24 Promoting Effective International Technology Co-operation

Key Messages

The private sector is the major driver of innovation and the diffusion of technologies around the world. But governments can help to promote international collaboration to overcome barriers to technology development. Technology co-operation enables the sharing of risks, rewards and progress of technology development and enables co-ordination of priorities.

Mutual recognition of the value contributed by country's investments in new technologies and innovation could usefully be built into international commitments.

International R&D co-operation can take many forms. Coherent, urgent and broadly based action requires international understanding and co-operation, embodied in a range of formal multilateral agreements and informal arrangements. Co-operation can focus on:

- Sharing knowledge and information, including between developed and developing countries
- Co-ordinating R&D priorities in different national programmes
- Pooling risk and reward for major investments in R&D, including demonstration projects

A global portfolio that emerges from individual national R&D priorities and deployment support may not be sufficiently diverse, and is likely to place too little weight on some technologies with global potential, such as biomass. International discussion and co-ordination of priorities for investment in R&D and early stage deployment could play an important role in developing a broadly-based portfolio of cost-effective abatement options.

A small number of technologies, including solar PV, CCS, bio-energy and hydrogen have been identified in international assessments as having significant global potential. **Dedicated international programmes could play a role in accelerating R&D in these areas.**

Both informal and formal co-ordination of deployment support can boost cost reductions by increasing the scale of new markets across borders. Transparency and information sharing have supported informal co-operation on renewable energy. Tradable deployment instruments could increase the effectiveness of support and allow greater co-ordination across borders. There is a strong case for greater international co-ordination of programmes to demonstrate carbon capture and storage technologies, and for international agreement on deployment.

International co-ordination of regulations and product standards can be a powerful way to encourage greater energy efficiency. It can raise their cost effectiveness, strengthen the incentives to innovate, improve transparency, and promote international trade.

24.1 Introduction

Co-operation to accelerate the development and diffusion of low-carbon technologies is likely to reduce the cost of achieving overall emission and stabilisation objectives. The benefits of developing cost-effective low-carbon technologies will be global but most costs will be incurred locally, including a significant proportion by the private sector.

This suggests that a combination of international and public-private co-operation may be required to increase the scale and effectiveness of investment in R&D[1] as outlined in Chapter 16.

An international approach to developing technologies can contribute to building trust and raising the overall ambition of action to tackle climate change. At the 2005 Gleneagles summit G8 leaders recognised the need for greater international co-operation and co-ordination of research and development of energy technologies[2]. At the same time, the Heads of Government of Brazil, Mexico, South Africa, China and India issued a joint statement looking to build a "new paradigm for international co-operation" in the future[3] including improved participation in R&D, international funding for technology transfer, and a concerted effort to address issues related to intellectual property rights (IPR).

Technology also has a vital role to play in adaptation. The development and diffusion of improved crop varieties, more efficient irrigation systems, and cultivation methods will reduce the costs of adapting to climate change in the agricultural sector. Improvements to design, materials and construction techniques can improve the resilience of infrastructure and urban development. Scientific and technological progress that improves the quality of climate predictions and weather forecasts will enable more effective adaptive responses to climate change. Some of these techniques are also relevant to mitigation – leading to lower emissions from rice cultivation[4], reduced energy use for space heating and cooling, for example.

This chapter explores the role of international co-operation on technology. The lessons apply for both adaptation and mitigation. Both formal multilateral action and a variety of arrangements to support co-ordinated or parallel action can play an important part in supporting co-operation. It looks at the role of international technology co-ordination (Section 24.2) and the models for R&D co-operation (24.3) and co-ordination of deployment programmes (24.4). In Section 24.5 it considers opportunities for greater international public-private co-operation at the commercialisation stage. Finally (24.6) it considers the role of global or regional co-ordination on regulation and standards.

24.2 The role of international technology co-operation

The bulk of new technology development and commercialisation takes place within the private sector, which also spreads new technologies rapidly between countries.

In several cases developing countries have been able to "leapfrog" to advanced technologies – by installing mobile phone networks without ever developing systems of landlines, or in some cases by designing cities from the outset with mass rapid transit systems in mind. This may not be possible in some technologies where tacit knowledge[5] is important but, may occur in sectors where rigid infrastructure is yet to be built, such as building efficiency and combined heat and power.

Multinational companies use research bases around the world. Microsoft's research is strengthened by its operations in China[6] and India[7] to take advantage of local expertise. General Motors is collaborating with Shanghai Automotive to develop fuel cell cars on a commercial scale[8]. BP has begun a new programme of research on biofuels in India[9]. Co-

[1] Research and Development: In this chapter the term R&D will also cover the demonstration stage - Research, Development and Demonstration (R,D&D can be used for this but this can lead to confusion over the final D since some people use deployment or diffusion)
[2] Gleneagles Plan of Action – Climate Change, Clean Energy and Sustainable Development http://www.fco.gov.uk/Files/kfile/PostG8_Gleneagles_CCChangePlanofAction.pdf
[3] Joint Declaration of the Heads of State and/or Government of Brazil, China, India, Mexico and South Africa participating in the G8 Gleneagles Summit http://www.indianembassy.org/press_release/2005/July/5.htm
[4] International Rice Research Institute (2006)
[5] Much of the knowledge embodied in a technology is 'know-how' or 'gardeners craft' that is not codified
[6] http://research.microsoft.com/aboutmsr/labs/asia/default.aspx
[7] http://research.microsoft.com/aboutmsr/labs/india/default.aspx
[8] http://www.gm.com/company/gmability/adv_tech/400_fcv/fc_milestones.html
[9] http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7014607

operation between developing countries is also taking place through the private sector – including initiatives by Brazilian companies to market their biofuels technologies in Southern Africa. China has a number of highly competitive businesses exporting solar water heaters to other developing countries.

However, governments do have a role to play in sectors where the market under-provides new technologies. As outlined in Part IV, this requires governments to ensure that the private sector invests in developing and deploying low-emission technologies by creating a value for greenhouse gas emissions through pricing the externality. Additionally, in some climate sectors relevant to climate change, governments provide a significant proportion of R&D funds, and create markets through policy frameworks for deployment support. The central questions here are how to ensure that the combined international effort is sufficient relative to the scale and urgency required, and what types of co-operation and co-ordination are most useful.

Multilateral frameworks and joint funding arrangements have already supported technology development in other areas, and will be increasingly important for climate change technologies.

