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INTERNATIONAL ENERGY TECHNOLOGY COLLABORATION AND CLIMATE CHANGE MITIGATION

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FOREWORD

This document was prepared by the OECD and IEA Secretariats at the request of the Annex I Expert Group on the United Nations Framework Convention on Climate Change. The Annex I Expert Group oversees development of analytical papers for the purpose of providing useful and timely input to the climate change negotiations. These papers may also be useful to national policy makers and other decision-makers. In a collaborative effort, authors work with the Annex I Expert Group to develop these papers. However, the papers do not necessarily represent the views of the OECD or the IEA, nor are they intended to prejudge the views of countries participating in the Annex I Expert Group. Rather, they are Secretariat information papers intended to inform Member countries, as well as the UNFCCC audience.

The Annex I Parties or countries referred to in this document refer to those listed in Annex I to the UNFCCC (as amended at the 3rd Conference of the Parties in December 1997): Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, the European Community, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland, and United States of America. Korea and Mexico, as new OECD member countries, also participate in the Annex I Expert Group. Where this document refers to “countries” or “governments”, it is also intended to include “regional economic organisations”, if appropriate.

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EXECUTIVE SUMMARY

International technology cooperation, by sharing information, costs, and efforts, might accelerate and facilitate technical change towards more climate-friendly technologies. Cooperation between countries should not preclude competition between companies, and may drive governments to increase their efforts, especially in supporting basic research and development. Increased technology cooperation between countries could help engage more countries into action to mitigate greenhouse gas emissions.

The current globalisation of investment, trade and innovation should be seen as an opportunity for leveraging direct efforts toward development and dissemination of climate-friendly technologies. However, governments must act to strengthen and green trade and investment in order to realise this opportunity. National policies and governance are also fundamentally important as they create an environment conducive to wider dissemination of climate-friendly technologies.

Technology transfer to developing countries has been a primary concern of climate negotiators, with the concept embracing technology needs assessments, technology information, enabling activities and capacity building. The Global Environmental Facility that serves as the financial mechanism of the Convention is financing numerous concrete projects in these areas as well as enabling activities. Some of these projects have the explicit aim of reducing the costs of climate-friendly technologies by increasing their market shares. The Marrakech Accords created three new funds to deal with, amongst other things, technology transfer for adaptation and mitigation purposes. These mechanisms were explicitly designed to create conditions and leverage for private financing.

The flexibility mechanisms in the Kyoto Protocol will also contribute to technology dissemination and transfer. The Clean Development Mechanism is expected to help with technology transfer to developing countries. The flexibility mechanisms can also increase the availability of private financing in this area at a time of scarce public resources in most countries.

As far as collaboration on energy technology research and development is concerned, the IEA has acquired one of the highest levels of experience and capabilities in the world. It has more than 40 “Implementing Agreements” covering virtually all aspects of energy technology that are relevant for climate change. They organise country participation on a voluntary basis to share information, results, tasks and costs. In 2003 the IEA has further opened its implementing agreements to private companies and, most importantly, to developing country participation. The Climate Technology Initiative – devoted to technology transfer – was also turned into a new implementing agreement in 2003.

Developed countries have undertaken many other efforts to support technology development and transfer to developing countries, through bilateral agreements and multilateral organisations. The last G8 meeting in Evian adopted an Action Plan on Science and Technology for Sustainable Development that contains a substantive energy section.

Further strengthening international technology cooperation for mitigating and adapting to climate change and may follow several avenues.

First, an important area would be to further strengthen and "green" international trade and investment. This is likely to imply continuing the market reforms at a controlled pace, supplementing these reforms with environmental policy reforms, and possibly revising the rules governing the behaviour of multilateral and bilateral financing institutions.

Second, another possibility is to seek new or strengthen existing agreements in ways to share the "learning investments" necessary to bring new climate-friendly technologies into the marketplace. Through the Global Environment Facility, industrialised countries explicitly support learning investments but in developing countries only. Co-ordination of related activities at a global level, i.e. to include developed countries, which takes various other roads, could be strengthen, as support for early deployment in any country is likely to help advance investment conditions favourable to technology development and transfer.

Third, despite low prospects for comprehensive agreements on technology dealing with every aspect of technical change, better coordination between governments in a number of areas could help. These might include testing methods and consumer information obligations, and possibly performance standards as well as promotional labelling. They may facilitate simultaneously international trade and efficiency improvements in the best interests of industries, consumers and the environment.

Finally, the possibilities of the flexible mechanisms in fostering technology transfer might be greatly enhanced by a move from project-based mechanisms to international emissions trading, where such a system included not only industrialised but also developing countries. Such a move is likely to take time and require a willingness on the part of all countries to extend the current policy architecture governing mitigation action.

Effectively dealing with climate change will require deep technical changes. As it takes times to develop, demonstrate and manufacture new technologies, there is urgency in getting stronger collaboration. As effective technology change requires a combination of both new technologies and new policy measures to induce take-up of these technologies, international collaboration on technology policy can be equally important as collaborative R&D. Finally, technology transfer to developing countries may induce "leapfrogging" to today's best technologies thus avoiding the polluting technologies of the past.

1. INTRODUCTION

1.1 Context and background

Climate-friendly technologies are likely to play a prominent role in mitigating climate change. Thus, technology research, development and dissemination require careful attention from all governments. Having considered a "scoping paper" on technology proposed by the Secretariat (Bygrave, 2002), the Annex I Expert Group (AIXG) decided in its September 2002 meeting to focus attention on the numerous challenges faced in promoting new and alternative, low and carbon-free technologies. The AIXG reviewed and agreed to release in June 2003 an initial paper entitled *Technology Innovation, Development and Diffusion* (see box 1).

The AIXG indicated an interest to focus the next issue paper in this area on the international dimensions of technical change, and in particular to the issues related to international technology co-operation. This paper responds to that request. It aims to provide an overview of the various issues faced by governments of both OECD and non-OECD countries when trying to enhance technology cooperation in the scope of climate change mitigation.

The paper is in three parts. The first section considers the potential advantages and drawbacks of international technology collaboration from various standpoints. The second section is an assessment of the current landscape: what has been said and done so far, what seems to be working and what seems not to be working and why. The third section elaborates on these issues to consider ways and means to increase international technology collaboration. These suggestions are aimed at policy makers of both OECD and non-OECD governments and may or may not be best considered in the context of the UN Convention on Climate Change. The conclusion summarises the discussion and considers options for future work.

1.2 Defining technology collaboration and transfer

The UNFCCC definition of technology transfer is somewhat narrow, as it only reflects technology transfers flowing from Annex II countries to non-Annex I countries.

The Intergovernmental Panel on Climate Change (IPCC) uses technology transfer in a much broader sense than the UNFCCC does. For the IPCC (2002), "technology transfer" (is defined as) "*a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, non-governmental organizations (NGOs) and research/education institutions*." (…) *"The broad and inclusive term "transfer" encompasses diffusion of technologies and technology cooperation across and within countries. It covers technology transfer processes between developed countries, developing countries and countries with economies in transition, amongst developed countries, amongst developing countries and amongst countries with economies in transition."* This paper uses the term international collaboration in a way that resembles the IPCC's definition of technology transfer.

This structure of this paper does not reflect a clear-cut distinction between technology collaboration and technology transfer – though, arguably, technology transfer from industrialised countries to developing countries might be very different from many viewpoints from technology collaboration between, for example, two or more industrialised countries. The distinction in this paper is somewhat different: technology collaboration means every effort made to share technology innovation, development and diffusion. The analysis thus includes technology transfer but is not limited to nor focused on it.

