of its innovation cycle; regular evaluation and, critically, the ability to move resources from unsuccessful to successful programmes.

The need for specific packages of interventions limits the utility of general technology funds and promotion activities. Without a top-down strategic approach it is unlikely that a bottom-up demand driven funding mechanism will produce efficient and timely innovation in the highest priority areas.

Agreeing a set of TAPs would provide a straight-forward way to scale-up and structure global technology cooperation, making it possible to divide the technology challenge into manageable pieces, and to select tools that are appropriate for the various technologies ranging from R&D to market creation. Actions could include: joint research and co-development of new technology; co-operative demonstration programmes; development of regulatory approaches; agreement on harmonised standards across markets; coordinated government purchasing and market creation incentives for new technologies.

Actions agreed under TAPs would be given priority for funding under the financial instruments agreed at Copenhagen, such as the proposed Global Innovation and Diffusion Fund outlined below. Parties would agree to co-operate and link up existing national programmes in these areas. Contributions from Developed Country Parties would need to be measurable, reportable and verifiable (see section below), although only a few parties would be expected to actively participate in each Action Plan. It is also critical that developing country parties with strong innovation capacity, such as China, India, Brazil, South Africa and Malaysia, have incentives to participate in co-developing technologies which are relevant both for their national circumstances and for diffusion to other countries at similar levels of development.

A similar global cooperative effort was established under the Montreal Protocol 20 years ago, and that effort was highly successful in phasing-out ozone depleting substances. The European Union is already applying this approach by developing Strategic Energy Technology Plans in specific areas.

Potential priority action plans

Not all important technologies will need to be addressed by a TAP. In some areas, for example, wind power, a combination of public incentives and private investment is already driving large scale innovation. Prioritisation of technologies to be addressed under TAPs would rest on three criteria:

- Potential contribution to global mitigation and adaptation; informed by technology needs assessments and national adaptation plans;
- Structural gaps in current innovation efforts e.g. missing or orphan markets, sub-critical scale R&D programmes, regulatory or business model barriers;
- Global public good nature of the technology.

Examples of critical technologies which could comply with these criteria are:

- Mitigation
    - CCS in coal power stations and cement production;
    - Concentrated solar power;
    - Large scale energy storage and distributed grid control;
    - Hybrid/highly efficient transport units and systems;
    - Advanced energy-saving construction methods;
    - Ultra-low carbon steel, cement and aluminium production.

- Adaptation
    - Advanced crop management information systems;
    - Low-energy desalination technologies;
    - Drought and salt resistant staple crop varieties.

There is also a case for having a part of the TAP portfolio dedicated to 'worst case scenario' technologies which could provide very rapid reductions of atmospheric carbon in the event that dangerous climate tipping points appear to exist at lower concentrations than currently anticipated. Examples could include advanced biomass-fired CCS plants or CO_2 air capture technology.

Administration, participation and linkages

Innovation programmes require a different structure of administration than mechanisms to diffuse and adapt existing technologies. Innovation programmes require a strong strategic focus and an ability to switch resources between programmes based on performance. Also only a small group of interested countries and actors would wish to engage in each innovation area suited to their national strengths and interests.

While the innovations generated by the TAPs would be available to all, in order to have effective programmes, participation would be limited to those with *real* resources to contribute. Priority TAPs for a particular five year time period would be decided by Parties based on a set of proposals and analysis from a designated executive body. This executive body would then be mandated to draw up the TAPs in consultation with Parties and other stakeholders, and would lead the implementation process. Progress would be reported periodically to Parties along with recommendations to scale funding up or down, revise overall strategies, request enhanced cooperation or terminate a TAP. This process would include an independent assessment of progress. This assessment could be undertaken by the Experts Group on Technology Transfer (EGTT) as part of its forward work programme, but could also be performed by an independent body.