Formal co-operation on technology has supported advances ranging from basic science to space exploration and the launch of commercial satellite systems. There has been a growing debate over the importance of formal international agreements on technology co-operation as part of efforts to tackle climate change.

Carraro and Buchner[10] have suggested that technology could form an easier basis for international co-operation than carbon pricing, though ultimately a less effective one. Technology has some characteristics of a “club good” rather than a pure public good, in that despite the spillovers, some of the benefits of co-operation on innovation can be limited, for a time, to participants[11]. Benedick[12] has highlighted the importance of industry and government co-operation in identifying alternatives to the use of ozone depleting substances, and in developing appropriate timetables and safety valves for phasing out the polluting chemicals.

Barrett[13] examines the scope for international treaties focused on technology and R&D. In a recent paper he concluded that these are subject to the same underlying challenges for international collective action as those described in Chapter 21. But, he identified specific cases where formal international technology co-operation is important: where R&D can lead to breakthrough technologies that exhibit increasing returns to scale and where R&D co-operation might sustain a strong international response. Examples of technologies where formal co-operation may offer significant benefits include improved solar technologies, and the development of the infrastructure and networks required to support the use of hydrogen.

Informal arrangements can also play a valuable role in supporting co-ordinated or parallel action.

Co-operation on technology goes far beyond formal multilateral arrangements. Links between universities and research networks help to ensure that breakthroughs in basic research are widely available. Partnerships play a key role in bringing together smaller groups of public and private bodies to take a lead in developing particular technologies.

Recent IEA work[14] on the effectiveness of IEA and other technology partnerships highlights two key lessons. First, the involvement of a range of stakeholders, including the business community, is essential to the success of technology partnerships. Second, developing country participation is important, and not only from the point of view of building capacity and know-how. Increasingly, the wealth of scientific and technical expertise in developing countries means they have important contributions to make in their own right. A good

[10] Carraro and Buchner (2004)
[11] Also in Neuhoff and Sellers (2006)
[12] Benedick (2001)
[13] Barrett (2006)
[14] IEA (2005a)

example of this can be found in the case of biofuels (see Box 24.1), and in solar thermal technology.

Box 24.1 The Brazil-UK-Southern Africa biofuels taskforce

The aim of the project is to increase the production of biofuels[15] in Southern African countries using Brazilian technology. Brazil is the world's leading producer of biofuels (and the flexi-automobile engines which can use it) and a number of Southern African countries have the technical potential to produce sugar cane for local bioethanol production. There are considerable potential markets for bioethanol in Africa and globally.

A technical feasibility study on the potential for bioethanol production in Southern Africa has now been completed and a taskforce of interested countries to undertake more detailed feasibility studies is being set up. The initial group of countries identified, in addition to Brazil, was South Africa, Mozambique, Zambia and Tanzania.

This project has the potential to contribute to multiple aims in Southern Africa - rural development, added value to agricultural production, energy security, emissions reduction; and to enable South-South technology transfer from Brazil to Southern Africa. The objective is to more than double sugar cane production from around 0.7 to 1.5m hectares by 2020.

International monitoring of R&D and deployment support should encourage greater recognition of national efforts to introduce relevant technologies as part of formal multilateral frameworks or informal arrangements for co-operation.

Data gathering and modelling by numerous institutions, particularly the IEA, enables policy makers to track technological progress. This can help to identify whether sufficient progress is being made and what further spending may achieve. It can also allow policy makers to check the balance of any support to ensure it is broadly proportionate to each technology's potential and stage of development.

National investment in technology is not currently recognised as a contribution to the objectives of the UNFCCC. Incorporating technology development into the measurement of national commitments under the UNFCCC would have the advantage of recognising those countries that make a disproportionately large contribution towards developing new technologies. It is not possible to translate the impact of investing in innovation into resultant emission reductions so it is not possible to directly "trade-off" between the two. Thus international recognition of investment in innovation should be considered as part of a broader range of metrics over different dimensions of effort.

24.3 Models for R&D co-operation

International arrangements to support technologies for mitigation and adaptation could focus on the further development of a number of different types of co-operation, including

- Sharing knowledge and information
- Co-ordinating R&D priorities in different national programmes
- Pooling risk and reward for major investments in R&D, including demonstration projects

Sharing knowledge and information

Various arrangements can help to promote the positive spillovers of knowledge between technology programmes in order to speed the pace of innovation.

The IEA's Energy Technology Collaboration Programme includes more than 40 international collaborative energy research, development and demonstration projects known as

[15] For more on biofuels see Boxes 9.5, 12.2 and 16.4 and Sections 12.6 and 16.3

Implementing Agreements. These enable experts from different countries to work together and share results, which are usually published for a wider audience.

Sharing information with developing countries who have not been strongly involved with these networks is important. It supports the development and transfer of technology as discussed in Section 23.4. The IEA has recently launched a further initiative on Networks of Expertise in Energy Technology (NEET) to encourage further co-operation with non-member countries. Conceived in response to a call from G8 leaders for more productive international partnerships for energy technology information exchange, IEA's NEET Initiative is set to play a catalytic role in promoting worldwide technology collaboration. It is linking existing energy R&D networks, bringing together policy-makers and stakeholders from the financial, business, research and other key sectors, in both IEA countries and major energy-consuming non-IEA emerging economies.

The challenge is not just creating new knowledge but ensuring that this knowledge is disseminated so it can be used effectively no matter where it originates from. This stimulates competition and reduces unnecessary duplication and ensures that other research efforts in both the public and private sector can benefit from the progress that is made.

Identification and co-ordination of research priorities

Competition plays an important role in driving innovation (see Section 16.1) but, international discussion, and to some extent co-ordination, can help to ensure R&D is directed towards the technologies that can make a significant global contribution to reducing greenhouse gas emissions. This is already happening to some extent, for example with hydrogen (see Box 24.2) and carbon capture and storage. However, as discussed below, there is scope to go further.

Box 24.2 Partnerships can contribute to sharing knowledge and information

The International Partnership for the Hydrogen Economy[16], launched by the US in 2003 is an international institution dedicated to accelerating the transition to the hydrogen economy.

The IPHE provides a mechanism for partners to organize, co-ordinate and implement effective, efficient, and focused international research, development, demonstration and commercial utilization activities related to hydrogen and fuel cell technologies. The IPHE provides a forum for advancing policies, and common technical codes and standards that can accelerate the cost-effective transition to a hydrogen economy. It also educates and informs stakeholders and the general public on the benefits of, and challenges to, establishing the hydrogen economy.