Box 1: Technology Innovation, Development and Diffusion

Philibert (2003) first assesses the options for reducing energy-related CO_2 emissions. It discusses in particular the role of existing and future technologies, and the question of competitiveness of non-carbon technologies. A related appendix examines more closely the main energy options, from end-use efficiency to fuel switching, nuclear, renewables, and carbon capture and storage, discussing long term potential for each. This examination suggests that, while a non-carbon energy future remain largely uncertain, excluding any option is likely to entail higher costs for achieving any given atmospheric CO_2 concentration target – or lead to higher concentration levels for any given amount of global expenses for mitigation.

The paper goes on by examining how technologies evolve, the respective role of technological and behavioural changes, and the need to create markets for new energy technologies. It considers learning-by-doing processes, and the path dependence that may result. One important conclusion was that Research and Development (R&D) efforts and investment decisions in the short term were critical in determining which long-term options will be available.

The paper continues by considering various policy tools that may induce technology change, some very specific (e.g., R&D subsidies), and others with broader expected effects (e.g. taxes or cap-and-trade systems). A broad conclusion is that policy mixes using a range of instruments seem more effective than any isolated measure in promoting technical change.

Finally, the paper reviews some international dimensions of technical change, such as international collaboration, spillover effects and technology transfer policies.

The overall conclusion is that policies specifically designed to promote technical change, or "technology push", could play a critical role in making available and affordable the new energy technologies that will be required given the depth of the emission cuts necessary to fulfil the Convention's objective. Although other instruments, notably market instruments, would also drive some technical change, the usual myopia of market actors is unlikely to provide for the broad changes required.

However, it is equally unlikely that an approach limited to "technology push" would be sufficient to achieve the Convention's objective, for two reasons (roughly similar but distinct with respect with timing). First, there is a large potential for cuts that could be achieved in the short run with existing technologies; and second, development of future new technologies requires a market pull as much as a technology push (IEA, 2003a).

2. THE POSSIBLE ADVANTAGES AND DRAW BACKS OF INTERNATIONAL TECHNOLOGY COOPERATION

In spring 2003, it took only four weeks to identify and entirely sequence the genome of the virus responsible for the severe acute respiratory syndrome (SARS). This result came from the co-operation of 13 laboratories in 10 countries, who shared their knowledge to the benefit of everyone. The SARS success story offers a striking example of the benefits of increased international co-operation: saving time and money in efforts to fight a new disease, and finally saving lives.

While the SARS case offers an example of how international co-operation can accelerate research results, the case of technology innovation, development and dissemination is, however, somewhat different.

Some analysts have stated that a climate strategy focused on broad technology cooperation would not be environmentally effective. Technological cooperation without environmental commitments would induce a growth in wealth and welfare – and not lower global GHG emissions (Buchner et al., 2003*a*). The case might be different, however, if one specifically considers technology cooperation focusing on zero or low GHG emitting technologies, as well as energy efficiency improvements, as suggested in this paper.

A few important aspects will be briefly considered in this section:

- The potential benefits from shared Research, Development and Dissemination (RD&D) efforts
- The possibility that cooperation might stimulate countries to provide more R&D, since environmentally-friendly technologies have some characteristics of a public good.[1]
- The possibility that technology co-operation can act as a political driver
- The potential drawbacks related to competition
- The possibility that collaboration may actually slow technological development

2.1 The potential benefits of sharing efforts

Cooperation on R&D allows each participant to benefit from others' efforts. It thus magnifies and accelerates results and helps disseminate them. International exchange of lessons learned and best practices in energy technology policies, from research to deployment, can contribute to improve the economic efficiency of increasing the use of clean and efficient technologies. Specifically, international collaboration on energy technology development reduces the costs of R&D by enabling the sharing of results and by avoiding the duplication of efforts, and through the resulting increased rate of technological progress. International science and technology development, exchange and diffusion through public-private partnership for technology absorption, capacity building and innovative project financing mechanisms are desirable and mutually beneficial to developed and developing countries.

The IEA implementing agreements, described in more detail in the next section, provide an insight to the value of international collaboration. Information sharing is the first step in cooperation. As it increases towards more integrated collaboration, it could take the form of task sharing or cost sharing or both. Under task sharing, collaborating entities manage to undertake separately various tasks from a common agenda. They do not only share results – they work in a coordinated manner from the onset to avoid duplicative efforts, saving time and money. Under a cost sharing scheme, they contribute to a common fund for conducting an experiment or equipment purchase, operation of a single facility, or information exchange and processing in an international centre, or operation of a secretariat.

In few cases, the amount of investment needed to go ahead would simply discourage any country to work alone. This is, for example, the case for fusion R&D, where the four major fusion programmes (EU, Japan, Soviet Union and US) decided, at the end of the 1980s, to join the efforts together in the ITER[2] project, thus initiating one of the largest international co-operation projects in the technology field.

[1] Public goods are characterized by "non-rivalry" (the consumption by some does not diminish the consumption by others) and "non-excludability": nobody can be prevented from enjoying the benefits of environmental improvements. Economic theory shows that public goods are undersupplied by free markets.

[2] "The way" in Latin. Formerly interpreted to stand for "International Thermonuclear Experimental Reactor", although this usage has been discontinued.

2.2 R&D on clean technologies: twice a public good?

Another possible advantage of cooperation in R, D&D might be to induce countries to increase their effort. This is likely to be relevant for publicly financed R&D efforts – where companies, national or international, cannot easily be excluded from the results; hence the public good nature of R&D efforts – particularly basic research.

The reason why in this case countries may increase their effort stems directly from the economic theory of public goods, which explains why private agents have a tendency to invest too little in basic R&D. Rational economic agents acting in isolation are likely to limit their basic R&D effort so as to equalise the marginal cost of their own effort with the marginal benefit they get from it. The optimum would require, however, that they raise the level of their effort so as to equalise their marginal cost with the benefits that each of them get from the action of all. This is one of the rationales for governmental R&D programmes.

Simply replace "economic agents" with "countries" – and the usual justification for public R&D efforts or support (public funding of private R&D) seems to equally apply for justifying international R&D collaboration. Voluntary collaboration between countries would thus be the equivalent of the cooperation on financing public R&D between millions of citizens that only governments can ensure at country level.

This is all the more true when the goods that research and development efforts help produce are themselves public goods or, even more, global public goods. Climate change mitigation (and, to a lesser extent, adaptation) belongs to this category, as does public health (the SARS case considered above), but also international market efficiency, financial stability, equity, peace and security, etc. (see Kaul et al., 1999). In that sense, R&D efforts towards producing climate-friendly technologies might be thought of as having twice the characteristic of a public good.

However, the argument is limited to the extent that R&D results are "non-excludable" – that is, easily appropriated by other companies or other countries. This is likely the case for basic research results, as opposed to applied research results. For the former, the "public good" argument may be relevant, and increased international collaboration drives more efforts – higher R&D expenditures. However, as far as more applied research results are concerned, it may not work anymore. Thanks to the advantages that companies, and indirectly countries, may receive from R&D expenditures when other companies and countries are excluded from these results, these expenditures may not be increased as a "mechanical" result of more international cooperation, as companies or countries have a different set of motives to pursue R&D efforts in our competitive world – that of getting a competitive advantage.

However, this does not signify that current R&D expenditures in climate friendly technologies are "optimal" – on the contrary, there is evidence to suggest that they may not be enough to help mankind effectively deal with the threat of climate change.

2.3 International technology cooperation: a political driving force?

All countries are interested in being leaders in technology development – if not for protecting the climate, at least for competitive concerns. Therefore, one may think of technology cooperation as a way to engage more countries into action (or into more action).