To be effective TAPs would need to include a wide range of activity from joint R&D

to creating market pull for large scale deployment of new technologies, for example, through government procurement or regulation. Alongside research finance, the Executive Body would need to facilitate the agreement of sectoral and regulatory agreements between Parties (see section below); a strong link will, therefore, exist to other parts of the agreement. Developed countries would also be able to meet a part of their commitments through bilateral or regional activities that meet a set of negotiated criteria. This would prevent the TAP process being over-centralised and encourage more flexible forms of cooperation.

A decision would need to be taken as to whether TAPs should only finance activities in developing countries, as this may unhelpfully restrict involvement of innovative firms from developed countries. Innovations produced under TAPs would be subject to an open IPR regime aiming to maximise diffusion potential. This will be consistent with the broader approach to IPR agreed in the Copenhagen agreement.

TAPs would not be the only mechanisms for stimulating innovation and technology development in the Copenhagen agreement; they would provide a focused instrument for ensuring that innovation in the most critical areas of mitigation and adaptation of interest to the majority of Parties actually happens.

A process to develop technology action plans

Development of the TAPs would take time to complete. As a first step the general approach should be discussed at COP-14 in Poznan. COP-15 in Copenhagen could then decide which Action Plans to develop, agree the overarching rules and appoint the Technology Development Executive to oversee implementation. An initial set of TAPs could be developed immediately after Copenhagen for approval at COP-16; most others would be approved at COP-17.

Implementation of TAPs should begin as soon as the finance is available, utilizing existing mechanisms in the Global Environment Facility (GEF) and other funding vehicles.

Establishing Measurable Reportable and Verifiable (MRV) Criteria

Establishing MRV criteria will be essential to ensure countries can register actions for innovation and diffusion support as part of their overall commitment to the UNFCCC.

As outlined in the Bali Action Plan (Decision -/CP.13) there are two interlinked sides to assessing measurable, reportable and verifiable (MRV) action: the first being to

MRV nationally appropriate mitigation actions by developing countries; the second being to MRV technology, financing and capacity building support by developed countries.[160] The recommendations in this report only focus on the second aspect of the MRV debate, but we recognise that for a successful agreement in Copenhagen robust MRV criteria will be required for developing country enhanced actions as well.

The MRV criteria should set out the conditions under which national R&D and development spending by developed countries would qualify as a contribution to their UNFCCC commitments on technology, financing and capacity building support. These conditions would need to be carefully negotiated but could contain the following main elements:

- **Additionality:** Evidence showing that support is over and above existing ODA or national R&D spending;

- **Reciprocity**: National RD&D programmes in low carbon technologies should be open to researchers and companies from all countries, under fair conditions, as long as reciprocal access is given to their equivalent programmes.

- **Clear developing country benefit:** Demonstrable link to a developing country's low carbon development plan. This could include factors such as joint-demonstration of new technologies in developing countries, including developing country governments or research institutes as partners in the project; or adapting technologies to meet local circumstances in developing countries;

- **Increasing access to new technology:** Using public financing to ensure that intellectual property associated with new products and processes is freely available in the public domain, or to significantly lower the cost of global production;

- **Increasing developing country capacity to innovate and adapt:** Using public financing to enhance developing country capacity to use and develop new climate related innovations and to adapt to climate impacts;

- **Climate proofing development assistance:** Additional investments to adapt current ODA to provide resilience to climate impacts (in this case only the additional portion of spending would count for the purposes of MRV support).

In addition, MRV criteria should also be established in relation to the new Global Innovation and Diffusion Fund outlined below, and the Adaptation Fund. This would provide a system for assessing and monitoring developed country contributions and reporting back on progress.

[160] UNFCCC, 2007a

Work on establishing these criteria should begin immediately with a view to concluding this process at Copenhagen in December 2009. The Technology Development Executive, as described above, should be given responsibility for implementing the criteria. Developed countries would be expected to make regular submissions to the Executive on initiatives they are supporting which meet the MRV criteria. The Executive would be responsible for verifying these submissions and providing an annual report to the Conference of Parties on progress.