It does not provide direct funding for research. However, it secures increased awareness and recognition of significant international collaborative research, development and demonstration projects. The strength of the IPHE is that it is a top-level political initiative – launched by Ministers – with high level official representation on its Steering Committee.

A global portfolio that emerges from individual national R&D priorities is likely to be unbalanced in respect to the global potential for different technologies.

As outlined in Chapter 16 the uncertainty and risks inherent in developing low-emission technologies are suited to a portfolio approach. National R&D policy focuses on technologies where there is a compelling local need or a perceived first-mover advantage, in order to capture national benefits linked to lower cost energy, local health or agricultural priorities, and the development of new industries. The competitive and entrepreneurial energies motivated by seeking first-mover advantage have a powerful effect in spurring innovation. Nevertheless there are also disadvantages that policy can help overcome.

[16] http://www.iphe.net/

- Where a first-mover advantage exists, it is more likely to relate to products with significant economies of scale, production processes that are complicated and difficult to imitate, and strong export potential, including low transport costs.

- A policy focused only on first-mover advantage encourages countries to seek to reduce spillovers that would be beneficial to other countries, in the interest of their national industries.

- It can encourage a policy bias for local production rather than co-operation in developing manufacturing bases in other countries or using imported technology.

- It can bias the choice of technologies. Developed countries focusing on the technologies where they have comparative advantage, or where there are developed country applications, may fail to provide the technologies required for cost-effective reductions in the developing world, for example biomass and solar power.

- A fragmented approach is unlikely to create a sufficient market size to realise the learning potential of any technologies.

There is a wide range of models for international co-operation of research priorities in energy and transport technologies.

Extensive modelling work has provided an increasingly clear picture of the technologies that are likely to form part of the future energy portfolio[17]. This modelling often incorporates the cost uncertainty of future technologies and reflects this in the range of outcomes it delivers. There are further promising analytical tools being developed to aid understanding of a suitable global portfolio such as real options pricing[18]. Despite the inevitable uncertainty that surrounds such work, it provides a useful tool for policymakers to evaluate existing and planned policies and should be encouraged.

The G8 and OECD have both made efforts to identify international priorities for technology development. At the Evian Summit, G8 leaders issued an Action Plan on Science and Technology for Sustainable Development[19]. The Energy Research and Innovation Workshops hosted by the UK and Brazil fulfilled one of these commitments - delegates of energy policy and research experts from the G8 countries, Brazil, China, India, Mexico and South Africa have begun to meet annually to discuss how to facilitate co-operation in technology development amongst developed and developing countries[20]. It also led to the launch of international partnerships on specific technologies, including bio-energy (see Box 24.3), hydrogen and carbon sequestration. This work could provide a platform for a more significant effort to accelerate these technologies.

[17] For example IEA (2006)
[18] Pindyck and Dixit (1994)
[19] http://www.g8.fr/evian/english/navigation/2003_g8_summit/summit_documents/science_and_technology_for_sustainable_development_-_a_g8_action_plan.html
[20] The Energy Research and Innovation workshop held in Oxford 2005 and followed up in Brazil in September 2006 http://www.ukerc.ac.uk/content/view/75/67/

Box 24.3 The launch of a Global Bio-energy Partnership responded to developing country priorities

The Global Bio-Energy Partnership[21], launched by Italy in May 2006 following the G8 meeting the previous year, focuses on the potential for the greater use of bio-energy. The involvement of developing countries is particularly important.

Biomass is widely used in developing countries as a source of domestic heat. Traditional biomass is a major source of indoor air pollution causing ill health and mortality (see Box 12.2). Biomass technologies could have a significant impact at the village and household level. Biomass also has the potential to form a significant part of mitigation in the power generation and transport sectors leading to export opportunities.

The partnership will increase and facilitate an exchange of experiences and technologies not only North-South, but also South-South and South-North. The short and mid-term goals include the review of the current stakeholders network, knowledge and gaps in the understanding about bio-energy as well as the formulation of standard guidelines to measure the greenhouse gas emission reductions through the use of bio-fuels.

The OECD Roundtable on Sustainable Development brought together scientists, heads of research councils and policymakers to undertake a full assessment of the current portfolio of research in energy technologies. The report, discussed by science and energy ministers from OECD and developing countries in June 2006, concluded[22] that the current portfolio is too small. It recommended that more attention should be given to funding research in:

- solar
- battery technologies
- carbon capture and storage

These technologies offer the prospect of substantial emissions savings because they have the potential to provide for a significant proportion of the market and all currently have limited public support.

These international assessments build on and complement existing national processes to allocate research funding and offer a model for further efforts at co-ordination of energy and transport priorities. A successful international model of R&D co-operation can be found in the case of the Consultative Group on International Agricultural Research (CGIAR) (see Box 24.4).

[21] EC (2005a)
[22] OECD (2006) and Chairman's summary: http://www.oecd.org/dataoecd/38/59/37041713.pdf

Box 24.4 Lessons on R&D co-operation from CGIAR

A strong precedent exists for international collaboration on research and development in agriculture.

In the 1950s and 1960s a major concern was how to increase food supply given that the scope for increasing agricultural land area was becoming limited and the world's population was set to double by the end of the century. A major and successful effort was made to improve yields of agriculture research and extension, by bolstering both national research stations facilitated by a network of international research centres, later brought together under the aegis of the CGIAR under the chairmanship of the World Bank.

The CGIAR was created in 1971; it now has more than 8,500 CGIAR scientists and staff working in over 100 countries. It draws together the work of national, international and regional organisations, the private sector and 15 international agricultural centres to mobilise agricultural science, promote agricultural growth, reduce poverty and protect the environment. It has an impressive record and can be expected to play a strong role in enabling the agricultural sector to adapt to the impacts of climate change through research on new crop varieties and farming methods. There is a good case for expanding this role to support mitigation and adaptation from the agricultural sector[23].

Several lessons from the experience of agriculture are relevant for an international programme in the development and use of low carbon technologies and practices. In the case of agriculture:

- There was a shared commitment among the sponsors;
- The programme evolved from an already extensive network of national research centres and supplemented and enhanced national efforts;
- It was based on real demonstration and R&D projects, and was not simply a 'talking shop';
- The efforts were not centred on one institution in one country, but divided across a set of institutions in several countries specializing on particular crops (rice, wheat, maize, agro-forestry and so forth) and livestock farming;
- There were good working links between the international and national centres of R&D;
- There were also good working links between the programme and the users (extension services and farmers), so that technology and knowledge could be rapidly diffused to those who would use it.