This is particularly true for developing countries, whose negotiators often recall Article 4.7 of the Convention that reads: "The extent to which developing country Parties will effectively implement their commitments under the Convention will depend on the effective implementation by developed country Parties of their commitments under the Convention related to financial resources and transfer of technology

(…)”. Probably, however, the effectiveness of technology cooperation in engaging more countries into more action might be relevant for all countries, not only developing ones.

Countries reluctant to adopt binding quantitative commitments on their emissions that may be felt unduly “restrictive” in terms of economic development, lead to unknown costs and raise concerns from various stakeholders might find in technology cooperation a more “positive” way of introducing – at least in part – the same kind of changing patterns.

From a theoretical standpoint, extensive cooperation on global environmental issues is difficult to achieve because the public nature of the global environment creates strong incentives to free-ride. The literature often suggests “issue linkage” as a way to overcome such difficulties. Buchner et al. (2003*b*) have investigated if a linkage between cooperation in the field of low carbon technology R&D and cooperation in emissions control could provide an incentive for the US to “come back” to the Kyoto Protocol. The incentive would thus be, for the US, to benefit from technological spillover arising from R&D efforts undertaken by others – namely the EU, Japan and the Former Soviet Union in this study. Their conclusion is that such issue linkage would not be an effective strategy, because it would be based on an implicit non-credible threat. By refusing to cooperate with the US on technology, the EU, Japan and Russia would simply increase their losses: *“They would thus prefer to cooperate with the US on technological innovation and diffusion even when the US free-ride on climate cooperation”.* One key factor explaining this result may be the high R&D expenditures level in the US making technology cooperation profitable to others. However, this analysis also suggests that all Annex I countries would benefit from technology cooperation.

For other countries however, notably most developing countries, such an “issue linkage” between technology cooperation and emission control may prove effective and induce more countries into taking more action. Taking an example from the Montreal Protocol, Benedick (2001) writes that *“technology provides an irresistible incentive for developing countries to accept commitments”*. Of course, some experts in developing countries may argue that such a linkage would be unfair as technology transfer is a commitment of developed countries under the Convention. However, Article 4 commits all Parties to *“Formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to mitigate climate change”*. Moreover, such a linkage is already embedded in the Convention Article 4.7 recalled above.

Technology co-operation may ease some of the barriers to strengthen emissions mitigation co-operation, even if no direct linkage is made between the two. This could be achieved by (a) promoting a deeper understanding of each others difficulties; (b) helping build confidence among countries; (c) increasing the depth of relationship between government, NGO or business people in and between the various countries; and (d) remaining engaged on common mitigation action at a time when countries have difficulties agreeing on any global scheme to address greenhouse gas emissions.

2.4 Cooperation and competition: a conflict of interest?

How do cooperation and competition coexist? Competition is well-recognised as a very important driver for innovation. While collaboration may be seductive as far as basic knowledge is required, as suggests the genome sequencing of the SARS case, requiring collaboration when technology is at stake may be thought of as a killer for competition.

In this respect, one must first distinguish how firms and how countries – or states – compete. Countries compete to some extent, but also need each other. Firms do not really need competitors – though competition is good for consumers. Consider the two multinational giants of sodas: if one of them went bankrupt, the possible negative effect on the other’s selling would be close to nothing. Pepsi workers represent a trivial number of Coca-Cola’s consumers, and vice-versa. If they become jobless and poorer, the survivor's selling will not significantly decline – while they would likely increase a lot from the disappearance of the most significant competitor.

Consider now the EU, the US and Japan – the three largest economies. EU and Japanese consumers are important for US firms – and US consumers important for EU and Japanese companies. They are deeply interlinked. Recession in one country weakens the others' economies. This does not prevent states competing on a wide number of grounds, and supporting by various means their "national companies" and workforce in the international competition is a permanent temptation. It is recognised as unfair and globally inefficient, though, and a large part of the international agenda is made of talks – or procedures – attempting to remove subsidies and other barriers that may distort fair competition.

These dimensions are all present in international collaboration for technology. Countries have a common interest in fostering the development of innovative technologies, but they are also interested in helping their own companies to take the lead in the international economic competition. As notes Martin (1999), *"theories of international cooperation made a big leap forward by accepting the assumption that states are self-interested and have conflicts of interests with one another.* (…) *Theories of international cooperation define cooperation as mutual adjustment of state policies to achieve outcomes that all prefer to the status quo. Cooperation is clearly differentiated from harmony, in which states pursue policies that other states prefer without any explicit mutual adjustment".*

Cooperation most often occurs in the early stages of technology development, where primary research costs are prohibitive and the prospects for commercialization and/or cost recovery are not readily apparent. For example, long R&D cycles and significant investment, such as CO_2 sequestration and hydrogen, require cooperation to defray costs. However, as development proceeds closer to commercialization along the "development supply chain", domestic competitive concerns become dominant and the prospects for cooperation become increasingly limited. Commercially sensitive R&D is typically done by industry behind closed doors.

2.5 International collaboration: A potentially unproductive process?

International technology collaboration may have a number of benefits. However, there might be several draw backs as well. Here are some possibilities:

- The search for wide agreement may require time and resource consuming efforts, and thus slow, rather than speed, the innovation and diffusion process;
- Some players might deliberately slow processes in some technologies in order to protect vested interests in competitive technologies;
- A difficulty to protect intellectual property rights in close cooperative work may offset an incentive for some players;
- Premature technology selection might impede necessary competition between various technology options. Cooperation can prematurely foreclose good and potentially-significant technology pathways. "Following the crowd" can be a drawback to finding the transformative technologies which are needed to make significant improvements.

The problem therefore is to create approaches that make effective use of competition, where appropriate, and to utilise cooperative means in those circumstances that are not easily accommodated by competitive approaches.

3. INTERNATIONAL TECHNOLOGY COLLABORATION: THE LANDSCAPE

This section describes the current state of international technology cooperation, focusing mainly on cooperation between industrialised countries, on the one hand, and developing countries on the other. It considers first the context of globalisation in trade and investment, then recalls the most important outcomes from the UNFCCC negotiations, before examining the IEA experience, the Climate Technology Initiative, and finally bilateral and other multilateral efforts.

3.1 The globalisation context

Trade liberalisation and the globalisation of capital markets have significant implications for climate change policies. As Charnovitz (2003) noted, "*On the one hand, lowering trade barriers and opening markets boosts economic growth, which tends to increase GHG emissions. On the other hand, bigger markets spur technological innovation and diffusion, which can reduce the GHG intensity of economic growth. Moreover, as trade promotes higher national incomes, some countries will find themselves better able to afford emission abatement efforts*."

Therefore, independent of any technology cooperation and transfer policy, technologies diffuse from country to country through a wide number of channels, including trade, foreign direct investment and patent licensing, but also through other, more indirect means, such as emigration, travels and visits, exchanges of students, international scientific and technology journals and conferences, the Internet and others. As a result, in the course of industrialisation, newcomers have seen their energy intensities peak at lower levels than countries industrialised earlier (Martin, 1988). In the current context of globalisation, this trend cannot but be reinforced.[3]

This does not mean, however, that globalisation and development will, by their own virtues, find a solution to the climate change or other environmental problems. Indeed, emissions of pollutants with local effects usually increase, and then decrease in the course of industrialisation, following what has been called an "environmental Kuznets curve". Moreover, as notes Sugiyama (2003), "*the lessons from the history of pollution control suggest that followers have been always doing better than precedents. For SO_x emissions, for example, massive reduction measures were taken around 1970 in Japan and around 2000 in China. It is remarkable that China did it at income level of less than USD 1000, which is a tenth of Japanese income at 1970*". Indeed a wide literature on the environmental Kuznets curve suggests that environmental performance is driven by a variety of other factors in any particular country. For example, civil liberties, participation and other governance factors play a big role by raising public awareness and influencing political will to improve the environmental performance that accompanies development (Pacala et al. 2003).