Establishing MRV criteria in this way would provide a strong incentive for developed countries to ensure that national actions on climate innovation are linked to TAPs with clear developing country benefits. This would allow bilateral programmes such as the UK-China NZEC to gain formal recognition within the UNFCCC process and encourage similar partnership programmes to be developed (Box 6.1).

Box 6.1: UK-China Near-Zero Emissions Coal Project (NZEC)

The NZEC (Near-Zero Emissions Coal) initiative is a key part of the EU-China Partnership Agreement on Climate Change established at the EU-China Summit in 2005. At the Summit the EU and China committed to "develop and demonstrate in China and the EU advanced, near-zero emissions coal technology through carbon capture and storage – CCS".[161] The UK-China bilateral initiative was developed to support the wider agreement. It is carried out as a partnership between UK government departments, DEFRA and BERR, and the Chinese Ministry of Science and Technology (MOST).

The joint UK-China NZEC project aims to have a CCS demonstration plant constructed and operational in China by 2014, with three key phases:

- Phase 1 – Explore options for CCS demonstration and build capacity in China (due to be completed in Autumn 2009);
- Phase 2 – Detailed design of identified projects (due to be completed by 2011-12);
- Phase 3 – Construction of a demonstration plant (by 2014);
- Phase 1 of the project is underway. The UK government has committed £ 3.5 million for Phase I.

[161] RAPID, 2005

Knowledge sharing with other CCS initiatives is a key activity of NZEC, including close cooperation with the COACH project (Cooperation Action within CCS China-EU) supported by the European Commission.

Source: http://www.nzec.info/en/what-is-nzec/

http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/05/298

Market creation for low carbon technologies

Market creation mechanisms should build on the agreement of a new UNFCCC commitment period and should also include sectoral agreements for developing country enhanced actions, international standards agreements, and public sector purchasing commitments.

Increasing the size and certainty of markets for low carbon technologies will be vital to spur private sector activity and pull technologies through the innovation chain. The agreement of a new UNFCCC commitment period with ambitious, binding targets for mitigation in industrialised countries will be core to achieving this.

In addition, developing country enhanced actions (e.g. specific sustainable development policies and measures or sectoral agreements) would create global markets for low carbon technologies in key industries. Achievement of these enhanced actions would be linked to the TAPs and MRV support from developed countries.

International standards agreements could play a key part in creating demand to support the roll-out of more efficient end-user products. Although many national and regional initiatives already exist current measures do not go far enough. Action at the multilateral level would provide increased incentives for companies to invest in meeting these standards. A large number of energy efficiency savings can be made, but non-market barriers (such as high transaction costs) limit take-up. A set of core dynamic international standards in each of these sectors should be developed to drive energy efficiency improvements over time.

However, developing and agreeing such standards would be a lengthy and technical process, and thus, if conducted within the UNFCCC, should be done through technical panels such as the Technology & Economic Assessment Panel (TEAP) of the Montreal Protocol. Action between now and Copenhagen should focus on establishing the sectors for which international standards would be developed and the country groupings to which they should be applied, along with the negotiating body and process to conclude negotiations on the specific standards. Priority areas for international standards include:

- Domestic appliances;
- Lighting (public, domestic and office);
- Car and aviation fuel efficiency;
- Air conditioning units;
- Buildings thermal efficiency;
- Solid fuel small combustion installations.[162]

We recommend that these standards should apply to all Annex I countries and to developing countries on a voluntary basis as part of their enhanced actions. Developing countries could undertake to meet the agreed standards within a designated time period in return for MRV support. The standards should be dynamic with an expectation that the level of efficiency required should be automatically updated over time. If it is not possible to establish a set of technical panels under the UNFCCC, an outside body such as the International Standards Organisation (ISO) could be tasked to lead the design and implementation of standards, reporting progress annually to the COP.