Pooling risk and reward for major investments in R&D

Co-operation can go beyond sharing information and co-ordinating of national priorities to include formal arrangements to spread the risk and cost of investing in new technologies.

The scale of some low-carbon technologies is too large for one country to take on alone. The classic example of this is nuclear fusion, where the benefits of a successful programme could be very large, but the technical challenges and scale of investment required are daunting.

The ITER[24] project to demonstrate the scientific and technical feasibility of nuclear fusion power is supported by European Union, Japan, China, India, the Republic of Korea, the Russian Federation and the USA each of which has committed to financing the projects $10 billion cost. The costs are shared amongst the participants: Europe will contribute 45.45%, and China, Japan, India, Korea, Russian Federation and the USA will contribute 9.09% each. It can prove difficult to negotiate one-off projects where key questions of national interest arise The start of the ITER project was delayed for several years as a result of disagreements on its location. Where these problems can be overcome, however, the rewards can be appreciable. Discussions on a series of linked demonstration projects or for

[23] For more see Section 16.3 and Box 26.3
[24] http://www.iter.org/

a number of different technologies could increase the opportunities to share the benefits of co-operation amongst the participants.

Traditionally OECD nations have been the primary focus of innovative investments. Arrangements that involve scientists and engineers from developing countries in the tasks of R&D in low carbon energy technologies and practices would have considerable economic merit. Already China and India are each graduating 250,000 engineers and scientists every year, as many as in the US and in the European Union combined. It is clear that a rich source of innovation is emerging and the traditional North to South view of technological progress is becoming outdated.

Dedicated international programmes could play a role in setting research priorities and sharing the costs of accelerating key technologies.

The number of technologies that have been proven viable and could potentially meet a large proportion of future energy needs, including those identified as part of the OECD assessment described above, is relatively small. An estimate of the learning cost of reducing the price of just one of these, solar PV, to the point of market competitiveness is €20 billion[25]. Costs of this scale provide a rationale for international co-operation (see Box 24.5 for an example of the costs and benefits of an ambitious international programme).

Box 24.5 Illustrative estimate of the scale of costs and benefits of an international programme of R&D in clean energy[26]

The increases in R&D and deployment support outlined in Section 16.8[27] would probably be achieved mostly through national frameworks for supporting innovation. However, an international programme in fundamental R&D, support for demonstration projects and early stage deployment support could make a significant contribution to the global effort.

For example, a 20 year international programme to develop low carbon technology on a significant scale aggregating to perhaps 1-2 GW of electricity production per year, would require investment in the region of $6-10 billion per year. This would target technologies with significant potential for reducing greenhouse gas emissions where the nature of the costs and benefits of developing the technology benefit from action at an international scale. Around 50% of this cost could be leveraged through private investment, international offset programmes such as the CDM, and sales of the actual energy produced. Higher leverage rates would be achievable as the programme progressed and as conversion efficiencies and confidence in the industry improved. A key feature of such a programme could be involving scientists and engineers from developing regions which would deliver significant benefits. Such a programme could be built on existing international institutions or through collaboration between national programmes, and be perceived as part of international outreach and co-operation from developed countries.

The positive externalities of such a programme would be substantial. The incremental costs of present programmes of investments in low carbon technologies (the cost beyond market dominant alternatives) in OECD countries amount to around $85 per tonne of CO_2 abated. But costs are declining and may become as low as $45 per tonne of CO_2 abated in 20 years time and $25 per tonne or less by 2050. Together the national and international programmes of R&D, plus the incentives provided by the more familiar instruments for encouraging innovation, are fundamental for such reductions to be achieved, and could reap worldwide benefits (as measured by consumers' plus producers' surpluses) of over $80 billion per year per gigatonne of carbon abatement.

There are other examples of countries pooling significant funds for R&D and investment in innovative new technologies, including the EU's R&D framework programme and the

[25] This is heavily dependent on the assumed learning rate. Source: Neuhoff (2005)
[26] Source: Dennis Anderson - Estimates from analysis undertaken as part of this review available at www.sternreview.org.uk
[27] Increase in public energy R&D of $10 billion and of deployment support of between $33 billion and $132 billion.

arrangements for public-private co-operation that have underpinned the Galileo satellite navigation system[28]. The European Commission is proposing that the model for European collaboration used in the Galileo project should now be rolled out as a new Community Instrument - the Joint Technology Initiative.

These initiatives, mainly resulting from the work of European Technology Platforms and covering one or a small number of selected aspects of research in their field, will combine private sector investment and national and European public funding, including grant funding from the Research Framework Programme and loan finance from the European Investment Bank. There is currently a proposal for a Joint Technology Initiative for hydrogen and fuel cells.

Box 24.6 EU 7TH Framework Programme for R&D

Funding research and development at the EU level reduces the problem of spillovers and allows smaller countries to contribute to a large and diverse research portfolio. The EU has an R&D framework as part of the EU budget which will enter into its 7th programme, lasting 6 years and beginning in 2007, with a total fund of €48 billion (6% of the total EU budget). Of this, €5 billion will be spent on energy and environment issues.

EU research priorities are aligned using European Technology Platforms. These provide a framework for stakeholders, led by industry, to define research and development priorities, timeframes and action plans on a number of strategically important issues where achieving Europe's future growth, competitiveness and sustainability objectives are dependent upon major research and technological advances in the medium to long term.

Previous frameworks have invested in climate change research on:

- The science of climate change such as the impact on coastal zones[29] and adaptation[30];
- Technology development including wind turbines[31] and fuel cells[32].

The 7th Programme's energy and environmental themes ensure that there is likely to be a greater emphasis on climate change research in the next programme and an intention to involve developing countries. The scale of investment required and the urgency suggests that this should be the case and the forthcoming fundamental review of the EU budget, which is to report in 2008/09, should consider the appropriate level of longer-term EU support in this area. Rebalancing within the EU budget, when combined with national and other international funding, could make a significant contribution to the increases set out in Section 16.8[33].

There is a strong case for greater international co-operation between national programmes to develop and demonstrate carbon capture and storage technologies.