Further, rising incomes have generally not led to a decline in greenhouse gases. Observed reductions in greenhouse gas intensities of our economies have not been sufficient to offset increases resulting from economic growth. Reductions in emissions of local air pollutants sometimes reduce greenhouse gas emissions (if driven, for example, by a switch from coal to gas), but they do not necessarily do so (fuel cleaning or end-of-pipe devices, for example, on the contrary increase fuel consumption and related CO_2 emissions).

[3] However, it must also be noted that some developing countries remain left out, or partially left out from the current globalisation process– for various reasons, which will not be discussed here.

We will consider current trends regarding official development assistance, foreign direct investments, the globalisation of innovation and possible “spill over” of national policies.

3.1.1 Official Development Assistance

ODA flows were 10 % lower in 2000 than in 1990, however this declining trend has begun to reverse itself, with growth in ODA occurring in the three years prior to 2002 (OECD 2003). This evolution of an overall decline in ODA flows over the last decade is inconsistent with the thirty-year-old commitment by most developed countries to increase their level of assistance to 0.7 % of their gross national incomes. However, the decline is largely explained by a decline of strategic and military aid, while aid for social programmes (education and health) and environment investments has increased (Heller & Shukla, 2003).

Moreover, the assistance that donors now favour has shifted in quality from hard, technological assistance to soft, institutional and selective aid for which both nations (those most committed to governance reform) and population (those most in poverty) qualify. However, strategic and political considerations have remained of primary importance for most donor countries. Many of the rapidly developing and relatively “wealthy” developing countries remain the largest recipients of aid today.

These trends, as well as the tighter context of public money in most developed countries, suggest that while some public funding will remain available for financing the “software” of technology transfer – capacity building, enabling environments, etc. – “hardware” financing should increasingly be expected from private investments. Government interventions in both investor and host countries might direct this towards cleaner technologies.

3.1.2 Foreign Direct Investments

As official development assistance stagnated, private flows to developing countries increased roughly five-fold over the past decade – and decreased in both 2001 and 2002 after the 2000 peak (Heller & Shukla, 2003). Foreign direct investments (FDI) took the lion’s share over other forms of external financing such as bank lending, but flowed disproportionately to a small number of developing countries. In 2002, developed countries received about three quarters of total FDI inflows (US$ 460 billion) while developing countries received one quarter (US $ 162 billion – including South-South transfers) – though China became the first recipient country.

Between 1970 and 1990 investment in state-controlled power sectors was in the form of soft loans from state development banks and multilateral concessionary financing. Since these sources began drying up in the 1990s, countries like Brazil, China, India and Mexico increasingly looked to foreign investors and initiated reforms to attract them. From 1990 to 2000 more than US$ 680 billion of FDI went to infrastructure in more than 120 developing countries. Electricity and natural gas investment accounted for a third of the total flow, following only Telecom investments. (Heller & Shukla, 2003)

OECD (2002b) examines in detail the issue of FDI and technology transfer, from the firm’s point of view in a developed country perspective. There are three basic ways for a firm to exploit its technologies abroad, and consequently, three different ways for countries to acquire that technology.

- Through <u>trade</u>: international technology transfer through trade occurs when a country imports higher-quality (than it can produce itself) intermediary goods to use in its own production processes. A 1999 study, using data from 87 countries, concludes that trade indeed serves as a channel for international technology transfer to developing countries. It would appear however that intra-industry trade plays a more important role in technology transfer than inter-industry trade. The former trade is more pervasive among developed countries, and inter-industry trade is more prominent between developed and developing countries. Hence, an immediate implication of their findings is that developing countries enjoy relatively less technology transfer from trade than developed countries.[4]

- Through licences: a firm may *licence* its technology to an agent abroad who uses it to upgrade its own production. Successful penetration of foreign markets can seldom be based on exports alone. Various tariff and non-tariff barriers, government policies or the general investment climate can make exporting a costly option. Also, for certain industry sectors, notably in services, trade can be a complicated means to exploit a firm's superior technology or management capabilities overseas. In this case, a firm may choose to license its technology to a local firm.
- Through investment: a firm can set up a foreign establishment to exploit the technology itself. FDI is the most important means of transferring technology to developing countries. Technology transfer through FDI generates benefits that are unavailable when using other modes of transfer. For example, an investment is not only comprised of technology, but also includes the entire "package", such as management experience and entrepreneurial abilities which can be transferred by training programmes and learning by doing. Further, many technologies and other know-how used by MNE affiliates are not always available in the market, and only available through the MNE itself. Also, some technologies, even if available in the market, may be more valuable or less costly when applied by the firm that developed them rather than by an outsider. (Tebar Less C., 2003)
- Similarly, options for firms from a developing country perspective have been considered by Ramani et al. (2001). They distinguish technology purchase, or market purchase of machines, patents, licenses or even firms, and technology collaboration, which involves joint control of resources and networking. Elaborating on the Indian biotechnology sectors, they suggest that the learning capacity of firms in developing countries is the key criterion for success: firms with strong learning capacities would be as well off with technology purchases, while firms with weaker capacities would prefer to engage in collaboration with foreign companies. However, foreign companies will themselves prefer to engage in collaboration with a developing country firm with the stronger learning capacities – not the weaker.
- One important dimension of this rise in FDI, especially when going to developing countries, has been the role of Export Credit Agencies (ECA). These financial institutions promote exports and facilitate investments in riskier markets. During the last decade, ECA financing through loans, project guarantees and investment insurance averaged around US$ 90 billion per year – representing almost a third of all the long term financing received by developing countries.

Both greenfield investments and mergers and acquisitions (M&A) are part of foreign direct investment and both are relevant to technology transfer. M&A have proven effective in fostering cooperation and transfer, especially when combining diverse capabilities and experiences gained in different fields. For example, Martin (1996) notes that in the last three decades, of the various technological paths, that of combined cycle turbines has had the most success, *"because technological developments have been supported by a restructuring trend, closing the gap between electromechanical engineering and aircraft engine manufacturers. Examples of this include: the merger of ASEA-Brown Boveri (ABB) with GCE-Alsthom; the ABB-NEI joint venture; the extension of the Westinghouse-Mitsubishi alliance; the European Gas Turbine joint venture; the production agreements between General Electric (GE) and Toshiba and between GE and Hitachi; the Pratt and Whitney-Siemens alliance; and the extension of the alliance between Rolls Royce and Westinghouse."*

According to the OECD (2001), in general, multinational enterprises [MNEs] operate at the highest corporate standard of environmental performance world-wide, rather than tailoring their production methods to the level of regulatory enforcement prevailing in host country markets. However,

[4] OECD (2001), quoting Hakura and Jaumotte (1999).

multinationals may still transfer, as it often happened in the past, obsolete or inefficient technologies to developing countries through subsidiaries or licensing arrangements. It must be noted that the OECD has adopted in 2000, together with a few non member countries (notably Argentina, Brazil, Chile) – and its member countries, as well as a few developing countries, are committed to promote – guidelines for MNE that aim at promoting responsible business conduct from various perspectives – including the environment (see at www.oecd.org/daf/investment/guidelines/).