As described in Chapter IV the public sector is a major player in many of the markets critical for tackling climate change; public sector purchasing could have a significant impact on market creation in these areas. We recommend the formation of public sector purchasing commitments within the UNFCCC to accelerate the diffusion of mitigation and adaptation technologies and increase the rewards for innovation. Alternatively, the UNFCCC could establish principles for public purchasing agreements which could be agreed by sub-groups of countries willing to take on these disciplines (as already occurs in the WTO plurilateral agreement on public purchasing).

The Global Innovation and Diffusion Fund

A new multilateral fund should be established to implement technology action plans (TAPs). The fund should have two windows of operation to increase both research, development and demonstration (RD&D), and diffusion of new technology. While the RD&D Window would finance both adaptation and mitigation technologies, the Diffusion Window would only support the diffusion of mitigation technologies. We envisage that the proposed Adaptation Fund would cover the diffusion of adaptation technologies.

[162] For a complete list of priority areas of the Eco-design of Energy Using Products Directive of the European Commission, visit http://ec.europa.eu/energy/demand/legislation/doc/issues_to_be_studied.pdf

In order to implement the TAPs, the Copenhagen Agreement should establish a new Global Innovation and Diffusion Fund. This would be a new multilateral fund overseen by the Technology Development Executive supported by a single set of regional centres. The Global Innovation and Diffusion Fund would integrate existing activity at the multilateral level (e.g. The World Bank Climate Investment Funds) into a single mechanism under the UNFCCC. This would ensure co-ordination and legitimacy of activity while still allowing the development of path-finding initiatives in the short-term. The Fund would have two distinct windows of activity:

- **The Research, Development and Demonstration (RD&D) Window:** This would be responsible for the development of new technologies with a focus on applied research and demonstration to push new technologies down the innovation chain and adapt them for use in developing countries;

- **The Diffusion Window:** This would be responsible for wide-scale uptake of new technologies including direct financing; patent buy-outs; and capacity building to ensure developing countries have the supporting systems necessary to use new technologies.

The RD&D Window would focus on the development and demonstration of both mitigation and adaptation technologies as established by the Technology Development Objective. However, we envisage that the deployment of adaptation technologies would be covered by the new Adaptation Fund which is currently being negotiated. Therefore the Diffusion Window of the Fund would focus on mitigation technologies.

Research Development and Demonstration Window Design

The RD&D Window would grant co-financing for research, development and demonstration of adaptation and mitigation technologies, and would receive applications for joint projects. This could be done partly on a venture capital basis, providing seed money to develop technologies with follow-up support to scale-up successful projects. The RD&D Window would allow both companies and governments to apply for funding, guided by individual TAPs. The Window would seek matching funds from the applicants wherever possible. This could enable 50%[163] of total project costs to be covered from private sources.

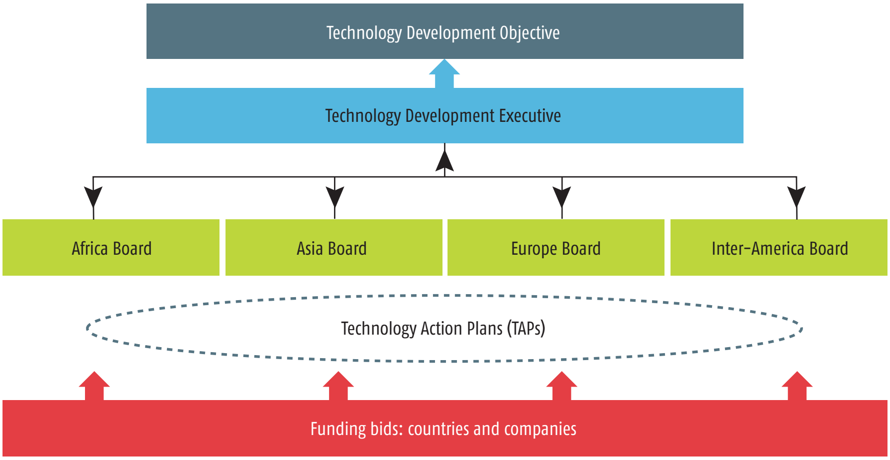
The governance system for the RD&D Fund would be overseen by the Technology Development Executive with four Regional Centres in Africa, Asia, Europe and Inter-America (see Figure 6.3 below). Regional Centres would work in close cooperation