Carbon Capture and Storage[34] (CCS) is a process that is yet to be deployed at full commercial scale in the power sector, so it remains at the demonstration stage of the innovation process. The IPCC special report on CCS suggested it would provide between 15% and 55% of the cumulative mitigation effort up to 2100. Failure to develop CCS would result in a narrower portfolio of low-carbon technologies and this would, on average, increase abatement costs. Recent IEA modelling shows that, without CCS, less abatement occurs at a higher cost as marginal abatement costs would increase by around 50%[35]. Modelling work undertaken for the Global Energy Technology Strategy programme showed that removing the option of CCS more than triples the cost of stabilisation for all concentration levels analysed.[36]

[28] http://www.euractiv.com/en/science/galileo/article-117496
[29] http://ec.europa.eu/research/success/en/env/0069e.html
[30] http://ec.europa.eu/research/success/en/env/0336e.html
[31] http://ec.europa.eu/research/success/en/ene/0059e.html
[32] http://ec.europa.eu/research/success/en/ene/0265e.html
[33] Doubling of global public energy R&D from $10n billion to $20 billion.
[34] For more on CCS see Boxes 9.2 and 24.8.
[35] IEA (2006)
[36] GTSP(2005)

This prominent role in future mitigation can be linked to the expected global growth of coal use.

The IPCC recently completed a special report[37] on the potential of CCS, providing an important assessment on key issues including the likely availability of geological storage sites. The Carbon Sequestration Leadership Forum[38] acts as a focal point for participating governments and industry to share updated information on national programmes and opportunities. A number of projects are under development, but so far, national governments have found it difficult to set up policy frameworks to cover the additional costs required for a full demonstration project.

A single CCS demonstration project costs several hundred million dollars over and above the cost of a standard power station. The IEA recommend that 10-15 such projects should be in place by 2015 at an estimated extra cost of $2.5 to $7.5 billion in order to demonstrate the commercial viability of the technology[39]. This is a dramatic increase on the $100 million that is currently spent on CCS R&D[40]. The 'lumpy' nature of CCS investments implies that it may be better for a limited number of countries to demonstrate CCS, but there are currently no arrangements for co-ordinating these efforts.

There have been several announcements from governments and the private sector on planned CCS projects. These include:

- the US Futuregen project[41] which is linked to the demonstration of IGCC coal generation technology

- BP's proposed project at Peterhead[42] which includes a 350MW hydrogen plant capturing 1.2 million tonnes of carbon each year; and RWE's feasibility study for a post-combustion techniques in a 1000MW coal plant in Tilbury; UK[43]

- A Japanese proposal to capture a sixth of all their emissions by 2020.

- Vattenfall's plan to build a 30 MW pilot coal plant in Germany. Construction has started and the plant will be in operation by mid 2008[44].

- A geological storage pilot project in the Otway Basin in Western Victoria[45] planned by a public-private research organisation in Australia. An LNG project[46] Gorgon (North West Shelf), and the Stanwell ZeroGen IGCC-CCS project[47] are at the proposal stage.

- The EU has an initiative seeking to develop a CCS plant in China (see Box 24.7).

[37] IPCC(2005)
[38] www.cslf.org
[39] IEA (2006)
[40] Page 38, OECD (2006)
[41] http://www.fossil.energy.gov/programs/powersystems/futuregen/
[42] http://www.bpalternativenergy.com/liveassets/bp_internet/alternativenergy/next_generation_hydrogen_peterhead.html
[43] http://www.npowermediacentre.com/content/detail.asp?ReleaseID=676&NewsAreaID=2
[44] http://www.vattenfall.com/www/vf_com/vf_com/365787ourxc/366203opera/366779resea/366811co2-f/index.jsp
[45] http://www.co2crc.com.au/pilot/OBPP.html
[46] http://www.greenhouse.gov.au/challenge/members/chevron.html
[47] http://www.zerogen.com.au/project/overview

Box 24.7 Near-Zero Emissions Coal initiative in China

The EU agreement to develop a near-zero emissions coal plant in China is expected to lead to the construction of the first CCS project sited in a non-OECD country. This should create significant opportunities for learning. Undertaking this project as a joint venture encourages shared understanding of deploying CCS technology and reflects shared concerns over climate and energy security and the use of coal for power generation.

The Near-Zero Emissions Coal initiative was announced as part of the EU-China Partnership on Climate Change at the EU-China Summit in September 2005. It stated that the EU and China will aim "to develop and demonstrate in China and the EU advanced, near-zero emissions coal technology through carbon capture and storage" by 2020.

A Memorandum of Understanding (MoU) was signed between the UK and China on December 19th to detail specific UK funded action (Phase 1 Assessment). A complementary MoU was signed between China and the European Commission on February 20th 2006. This ambitious initiative will take place through a phased approach over several years allowing for the development, funding and implementation of the demonstration project::

Phase 1	Identifying early demonstration Opportunities	2006-2008
Phase 2	Define, Plan and Design a Demonstration Project	2009-2010
Phase 3	Construct and Operate a Demonstration Project	2011-2014+

The assessment of early opportunities for CCS demonstration under Phase 1 will begin in November 2006 with funding from the UK and the EU.The forecast investment of coal power stations in China provides a strong rationale for accelerating such a valuable project to create the option of more widespread deployment. Consideration should also be given to the case for demonstration projects in other developing countries with significant coal resources.

Building on these announcements, the enhanced co-ordination of national efforts could allow governments to allocate support to the demonstration of a range of different projects, and demonstration of different pre and post combustion carbon capture techniques from different generation plants[48], since the appropriate technology may vary according to local circumstances and fuel prices (see Box 24.8). One element that enhanced co-ordination could focus on is understanding the best way to make new plants "capture-ready", by building them in such a way that retrofitting CCS equipment is possible at a later date.

Governments should also develop legal, regulatory and policy frameworks to encourage deployment after demonstration. During the demonstration stage governments should simultaneously develop a regulation and policy framework, including the liability for any leaked CO_2 and reducing the probability of such an occurrence. Integrating this into policies such as emissions trading schemes and programmes to encourage renewables could have an important impact on deployment.

24.4 Co-ordinating deployment support

Chapter 16 estimated that the current level of deployment support should increase by 2 to 5 times to help deliver an appropriate portfolio of technologies. Understanding that others are taking significant measures to support technologies can encourage countries to increase their effort. Countries can also benefit from discussing effective policies and how to foster an appropriate portfolio of technologies, moving towards a common understanding of what this means. Most OECD and larger developing countries already have some sort of deployment support for low-carbon technologies, but they need to be increased to sufficient scale and ensure that potentially cost effective technologies are not ignored. International co-operation

[48] Integrated Gasification Combined Cycle and more traditional Pulverised Coal plants and dominant gas generators - Combined Cycle Gas Turbine generators.

can complement national support strategies in enhancing investors' confidence for future markets, and thus encouraging innovative investments[49].