Neumayer (2001) finds little evidence of pollution-intensive industries leaving countries with high environmental standards for the so much-feared "pollution havens" in developing countries. He suggests various explanations: some industries are dependent on being close from their product markets; the costs of environmental compliance might be too low to play a role, or do not represent a big issue as they apply equally to all competitors; investors anticipate that standards will be raised in developing countries; scale economies in reducing pollution may justify expansion in home country rather than new units in foreign countries; it may simply be more efficient to run a single set of environmental practices worldwide than to scale back environmental practices at a single overseas location; foreign investors might fear for their international reputation (and negative effects on their capital market value) if they are perceived as environmental villains exploiting low standards in poor countries. This risk is perhaps compound by the high visibility of MNEs in developing countries, which can make them particularly attractive targets for local enforcement officials.

3.1.3 Globalisation of innovation

One aspect of particular interest is globalisation of innovation, and several indicators illustrate this trend. Following Archibugi & Iammarino (1999), globalisation of innovation consists of three different categories: the international exploitation of technology produced on a national basis; the global generation of innovation; and the global technological collaboration.

Representative of the first category is perhaps the annual average growth of 13% of international patents in the decade 1985-1995. The second category includes notably patents generated in foreign subsidies of large firms – a real but still limited phenomenon that is slowly growing. The third category is international techno-scientific collaboration between firms. The number of international technology agreements between firms has doubled in the 1980s, representing 60% of all inter-firms (national and international) technology agreements.

The share of R&D financing in OECD countries from abroad doubled between 1985 and 2001, rising from 7.7% to 15.5% in Canada, 1.2% to 2.1% in Germany, 6.6% to 12.4% in Ireland, 8% to 16.3% in the UK, and 3.7% to 7.7% in the EU as a whole. In some OECD countries (Austria, Belgium, Iceland and the Netherlands), this growth rate was even higher. Another indicator of the globalisation of innovation might be the technology balance of payments -- money paid or received for the acquisition or use of patents, licenses, know-how, trademarks, patterns, designs, technical services (including technical assistance) and for industrial R&D carried out abroad, etc. It suggests that countries have performed very differently with respect to their ability to exploit their domestic innovations on international markets. The US steadily increased incomes from US$ 6 billion in 1981 to 22.5 billion in 2001, while the German deficit increased from US$ 0.5 to 4.8 billion over the same period. (OECD, 2002c)

Developing countries may not be left out of the internationalisation of private R&D. For example, China not only attracts significant Foreign Direct Investment (FDI) but also R&D investment from foreign own companies operating on its territory. Over 50 MNEs, including Intel and Microsoft, have established R&D centres in China to tap the local pool of technical personal. They are not only doing locally-oriented R&D (obviously an important part of technology transfer), but also act as nodes in these MNEs' global R&D activities (Liu & White, 2001).

3.1.4 Spillover

This context has significant implications when considering the global effects of national technology development policies. For example, Grubb et al. (2002) have considered spillover effects from the Kyoto protocol in terms of their aggregate impact on emission intensities over the next century, and found that positive spillover occurring spontaneously is likely to exceed leakage.

Technology spillover is not usually focussed towards GHG emissions reductions. For example, most projects backed by Export Credit Agreements (ECA) in the 1990s supported energy-intensive exports or investments into fossil-fuel power plants, oil and gas development, energy-intensive manufacturing and transportation infrastructures. However, things may be worse without these investments – as suggested by the decreasing curve of energy intensity peaks over the long run mentioned earlier. In any event, maintaining underdevelopment is not an option to mitigate climate change! Investments in gas infrastructure may displace growing coal use, newly-built power plants using state-of-art techniques used in developed countries are more efficient than alternatives built without foreign direct investment and other possible forms of technology transfers.

In sum, industrialised countries are not performing poorly in transferring various, “indiscriminate” technologies to developing countries. Rather, technology flows from developed to developing countries provide powerful potential leverage for action. An important means to influence developing country emissions possibly remains an effective action by developed countries to mitigate their own emissions – and develop the necessary technologies to do so (Grubb et al., 2003). However, the mere availability of climate specific technologies and processes (e.g. some renewables, geo-sequestration, flaring of vented waste gas) that do not have other drivers for adoption (such as energy efficiency or pollution reduction) will not result in developing country adoption, especially when these technologies are costlier than conventional technologies. In all countries there must ultimately be a set of signals to emitting industries and sectors to reduce emissions through government commitments, policies and programmes.

3.2 The UNFCCC outcomes

It is beyond the scope of this paper to recall all relevant decisions and activities taken by the Conference of the Parties or its Subsidiary Body for Scientific and Technical Advice on technology cooperation and transfer. Only the most important outcomes (and relevant articles in the Convention) will be highlighted.

3.2.1 The Convention text

Article 4.1 (c) stipulates that all parties shall “promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol in all relevant sectors, including the energy, transport, industry, agriculture, forestry and waste management sectors”. Furthermore, Annex I Parties shall (article 4.2 (e)) “coordinate as appropriate with other such Parties, relevant economic and administrative instruments developed to achieve the objective of the Convention”.

Regarding technology transfer, the most important article is 4.5 that stipulates “The developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention. In this process, the developed country Parties shall support the development and enhancement of endogenous capacities and technologies of developing country Parties. Other Parties and organisations in a position to do so may also assist in facilitating the transfer of such technologies.”

Subsequent negotiations have usually aimed at developing the issues surrounding technology transfer – in the narrow sense of transfer from developed to developing countries – not the broader concept of technology cooperation. The following paragraphs reflect this trend.

It must also be noted that the issue of technology transfer – and even that of environmentally sound technology transfer – is not limited to climate change in the international arena – and the climate negotiations have also elaborated on this work.

For example, the Agenda 21 had already identified the most critical dimensions of technology transfer in its Chapter 34: "Environmentally sound technologies are not just individual technologies, but a total system which include know-how, procedures, goods and services, and equipment as well as organizational and managerial procedures. This implies that when discussing transfer of technologies, the human resources development and local capacity-building aspects of technology choices, including gender-relevant aspects, should also be addressed. Environmentally sound technologies should be compatible with nationally determined socio-economic, cultural and environmental priorities."

3.2.2 Technology transfer under the Convention and the Expert Group on Technology Transfer

At its fourth session in Buenos Aires (1998) the Conference of the Parties (COP) launched a consultative process on technology transfer. Countries and other stakeholders were invited to provide inputs. This consultative process proved instrumental in preparing further negotiations.

At its seventh session in Marrakech (2001), the COP established an Expert Group on Technology Transfer (EGTT) to enhance implementation of Article 4.5 of the Convention. Apart from this institutional setting, the technology transfer framework agreed upon at Marrakech includes four activities that are intended to be part of an integrated market transformation strategy and to create conditions for private and public technology transfer:

- technology needs assessments
- technology information
- enabling environments for technology transfers
- capacity building

With respect to technology needs assessments, more than 60 countries are currently undertaking technology needs assessments, mainly with GEF financing, while a UNDP-GEF handbook for so doing is still under development. Indonesia, Georgia and Ghana have already provided reports.

With respect to technology information, the Secretariat has developed a web-based technology transfer information system/clearing house (TT:Clear). This web site has the main goal of improving the flow of, access to and quality of the information relating to the development and transfer of environmentally sound technologies (ESTs) under Article 4.5 of the Convention and of contributing to a more efficient use of the available resources by providing a synergy with other ongoing efforts. It provides up-to-date information about technology transfer, allows direct access to databases, publications, and case studies and promotes an exchange of views on different technology transfer issues.