[163] Anderson (2006) suggests perhaps 50% of a 20 year programme to support demonstration projects (£3-6 billion pa) could be levered through private investment, international offset programmes such as the Clean Development Mechanism (CDM), and sales of the actual energy produced.

with the relevant national institutes of their member countries to create local centres of excellence. This model would provide a good balance between central accountability and regional expertise, to be able to meet competing demands for different types of innovation in different markets.

For innovation funds to be effective they require clear objectives in order to identify high value projects and be able to reallocate funding if sufficient progress is not being made. The Technology Development Executive would set the central objectives in relation to the Technology Development Objective and report back on progress to the COP. The Regional Centres would be responsible for tendering contracts and assessing local needs in relation to individual country circumstances.

Figure 6.3: Governance structure of the Global R&D and Demonstration Window



In order to encourage joint-ventures and public-private partnerships, the Technology Development Executive could generate a set of voluntary model agreements applicable to domestic and international partnerships. These agreements would deal with issues such as the sharing of IPR between different parties resulting from the joint venture. A similar set of model contracts (Lambert Model Agreements) were recently developed by the UK government to encourage innovation joint-ventures and could provide an initial input into these discussions.[164] There would be a presumption that, in return for public funding of RD&D activity, new IPR should be placed in the public domain to ensure maximum diffusion.

Access to the fund would be conditional on the transparency of national R&D programmes. Countries would also have to agree to the 'Protect and Share' IPR

[164] For more information, http://www.innovation.gov.uk/lambertagreements/

framework agreement (see below) in order to access funds. An Innovation System Review would be commissioned by the Board to ensure that efforts are not duplicated.

The Technology Diffusion Window

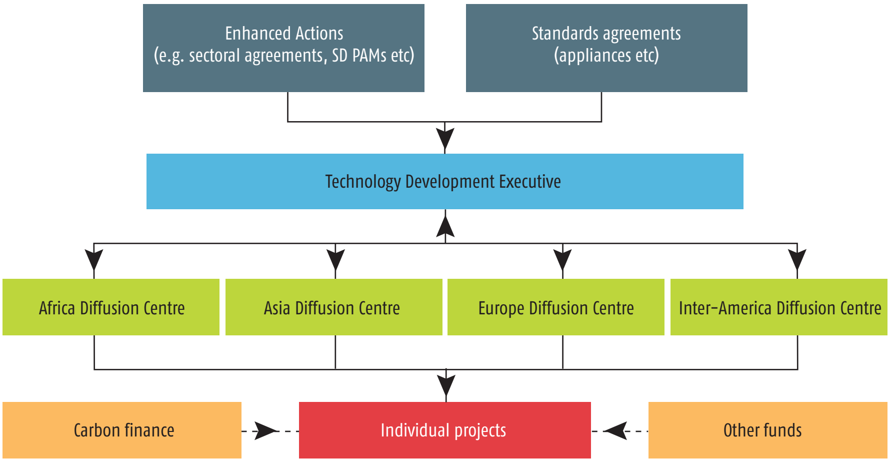
The Technology Diffusion Window of the fund would provide blended finance through a range of different instruments (e.g. direct grants, risk guarantees etc.) in order to rapidly scale up the use of existing and near market solutions. Where appropriate the Diffusion Window would also have the capacity to buy-out existing patents and place them in the public domain and establish advance purchase commitments (or prizes) for new technologies. However, as noted in previous chapters the effectiveness of such measures would depend on the specific technology and would not be appropriate in all situations. For example, patent buy-outs would be most effective for technologies where a single patent covers all of the relevant IPR and where reproduction is relatively easy and inexpensive. Advance purchase commitments and prizes would require the construction of a sufficiently robust legal framework to support the deployment of qualifying technologies. The Technology Development Executive would be responsible for identifying areas where patent buy-outs and advance purchase commitments would be a cost effective way to accelerate innovation and diffusion.