It is possible to conceive innovative policy structures to ensure that these goals are delivered. If the cost of developing technologies were not uncertain it would be possible to spread these globally in an equitable fashion. Given the inherent uncertainty, policymakers could agree a target level of deployment support and technology priorities and measure the contribution through the leaning cost incurred in each country (the cost beyond that of existing technologies within each country). However data on such costs may be hard to produce credibly and counterfactuals are unclear.

Informal sharing of experiences and, in some regions, co-ordination of deployment support appears to have provided an important boost to the use of renewable energy around the world.

Support for renewable energy sources is common throughout the OECD and in some non-OECD countries such as India and China. The structure and ambition of this support varies greatly across countries and often within countries. There are now 41 states, provinces or countries with feed-in-policies (price support) and 38 with renewable portfolio standards (quantity targets) including many outside the OECD[50]. In addition, a number of countries use tax incentives to encourage the deployment of renewables. China applies a much lower rate of VAT to renewable energy technologies, and Mexico offers tax relief on clean energy R&D.

There is no formal co-ordination but the Bonn and Beijing Renewables Conferences and the REN21 network [51] have provided a powerful mechanism to gather and share information on different national approaches and to raise awareness of the scale of national efforts amongst policymakers and industry.

It is possible to make comparisons of the level of deployment support in different countries. This is easier for price support, mechanisms as the price is clearly evident. While recognising that other ancillary benefits may justify support it is possible to calculate the implicit carbon price for different policies. The price required to support a technology indicates the current cost of the technology and the degree to which it is a viable technology or a learning investment for the future. It is possible to calculate the cost of price support for new technologies in terms of carbon abatement (see Table 24.1). It is harder to estimate costs from quantity based targets, such as the renewable portfolio standards used in the US, as the price is bound up in the overall electricity price. However, it is possible to make an estimate using deployment figures and cost estimates. This allows comparison of the scale of effort (in terms of learning investments) in different countries.

[49] Neuhoff and Sellers (2006)
[50] Source: REN 21 (2006)
[51] REN 21 is the *Renewable Energy Policy Network for the 21st Century.* It is a global policy network that provides a forum for international leadership on renewable energy. More details of the conference are available at: http://www.renewables2004.de/en/2004/default.asp

Table 24.1 Implicit cost of carbon in existing deployment support[52]

Country	Application	Imputed carbon price, \$ per tonne CO_2
Germany	Onshore wind	73
	Offshore wind	146
	Solar	1048
	Electricity from biomass	146
Austria	Wind	122
	Electricity from biomass	171
Spain	Wind	73
	Solar	804

More formal co-ordination of deployment support could include the use of internationally tradable policy instruments.

Currently, deployment policies such as renewables support mechanisms are implemented at the state or national level. However, learning depends on the overall global deployment, not where it takes place. The ability to trade obligations across borders would improve efficiency by ensuring that deployment takes place where it is cheapest to do so. The benefits from this may be significant where there are major differences between countries in, for instance, the availability of a natural resource such as sunshine, or in lower labour or other costs. Such harmonisation has yet to be attempted. Even the 22 states in the US with renewable portfolio standards cannot co-operate across state boundaries to help reduce costs. An IEA study[53] identified that deployment of some technologies within non-OECD countries could prove much more cost-effective, particularly in the case of solar technologies. Where this is the case, countries could consider including financial support for deployment in developing countries towards national deployment targets.

Harmonising existing instruments may be very challenging in practice. Within the EU, for instance, countries use a mix of quantity instruments, similar to US state renewable portfolio standards, and price instruments, such as the German feed-in tariffs (see Box 16.7). However, the scope for cross-border links should certainly be considered when developing new policy. This could help improve the value-for-money of deployment support. The likely widespread introduction of deployment policies for CCS technology over the next 5-10 years offers an opportunity to look seriously at how these could be designed to take advantage of possible efficiency gains from international trading (see Box 24.8 below).

Box 24.8 Options for supporting the deployment of carbon capture and storage

Carbon capture and storage technologies[54] have the significant advantage that their large-scale deployment could reconcile the continued use of fossil fuels over the medium to long term with the need for deep cuts in emissions. In the IEA's base-case, energy production doubles by 2050 with fossil fuels accounting for 85% of energy[55]. Coal use is forecast to grow in OECD countries, Russia, India, and China. The IEA forecast that without action a third of energy emissions will come from coal in 2030. Successfully stabilising emissions without CCS technology would require dramatic growth in other low-carbon technologies. The role CCS plays in avoiding these emissions will depend on the policy options that are chosen to support its deployment.

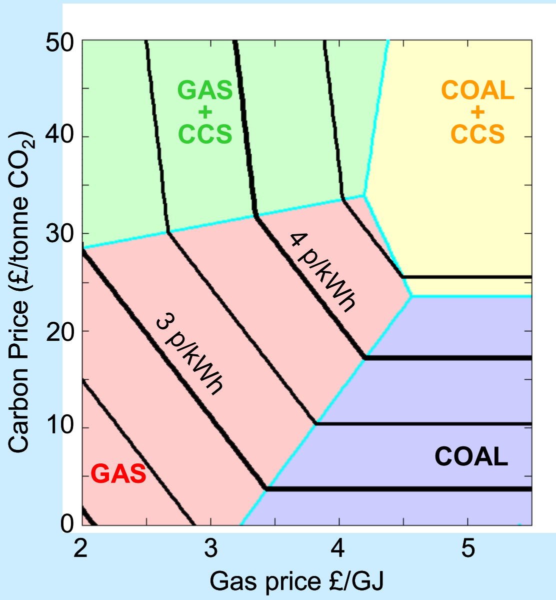
CCS is dependent on government intervention. Unlike other alternative generating technologies, CCS will always be more expensive than traditional fossil fuel[56] based alternatives, as it will always be cheaper to emit the CO_2 than to capture and store it. This is

[52] Source: Dennis Anderson paper available at www.sternreview.org
[53] IEA (2005b)

very similar to the problem of fitting flue gas desulphurisation equipment to tackle acid rain. This equipment is now widely used in OECD and developing countries, because it is recognised that the cost of using the technology is less than the cost of the externalities associated with sulphur dioxide emissions.