With respect to enabling environment, a workshop was organised in Belgium in April 2003, on the basis of a document prepared by the Tara Energy Research Institute (TERI, 2003). This paper defines "enabling environments" as government actions, including macroeconomic policy reforms, economic incentives, and legal and regulatory frameworks, that provide desirable conditions for cross-border transfer, internal diffusion, and uptake of mitigation and adaptation technologies. They are the responsibility of parties transferring as well as receiving technologies. While governments should create these conditions, they must be supported by multilateral organisations and banks, private industries and firms, academic and research institutions, and civil society organisations. Identified barriers to technology transfer are grouped in 8 categories: institutional, political, technological, economic, information, financial, cultural and general. TERI (2003) then looks at these barriers and ways to overcome them on a sector-specific basis, following the sectoral analysis of the IPCC (2000).

3.2.3 The Global Environment Facility

Since its inception, the Global Environment Facility (GEF), acting as the financial mechanism of the Convention, has given US$ 1 billion for climate change projects and leveraged more than US$ 5 billion in co-financing. Usually, GEF funds are linked to other loans from multilateral institutions (e.g., the IBRD or the ADB); they are also linked to projects financed with national or bilateral funds. The GEF is also intended to leverage private investment and technology transfer; however, *"many opportunities remain unexploited and many barriers still constrain GEF in engaging the private sector more widely in its projects"* (Christoffersen et al., 2002). More than half has been devoted to renewable energy projects and more than a quarter to energy efficiency projects in 47 developing and transitional countries. The 2002 repartition gave greater emphasis to enabling activities (12,3%) and sustainable transportation (4.4%) while the energy efficiency projects rose almost to the level of renewable energy projects, with 40.3% and 42.3% of funding respectively.

In 2002, just before the World Summit on Sustainable Development in Johannesburg, donor nations agreed to replenish GEF's trust fund by US$ 3 billion – the largest amount ever. The funds will be spent between 2002 and 2006 on the four initial GEF topics (biodiversity, climate change, international waters and the ozone layer) plus two new ones (land degradation and persistent organic pollutants).

The GEF operating programme n°7 is of particular interest, built around the notion of learning-by-doing. One of its objectives is the reduction in costs of low greenhouse gas emitting technologies by increasing their market shares. The program considers several backstop technologies for both supply and demand sides, although it emphasises:

- Photovoltaics for grid-connected bulk power and distributed power (grid reinforcement and loss reduction) applications;
- Advanced biomass power through biomass gasification and gas turbines;
- Advanced biomass feedstock to liquid fuels conversion processes;
- Solar thermal-electric technologies in high insulation regions, initially emphasising the proven parabolic trough variant for electric power generation;
- Wind power for large-scale grid-connected applications;
- Fuel cells, initially for mass transportation and distributed combined heat and power applications; and
- Advanced fossil fuel gasification and power generation technologies, initially to include integrated coal gasification/combined cycle technologies.

3.2.4 The Marrakech Funds

The Marrakech Accords created a Special Climate Change Fund under the Convention to provide additional assistance for adaptation, technology transfer, energy, transport, industry, agriculture, forestry, and waste management, and broad-based economic diversification. A Least Developed Countries Fund was also established under the Convention, while an Adaptation Fund was established under the Kyoto Protocol. Previously in Bonn, at COP-6 bis, a number of countries (the EU, Canada, Norway, New Zealand, Switzerland and Iceland) made a political statement that they would provide a minimum of US$ 410 million per year for climate change activities – including their climate contribution to the GEF. Recently, the Parties to the Convention agreed that the Special Climate Fund should serve as a catalyst to leverage additional resources from bilateral and multilateral sources. There was also agreement that top priority should be given to funding of adaptation activities to address the adverse impacts of climate change from the resources of the SCCF; and that technology transfer and its associated capacity building was also important.

However, these new funds were created in a context of increasing scarcity of public spending in most OECD countries. Many observers believe that while it will help to finance capacity building at national levels, it will never be large enough to finance the costs associated with the profound changes in the energy sector required to promote development while reducing global emissions. This scepticism is also fuelled by the decline in Official Development Assistance mentioned earlier.

3.2.5 The flexibility mechanisms

While the primary incentive for technology development is likely to come from the establishment of "caps" on emissions at both country and firm levels, emissions trading is more likely to encourage technology diffusion than innovation. By reducing the equilibrium permit price, trading per se tends to reduce the incentive for firms to innovate that arises from restricting emissions.

However, flexibility mechanisms such as those in Articles 6, 12 and 17 of the Kyoto Protocol are likely to encourage the diffusion of cleaner technologies. The technology transfer dimension of the Clean Development Mechanism is now well-recognised by most experts and countries – although developing country representatives rarely miss an opportunity to recall, as China did that "*The CDM under the Kyoto Protocol should have a component of technology transfer. However technology transfer under CDM should be additional to the commitments of the Annex II Parties under the relevant provisions of the Convention on technology transfer.*" (FCCC/SBSTA/misc02)

What really makes the CDM additional to countries' efforts, however, is its ability to raise private instead of public money and to encourage technology transfer directly from the private sector. It is still unclear, however, if the CDM will have much leverage power (see, e.g., Philibert, 2003; Ellis et al., 2004). Governments of some industrialised countries may also end up being important players in this field.

3.3 The IEA experience

Since its creation in 1974, the International Energy Agency (IEA) has provided a structure for international co-operation in energy technology research and development (R&D) and deployment. Its purpose is to bring together experts in specific technologies who wish to address common challenges jointly and share the fruit of their efforts. Within its structure, there are currently more than 40 active programmes, known as the IEA Implementing Agreements. Almost three decades of experience have shown that these Agreements are contributing significantly to achieve faster technological progress and innovation at lower costs. Such international co-operation helps to eliminate technological risks and duplication of efforts, while facilitating processes like harmonisation of standards.

Box 2: The IEA Framework for Implementing Agreements

The IEA Implementing Agreements represent a successful form of international energy technology collaboration which has existed almost since the Agency's inception.

An implementing agreement (IA) is a contractual relationship established by at least two IEA member countries and approved by the Governing Board, with the purpose to help them carry out programmes and projects on energy technology research, development and deployment. Implementing agreements gather Contracting Parties but also Sponsors.

Contracting Parties may be the governments of both OECD member and OECD non-member countries; the European Communities; international organisations in which the governments of OECD member countries and/or OECD non-member countries participate; and any national agency, public organisation, private corporation or other entity designated by the government of an OECD member country or an OECD non-member country, or by the European Communities. Sponsors may be entities of OECD member countries or OECD non-member countries that are not designated by the governments of their respective countries to participate in a particular Implementing Agreement; and non-intergovernmental international entities in which one or more entities of OECD member countries or OECD non-member countries participate.

These rules are based on the *IEA Framework for Implementing Agreements*, which was adopted in 2003. The Framework replaces the "Guiding Principles" adopted in 1975, as a result of the willingness of Ministers from IEA member countries to expand the energy dialogue with key OECD non-member countries and to encourage industry to participate in energy research, development and demonstration.

Thirty-seven countries participate in 42 Implementing Agreements. Six IAs concern fossil fuel energy, including clean coal and carbon dioxide capture and storage. Nine IAs relate to nuclear fusion power. Eight agreements promote R&D on renewable energy sources, as well hydrogen production and use. Fourteen IAs are devoted to end-use efficiency improvements in transportation, industry and building. An extensive description of the work conducted under Implementing Agreements can be found at: *http://www.iea.org/techno*. The appendix highlights some of the most recent achievements.

The adoption of the *IEA Framework for Implementing Agreements* in 2003 (see Box 3) is intended to facilitate participation from companies and from developing countries. Moreover, while most implementing agreements are focused on technology innovation and development, others are specifically designed to overcome a well known barrier to technology transfer, the lack of information. For example, EETIC (Energy and Environmental Technologies Information Centres) collects, analyses and enhances international exchange of impartial information on new, cost-effective, energy-saving technologies that have been demonstrated in applications in industry, buildings, transport, utilities and agriculture. To date, details on over 1,600 new, energy-saving technology applications have been published in EETIC Energy Efficiency products, as well as information on over 7,700 organisations worldwide involved with greenhouse gas mitigating technologies, contact details for suppliers of technologies, services, equipment, R&D, data and literature in the various categories of fossil fuel, renewable, energy transfer, industry, buildings, transportation, nuclear technologies, and agricultural & forestry practices.