A range of domestic policy conditions are required for diffusion to occur. These include subsidy removal, standards and institutional changes. The Diffusion Window would assist with capacity building efforts to create the conditions for the rapid uptake of new technology; in order to gain access to the Fund countries would agree to reduce tariffs blocking the import of energy efficient products.

Although the operation of the Diffusion Window would be different to the RD&D Window the same basic governance structure could be used with a central Technology Development Executive and four Regional Centres. The diffusion arm of the regional centres would provide a number of different services to accelerate deployment of low carbon technologies including:

- Direct grant financing, loans and risk guarantees;
- Capacity building support;
- Standard voluntary joint-venture/licensing agreements (these could be similar to the models developed under the RD&D fund);
- Coordination with national centres of excellence.

Figure 6.4: Governance structure of the Global Technology Diffusion Window



The Technology Development Executive would need to keep track of the flow of carbon finance and other funds to determine gaps and direct its resources accordingly. The Executive would also need to track progress and best practices within developing countries, verify outputs and report on progress to the COP (Figure 6.4). To assist in this process, and to ensure real carbon savings are being delivered, countries benefiting from the Fund would have to commit to periodic market transformation reviews to evaluate progress and assist in setting future priorities for action.

Financing the Global Innovation and Diffusion Fund

To operate effectively the Global Innovation and Diffusion Fund would require significant new and additional funds. At present there is no consensus as to the precise size of the fund. However, it is clear that if we are to achieve a 2ºC stabilisation this will require a substantial increase in support. The various estimates that currently exist for energy and low carbon R&D and demonstration, suggest a 2-10 fold increase from current levels will be necessary.[165] For example, the Stern Review concluded that Government energy R&D budgets would need to double to about $20 billion, and Government support for deployment of clean technologies should double to $66 billion/year.[166] The UNFCCC estimated that additional investment in technology research and development (R&D) and deployment in energy at about $35 – 45 billion in 2030.[167] Based on current estimates we suggest that over the next 10-15 years global

[165] IEA, 2008a

[166] Stern (2006) suggests some $33 billion are spent globally each year on deploying low carbon energy sources but around half on nuclear.

[167] In 2030 to return to global GHG emissions to 26 GtCO2 (UNFCCC, 2007b)

public support should increase from current levels by a minimum of $15-$20 billion per annum for research development and demonstration. Additional direct support will also be required for diffusion although a significant share of the financing could be met through the carbon market. Further bottom-up work in this area is necessary to establish more robust estimates for total funding needs. The process of generating TAPs suggested above would be one way to achieve this.

Given the likely scale of the financing suggested by the current estimates it is clear that if this is left to a system of periodic pledges by developed countries (such as is currently used to fund the Global Environment Facility) there is a significant risk of under-provision and gaps in funding. This would have serious consequences both for delivery of the overall Technology Development Objective and the impact on developing countries meeting their individual measurable, reportable and verifiable enhanced actions.

To overcome this difficulty we would recommend that developed country payments into the fund come from an automatic mechanism such as a reserved share of the auction revenue they receive from issuing emissions permits, or a tax on bunker fuels (including aviation). This would provide an automatic replenishment facility for the Fund that is directly linked to the development of the global carbon market. As the level of auction revenue or taxation changes over time this will feed directly into financing for the Fund. The specific allocations, which each Annex I country would be responsible for providing, would require further negotiation and would depend on a number of factors including the level of emissions reductions by Annex I countries in the next commitment period, and the level of enhanced actions put forward by non-Annex I countries.

In addition to the share of auction revenue/bunker fuel taxation committed by Annex I countries, industrialising Middle Income Countries could make assessed contributions to the fund. This would be consistent with the principles set out in Mexico's proposal for a Multinational Fund for Climate Change.[168] Finally there would be an option for other developing countries to make voluntary contributions to the operation of the Fund in return for increased representation on the governance board; increasing the legitimacy and oversight of the Fund.