The economic viability of using CCS technology for power companies will reflect both the relative price of coal and natural gas and the level of the carbon price. Should the carbon price reach a sufficient level, with a credible expectation that it will remain there, widespread deployment of CCS can be expected. The choice of technology will also depend on the price of different fossil fuels, so if gas prices are high then coal will be chosen as shown in the figure below.

Impact of carbon and energy prices on CCS deployment[57]



Alternatively, international agreement could focus on a regulatory approach to deployment.. At the simplest level this would involve a commitment by participating countries to regulate that all new coal or fossil fuel electricity generation be fitted with CCS from a certain date. An example of this sort of regulation is the EU's Large Combustion Plant Directive, that places emission limit values on large plants with increasing stringency over time. It specifies different treatment depending on the age of the plant. It will ensure that by 2015 all European power stations conform to a common standard for air pollution emissions. For CCS, an agreement could set out a timetable for new plant to be capture-ready or to be fitted with CCS, and could establish differentiated responsibilities by giving more time or applying to a lower proportion of new plant in developing countries. The timing could be significant as mitigation costs will increase if significant investments are made in new capacity without, or precluding the addition of, carbon capture and storage technologies.

Renewable portfolio standards offer an alternative model for national or internationally co-ordinated policy instruments for the deployment of CCS. A CCS portfolio standard could require that a certain proportion of power supplied by generation companies is from plants fitted with CCS technologies[58]. This could begin with a very low proportion (e.g. 0.5%), consistent with the establishment by one or two operators in a market of demonstration plants. Other operators would share the risk of these projects through long-term contracts to purchase power from these plants to meet the CCS portfolio standard, and would pass the incremental cost through to all electricity consumers. Governments could set out a timetable

[54] For more see Box 9.2 and Section 24.3.
[55] IEA, 2006 - ACT MAP is a scenario in which includes CCS and where emissions are constrained to near current levels in 2050 following a technology 'push' for low-carbon technologies.
[56] Except perhaps under an extreme enhanced oil recovery scenario.
[57] Source: Gibbins et al (2006) Coal price £1.4GJ 25 year plant life and a 10% Investment Rate of Return.
[58] As suggested Jaccard (2006)

for a strong increase in the level of the portfolio standard provided that the demonstration projects showed that key criteria could be met. This policy approach could include a tradable element to pool efforts across larger markets, minimise costs across regions or maintain differentiated responsibilities between countries at different stages of development.

24.5 The use of international public-private co-operation to support commercialisation

Finding niche markets where new technologies can benefit from market learning and building these into large-scale commercialisation opportunities is a key challenge for companies with promising low carbon technologies.

The private sector often succeeds in commercialising technologies, where the incentives are right, without intervention.

Partnerships between industry and academia can support the commercialisation of new research from universities, including across borders. The SETsquared Partnership[59] is a collaboration between four UK universities and two US universities to develop further their joint works, encouraging collaborative applied research and complimentary commercial ventures[60]. Together, the universities of the SETsquared Partnership represent the largest single source in the UK for academic knowledge transfer to the private sector as discussed in Section 16.5. This has led to the creation of many companies, for example, in marine energy. In the last 2½ years, three SETsquared Partnership companies have achieved IPOs, with a total market capitalisation of £150 million.

Governments also play a role in supporting commercialisation, and could explore ways to extend this support across borders.

Organisations established by governments but independent of them, to allow the application of business acumen, have proved successful at encouraging commercialisation at a national level. Prominent examples include the Carbon Trust in the UK, Sustainable Development Technologies Canada, and a range of clean energy investment funds operated by around 20 US states. However, the niche markets may not exist in the innovator's own country, and it can take specialist support and expertise to identify overseas opportunities for new technology.

International co-operation between organisations such as the Carbon Trust could increase the access to international markets for technology developers. It is possible that a network of public-private investors could facilitate the creation of technology focused "commercialisation consortia", bringing together business participants and working to identify and overcome business, market and policy barriers to deployment.

Formal multilateral co-operation can also help in phasing out the use of emissions intensive products or processes for which a viable alternative exists, or in co-ordinating the introduction of infrastructure networks that are required to allow the adoption of a new low emissions technology.

There is a historical precedent for this approach with the Technology and Economic Assessment Panels (TEAPs) that were established to deliver reductions in CFC emissions following the Montreal Protocol. These played an important role in ensuring the roll-out of alternative technologies. This approach had the advantage of bringing government and business together to establish the technical feasibility of timetables for regulation. It built in some flexibility, with developing countries given more time to make the technological transition.

The scale and diverse range of sources of greenhouse gas emissions limits the applicability of the TEAP model in the case of the main greenhouse gases. It may be more relevant for

[59] http://www.setsquaredpartnership.co.uk/
[60] http://www.setsquaredpartnership.co.uk/news.cfm?item=59#viewing

setting limits on the creation of new sources of industrial gases with high global warming potential, such as Sulphur Hexafluoride (SF_6) and Perfluorocarbons (PFCs) (see Table 8.1).

It could also be relevant in the case of a major shift in transport fuels. Given the international market for vehicles, a global dialogue between vehicle manufacturers, fuel suppliers and infrastructure planners could help smooth a transition to a biofuel or hydrogen based system.

24.6 International co-ordination of performance standards, labels and endorsements

As outlined in Chapter 17, a range of failures and barriers in markets for energy efficiency determine that performance standards, labels and endorsements can complement or, occasionally, eliminate the need for, tax or trading instruments in order to elicit effective and efficient energy savings. In particular, such policies have the potential to drive demand for, and supply of, actions and investment to achieve energy savings. They can do this by: raising the visibility of energy costs; reducing uncertainty, complexity and transaction costs; inducing technological innovation; avoiding technology lock-in, for example where the credibility of carbon markets is still being established,. They can also help in communicating policy intentions to global audiences.

International co-ordination of performance standards, labels and endorsements can reduce costs and increase their effectiveness, particularly in markets for highly traded goods.