IEA implementing agreements have a limited term that can be extended; however, their executive committees must take stock of their achievements, their forward strategies and their outreach activities each time that approval is sought from the IEA *Committee on Energy Research and Technology* (CERT) for a term extension.

3.4 The Climate Technology Initiative

At the first Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in 1995, 23 OECD countries and the European Commission launched the Climate Technology Initiative (CTI). Its purpose was to accelerate development, application and diffusion of climate-friendly technologies and practices for all activities and greenhouse gases, cost-effective, environmentally sound production and end-use technologies. The CTI's work is closely linked to the UNFCCC process. The roots of the CTI grow from several articles in the UNFCCC that discuss commitments by Annex I countries in the field of technology transfer to developing countries.

Amongst many other accomplishments, the CTI published in 2001 "Technology without border – case studies of successful technology transfers" and in 2002 "*Methods for Climate Change Technology Transfer Needs Assessments and Implementing Activities: Experiences of Developing and Transition Countries*". It also launched the Co-operative Technology Implementation plans (CTIP) to help prepare and implement technology transfer plans. A comprehensive list of actions undertaken by the CTI between 1995 and 2002 might be found on its website (http://www.climatetech.net/).

While shaped for promoting technology transfers to developing and transition economies, the CTI has also demonstrated the value of international collaboration between developed countries in this task. Rather than developing an important autonomous body of expertise, the CTI has used the expert capabilities of several technical institutions of its Member countries, notably the *National Renewable Energy Laboratory* of the US Department of Energy ; the Japanese *New Energy and Industrial Technology Development Organization*, UK's Department of Trade and Industry, Canada's *Natural Resources* and the *Greenhouse Response Branch* of the Australian Ministry of Industry, Tourism and Resources, as well as some bilateral programmes UN agencies such as UNIDO, UNDP and UNEP.

The IEA hosted the CTI Secretariat during the period from 1995 to 2002 and covered those activities that the CTI Board of Management chose to channel through the CTI Secretariat. The CTI Secretariat was financed through voluntary contributions to the IEA from 13 of the 23 CTI member countries. Japan was the only consistent contributor during the period from 1996 to 2002 with 46%, and the US contributed 31% of the voluntary contributions from 1999 to 2001. The balance of CTI activities was financed through in-kind contributions.

In 2003, the CTI decided to turn itself into a new implementing agreement – the first to be devoted to technology transfer. As of July 2003, Canada, Germany, Norway, the UK and the USA have committed themselves to become contracting parties to this new implementing agreement. Denmark and Japan joined soon thereafter."

3.5 Bilateral and other multilateral efforts

Describing or simply listing all governments' bilateral or multilateral efforts to develop international technology cooperation, including transfer, would be beyond the scope of this paper. Bilateral cooperation programmes are numerous, especially (but not exclusively) regarding technology transfer – and many examples can be found in national communications under the UNFCCC. UN agencies, such as UNDP, UNEP, UNIDO and others, as well as other multilateral agencies, such as the World Bank or the OECD, notably through its Development Assistance Committee, are also deeply involved in the transfer of technologies as is, though in a different manner, the World Trade Organisation.

Amongst other initiatives, it is worth quoting the US Climate Technology Partnership (CTP) – a continuation of the former Technology Cooperation Agreement Pilot Project (TCAPP), active in Brazil, China, Egypt, Korea, Mexico and Philippines. Both TCAPP and CTP have focused on identifying country-driven technology priorities and assisting partner countries in implementing integrated market transformation strategies for these priority technologies. Other US programmes are designed to cooperate with one country (e.g., India) or one technology (e.g., coal bed methane). One may also mention the recent US initiative towards a new collaboration in the carbon dioxide capture and storage and hydrogen arenas – namely, the International Partnership on Hydrogen Economy (IPHE) and the Carbon Sequestration Leadership Forum (CSLF).

In the midst of bilateral and multilateral programmes there are also some relevant plurilateral arrangements – they do not gather almost all countries, as multilateral arrangements usually do (or are intended to do), but a more limited number, though superior to two. G8 is probably the most well-established "plurilateral" institution, and has considered climate change in various meetings and from various angles. For example, in 1999 the G8 Cologne Summit asked the Export Credit Agencies to harmonise their environmental policies and help developing countries address the challenge of climate change – as did the OECD Council at ministerial level in the same year. At the Evian Summit in 2003, the G8 went much farther and adopted an Action Plan on "Science and Technology for Sustainable Development". This document contains an important section devoted to energy technology (see Box 3).

Box 3: The G8 Action Plan

Action 2: Accelerate the research, development and diffusion of energy technologies

We will:

2.1 Promote energy efficiency of all sources and encourage the diffusion and uptake of advanced energy efficient technologies, taking pollution reduction into account. Possible measures include standards, public procurement, economic incentives and instruments, information and labelling;

2.2 Promote rapid innovation and market introduction of clean technologies, in both developed and developing countries, including at the Milan Conference of the Parties of the United Nations Framework Convention on Climate Change and beyond, at the International Energy Agency (IEA) and other international fora such as the UN Economic Commission for Europe, the Expert Group on Technology Transfer, etc, finding appropriate methodologies to involve the private sector;

2.3 Support efforts aimed at substantially increasing the share of renewable energy sources in global energy use:

- stimulate fundamental research in renewable energies, such as solar photovoltaics, off-shore wind energy, next generation wind turbines, wave/tidal and geothermal, biomass;
- collaborate on sharing research results, development and deployment of emerging technologies in this area;
- work towards making renewable energy technologies more price competitive;
- participate in the International Conference on Renewable Energies, spring 2004 in Bonn;

2.4 Accelerate the development of fuel cell and hydrogen technologies (power generation, transportation, hydrogen production, storage, distribution, end-use and safety):

- increase international co-operation and exchange of information in pre-competitive research based on the principle of full reciprocity through the IEA and other existing organisations;
- work with industry to remove obstacles to making fuel cell vehicles price competitive, striving to achieve this goal within two decades;
- accelerate developing internationally agreed codes and standards in appropriate existing organisations;
- work together to facilitate the use of hydrogen technologies in our and other markets, including through development of infrastructures;

2.5 Expand significantly the availability of and access to cleaner, more efficient fossil fuel technologies and carbon sequestration systems and pursue joint research and development and expanded international co-operation, including demonstration projects;

2.6 Encourage the Global Environment Fund to include energy efficiency, renewables, cleaner fossil fuel technologies, and sustainable use of energy when setting up its programme;

2.7 Develop codes and standards for next generation vehicles, cleaner diesel and biodiesel, recognising that social needs for fuel quality are diverse among G8 countries;

2.8 In accordance with our national procedures, promote clean and efficient motor vehicles including next generation vehicles;

2.9 Work in consultation with industry to raise energy efficiency of electrical and electronic equipment;

2.10 We take note of the efforts of those G8 members who will continue to use nuclear energy, to develop more advanced technologies that would be safer, more reliable, and more resistant to diversion and proliferation.

It remains to be seen how this G8 Action Plan will provide effective additional action from the G8. However, one may note, amongst others, the intention to *"collaborate on development and deployment of emerging technologies"* and to *"accelerate developing internationally agreed codes and standards"* – two areas further developed in the next section.