'Protect & Share' IPR and Licensing Framework Agreement

A new agreement is required to balance the protection of intellectual property with a framework to accelerate licensing and diffusion of technology.

Capturing the global public good aspect of low carbon innovation requires a new balance

[168] See CCAP, 2008 for details.

of risk and reward to ensure increased innovation and diffusion can happen simultaneously. To deliver this a new framework agreement on IPR protection and licensing is needed. The framework agreement would provide government-to-government commitments to 'protect and share' low carbon technologies and encourage joint-ventures and public-private partnerships. Support would be made available under the Global Innovation and Diffusion Fund to strengthen IPR protection measures in developing countries. Any country that was found not to robustly protect low carbon IPR would risk having its access to the diffusion and RD&D funds blocked.

In addition to enhanced IPR protection the framework agreement would also establish the grounds for the licensing of low carbon technology to ensure rapid diffusion. This could consist of a range of standardised agreements covering five main areas:

- **Segmented/parallel markets:** to provide free licensing in certain developing country markets but prevent re-importation to developed countries so innovators can earn a fair rate of return;

- **Public sector buy-out:** to provide advanced purchase commitments under the Global Technology Innovation and Diffusion Fund for 'orphan' areas of research to guarantee a return to innovators and swift deployment of technology;

- **"Use it or lose it" agreements (compulsory licensing):** to allow countries to take legal steps for the compulsory licensing of technology if innovators withhold technology from the market after a certain time period;

- **Pay to license:** to provide direct subsidies or risk guarantees to increase licensing;

- **Global commons:** to allow countries to provide open access to IPR where they have control of patents.

The different characteristics of different technologies mean that there is no 'one size fits all' solution. The specific type of agreement would need to be determined on a case by case basis. It is unlikely that the whole of this framework could be agreed in time for Copenhagen. A more realistic scenario is that the core elements of the 'protect and share' principle are agreed at the COP, with a follow-on negotiation in 2010 (with input from technical experts) to define the specific elements of the licensing and protection measures.

The 'protect and share' framework should not require any unilateral action by a country to break its obligation under the TRIPS agreement; and therefore there should be no need to renegotiate any WTO measures to implement the Agreement. However, in the medium-term, it could be envisaged that a new category of 'green patent' be established under the TRIPS agreement to formalise these conditions.

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CHATHAM HOUSE

About "Innovation and Technology Transfer: Framework for a Global Climate Deal"

In 2007 the Intergovernmental Panel on Climate Change (IPCC) released its most definitive report to date, finding that human-induced climate change is already happening and will lead to catastrophic results if not addressed quickly. International negotiations are underway on a post-2012 framework for stabilising global greenhouse gas emissions and adapting to climate change impacts. An unprecedented global effort is required to accelerate innovation and diffusion of low carbon and adaptation technologies. The challenge is formidable but history shows that in a variety of fields, from the space race to the pharmaceuticals industry, concerted effort can deliver transformative results.

This report proposes a new institutional framework for the innovation and diffusion of low carbon and adaptation technologies, and points to critical features needed in the international agreement due to be signed at the UNFCCC Conference of the Parties in Copenhagen in December 2009. The report argues that:

- Faster and broader innovation is critical for delivering climate security while preserving energy security;
- Current innovation programmes are not adequate to manage the risk of policy failures and higher ranges of climate sensitivity;
- Developed countries need to shift their national strategic innovation priorities if international cooperation is to be effective;
- Developing countries require support to build effective innovation systems not just narrow technology transfer;
- Delivering innovation faster and to scale requires the creation of strong new markets for innovative low carbon products and a diversity of cooperation initiatives;
- A failure to constructively tackle IPR and competitiveness issues will limit the pace of innovation and diffusion, and potentially poison the international climate negotiations.

Further details about this publication, translated versions, downloadable resources and news of related activities are available at www.e3g.org