As outlined in Chapter 17, careful appraisal, design, implementation and management of successful performance standards, labels and endorsements is important to their cost effectiveness. The locus of market intervention (for example national, regional or global) is one important factor affecting their cost effectiveness. There are many successful examples of these policies implemented by individual countries within a range of markets (see Boxes 17.2 and 17.5 for details). In addition, policy leadership by individual countries is generally welcomed. However, it is often desirable to co-ordinate the design and delivery of such policies across national boundaries, where they apply to markets for highly traded goods and services, in order to:

- *Influence conditions within larger markets:* create stronger incentives to innovate by influencing conditions within a larger market, and encouraging greater competition between manufacturers of efficient products;[61]
- *Increase transparency across markets:* improve the capacity of consumers, producers and vendors to compare the performance of products and components across different markets, and provide policy makers and utilities with better information about the capabilities and limits of particular technologies;
- *Reduce compliance costs:* decrease design and production costs for manufacturers arising from differences in national or regional compliance requirements. Co-ordinated standards, labels and endorsements can reduce policy design and management costs by employing economies of scale;
- *Removal of trade barriers:* international co-operation to harmonise or increase the compatibility of test protocols can discourage protectionism and enhance competition for international technology procurement contracts.

There are widespread opportunities to elicit greater energy savings in a more cost effective way through co-operation, for example on: the efficiency of electrical appliances, ICT[62] technologies (see Box 24.9 on stand-by power below) and power supplies, support for a more formal international Energy Star endorsement programme, as well as co-ordination of test and compliance protocols more generally.

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[61] As markets and manufacturers move to comply with the new standards, the costs of product differentiation can create a tipping effect encouraging others to follow whether due to network effects, cost considerations (due to scale economies), or lock in. Barrett (2003) This occurred in the case of petrol where over 90% of the world petrol is now unleaded: http://www.unep.org/Documents.multilingual/Default.asp?DocumentID=277&ArticleID=3196
[62] Information and Communications Technologies

Box 24.9 Co-operation on Stand-by Power: The 1 Watt Initiative

Appliances and energy using consumer products are a major cause of growth in energy demand. They accounted for roughly two-thirds of the increase in electricity demand from buildings between 1973 and 1998 among IEA countries. Energy consumption used by appliances on stand-by mode is a major contributor.[63] In a typical Japanese or Danish household, for example, stand-by losses account for approximately 10% of total residential electricity consumption.[64]

International co-operation between policy-makers and stakeholders (including manufacturers and retailers) is necessary to reduce stand-by power related emissions (as well as those from the operating efficiencies of appliances). This is because the manufacturing, marketing and sales processes typically involve many countries. For example, a computer may be designed in the US, assembled in China using parts from Japan and Korea, and marketed and sold globally by a multinational company. As such, setting stand-by power use limits country by country would be unnecessarily difficult and costly.

The IEA launched the '1 Watt initiative' on the basis that more widespread use of existing power management technology could reduce total standby energy consumption by as much as 75% in some appliances and could form an important, cost-effective component of an overall global strategy to reduce greenhouse gas emissions. Countries including Australia have formally adopted the "1-watt plan" while others, including China, are seriously considering its adoption. In addition, the US now applies 1 Watt standards to federal procurement of energy using products (see Box 17.10). for further examples of driving efficiency through procurement.

There is considerable potential from energy efficiency policies implemented across the EU.

Policies implemented at the EU level to raise energy efficiency have the potential to be more efficient compared to subsidiary actions by individual states (although leadership from individual member states is welcomed). The EU Commission published a Green Paper[65] on Energy Efficiency which sets out proposals for delivering 20% energy savings by 2020. This builds on a suite of regulatory, information based and financing policies, as part of, for example, directives on: Eco-Design of Energy Using Products; Energy Performance of Buildings; Co-generation Energy End-Use Efficiency; and Energy Services.

The Energy Efficiency Action Plan adopted by the Commission in October 2006 represents an important opportunity to accelerate progress and set out ambitious action on energy efficiency. It has identified a number of priorities for action, in particular to: keep energy labelling up to date as well as set and progressively raise eco-design requirements for traded, energy using products and components (including on energy use). It also expands the scope of the Energy Performance of Buildings Directive to apply minimum performance standards for new and renovated buildings; and to build on existing on existing policies in relation to vehicle emissions.

The EU has a powerful role in shaping markets for automotive technologies, and its standards for vehicle exhaust emissions have been adopted in China and India. A voluntary agreement between manufacturers in the EU, Japan and Korea aims to reduce CO2 emissions to 140g per km across all passenger vehicles 1995 and 2008 (a cut of approximately 25% on 1995 levels). This agreement delivered reductions in CO2/km of approximately 12% between 1995 and 2004. Since then progress has slowed and the achievement of the 2008 target now appears unlikely, leading to the Commission to consider a stronger regulatory approach[66].

[63] One end-use metering campaign in 400 European households indicated that standby power now accounts for the largest potential energy saving among all non-thermal end-uses in the residential sector http://perso.club-internet.fr/sidler/index.html.
[64] IEA (2002)
[65] EC (2005b)
[66] http://europa.eu/rapid/pressReleasesAction.do?reference=IP/06/1134&format=HTML&aged=0&language=EN&guiLanguage=en

Harmonisation of test protocols could reduce costs and, where appropriate, provide a foundation for future consolidation of labels and standards.

Harmonisation of test protocols would bring reduced testing and compliance costs for manufacturers. It would also help consumers and manufacturers compare the performance of products and components across national boundaries; and, where necessary, provide a first step towards any future harmonisation of labels and standards. Successful harmonisation requires flexibility to account for regional and national differences in electricity, climate and local environments, product service features, and behavioural and product usage patterns.

Harmonisation of labels and standards can reduce costs but the cost effectiveness is likely to be greatest in markets where product characteristics and patterns of usage patterns vary least.

Harmonisation of labels and standards has the potential to deliver benefits in terms of increased transparency, reduced compliance and programme costs, and the promotion of innovation and growth. These opportunities are likely to be greatest for products in which characteristics and usage patterns vary least from country to country or region to region, for example, air conditioning units in South East Asia. However, significant barriers exist in certain product markets, for example in ‘wet’ goods (such as washing machines and dishwashers), in which regional and national differences in behavioural and product characteristics may mean the potential benefits for greater harmonisation are outweighed by the costs in terms of establishing tests, labels and standards at the lowest common national or regional denominator.

24.7 Conclusions

International technology co-operation can help speed the development and adoption of low-carbon technologies. It encourages the sharing of knowledge and information and the risks and rewards from major investments. It can also be used to monitor the pace of technological progress and the diversity of the portfolio of mitigation technologies being developed and ensure that investments are not disproportionately focused on particular technologies or regional interests.

This co-operation can take many forms with the complexities and uncertainties meaning that a range of approaches will be required in the future. Technology co-operation can build on existing experience and institutions though there may be some value in developing international programmes for research, demonstration and early stage deployment to complement national programmes.

24.8 References

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