4. STRENGTHENING INTERNATIONAL TECHNOLOGY COOPERATION

From the background discussion above, it seems that enhancing technological cooperation at all levels (from R&D to diffusion) can lead to benefits in terms of technological cost reductions as well as accelerated market penetration. It also seems that there is scope for improving technology collaboration in the area of climate change.

This section reviews four distinct fields for international technology cooperation and tries to find out:

i. If and how international trade and investment might be both strengthened and greened;

ii. If and how sharing learning investments might be conceived on a broader base;

iii. If and how more international collaboration on standards and norms might be useful;

iv. If and how flexibility mechanisms can be developed – in and beyond Kyoto.

4.1 Strengthening and greening international trade and investment

Although the last decade has witnessed significant emission reductions in some countries arising from economic recession, constraining economic development is by no means a viable option to mitigate climate change – especially in developing countries where poverty eradication is the number one priority. Increasing wealth and welfare, apart from being desirable per se, would also help countries better adapt to climate change impacts that are at least in part unavoidable.

Thus, further globalisation must be thought of more as a chance than a risk, even for climate mitigation purposes. Reinforcing and "greening" the framework for trade and investment can therefore play a key role in enhancing technology cooperation for mitigating climate change. As will be seen in this section, this may imply further market reforms in developing countries, as well as using appropriately the leverage power of Export Credit Agencies.

4.1.1 Market reforms

So far, many developing countries have undertaken far-reaching but incomplete structural and economic transitions. Virtually all major developing countries are to some extent in the midst of transition from a largely state-centered to a more market-centered system. As noted by Heller & Shukla (2003), however, this transition is contested and prolonged, and its likely endpoint is difficult to discern: *"In reality, the process of transition itself has become a semi-permanent state that is likely to persist for several decades. These countries are in a sense 'hybrid' states caught between markets- and state-centered regimes"*.

As a result both local and foreign companies have to struggle in a particularly complex regulatory environment. This may also influence the patterns of technology collaboration. For example, "*direct foreign investors may hedge against risk by acquiring local partners in a position to influence government decision making to structure markets, financing and contracts along favourable paths*." According to Heller & Shukla (2003), this may present "exceptional opportunities for climate action". For example, *"the proportion of natural gas that will be used in a fast-growing developing nation probably depends more on the capacity of sectoral groups to acquire political sponsorship, financing and tailored rules favouring the placement of pipelines, LNG terminals and urban distribution than on an integrated assessment of relative fuel prices (and environment shadow value)."*

Thus, it may seem that a relatively slow transition towards a full market economy might have some advantages over a more brutal transition – as experienced by some economies in transition since the fall of the Berlin wall. This is not to say, however, that the transition should stop: from both development and climate perspectives it should go on, but at a pace that allows new legal and regulatory regimes to be put in place before fully eliminating the old system. This is more likely to reduce risks for foreign investors, which remain an important vector for technical modernisation.

4.1.2 Export Credit Agencies and development banks

Most energy-related foreign direct investments in developing countries – a fair share of the total – have some support and guarantees from one or several investors' country export credit agencies. These have come under increased scrutiny by analysts, environmental or development NGOs, and multilateral organisations.

As an example, Maurer & Bhandari (2000) considered that the "failure to place ECAs within a wider development and environmental context is generating a policy perversity. Governments pursue one set of objectives through climate negotiations, while their finance and trade arms ignore the global environmental implications of their activities. (…) ECA financing to developing countries favours exports and investments that disproportionately benefit energy- and carbon-intensive industries." Effectively, 40% of foreign investments in developing countries went into fossil-fuelled power generation and oil and gas development from 1994 to 1999, and up to 60% to "energy-intensive" projects, including manufacturing and transport infrastructures. While Maurer & Bhandari fairly recognise that these investments are "likely upgrading infrastructures, introducing more energy efficient technologies, and permitting fuel switching from coal to less-intensive natural gas", they believe that "from a climate perspective, ECAs appear to be doing more harm than good."

Environmental NGOs, such as Friends of the Earth, went one step further asking international financing institutions (ECAs and multilateral development banks) to stop financing investments in the fossil fuel sector, including oil and gas pipelines. Some NGOs from developing countries, however, have adamantly criticised this: *"By forcing developing countries to stop using fossil fuel technologies without providing a framework for the World to move towards a renewable energy future, Northern groups* (i.e., NGOs) *are denying these countries the right to development"* (Sharma, 2000).

It would certainly be counterproductive to "stop fossil fuel investments in developing countries" from both climate and – of course – development perspectives. On the other hand, the great leverage power of international finance institutions could be better targeted, so as to ensure better coherence of ECAs activities with global sustainable development goals. Under the UNEP Finance Initiative, nearly 300 financial institutions in the world – bankers, insurance and assets managers – have undertaken to use that leverage power in support of sustainable development.

While development banks and ECAs should continue supporting natural gas development, they should also be more selective in the projects they support. If selection is based on a least lifecycle cost assessment[5], they should probably stop supporting the building of subcritical coal power plants in Asia – and turn to more efficient supercritical plants (Philibert, 2001) or even to gasification[6]. While costlier to build, these technologies are lower cost over the lifetime of the operating facility. Thus, they would not be criticised for unduly forcing developing countries to adopt a costlier development path for the sake of climate.

In December 2003, OECD countries announced an agreement to strengthen their common approaches for evaluating the environmental impact of infrastructure projects supported by their governments' ECAs with a view to ensuring that these meet established international standards.

[5] A least lifecycle cost assessment allows identifying the least cost solution taking into account all discounted operating costs as well as the initial investment cost.

[6] Gasification could follow several roads - from the well-known, if not wide-spread, "Integrated Gasification Combined Cycle" to the less well-known "polygeneration processes" defined as gasification to syngas ($CO+H_2$) for cogeneration of heat and power in gas turbines, production of chemicals and fuels (Simbeck, 2003).

Sussman (2003) identifies several policy options that might be used to further influence the decisions of ECAs, including (1) a pool of concessionary financing funded by donor contributions; (2) financial set-asides; (3) special lending provisions; (4) a climate-friendly portfolio standards with credits and charges; and (5) increased transparency in financial and emissions reporting by ECAs. For most of these options, concessionary financing appears to be key to turning technologies that are not commercial today into viable projects that are consistent with ECA financing rules.

Box 4: Intellectual property rights: anything to be changed?

Protecting intellectual property rights (IPR) has a benefit: it gives an incentive to innovators. But it has a cost: inventors obtain a return on their innovative activity through the use of a patent or by charging a monopoly price on the product. Thus, as Stiglitz points out (1999), the gain in dynamic efficiency from the greater innovative activity is intended to balance out the losses from static inefficiency from the under-utilisation of the knowledge or from the under-production of the good protected by the patent.

One part of the balancing act is to limit the duration of the patent. Too short a patent life would imply a low level of appropriation of results and, in turn, low levels of innovation. Too long a patent life would mean large losses in static efficiency, allowing innovators to get most of the fruits of the innovation, as they would not be subjected to competitive pressure. Other aspects of the patent system are also important, such as the breadth and scope of a patent claim. For example, an excessively broad patent system may also slow the overall pace of technical progress, for initial knowledge is a key input into the production of further knowledge; raising the price of this input may reduce the pace of follow-on innovations.

The provision of the Trade-Related Aspects of Intellectual Property Rights (TRIPs) Agreement stipulate that 20-year patent protection should be available for all inventions, whether products or process, in almost all technology fields. This may, or may not, be the best trade-off between the need to reward innovation and the need to speed diffusion. Though economists continue debating the matter, no clear case appears for revising these dispositions.

The TRIPs Agreement, however, explicitly directs developed country members to provide incentives to enterprises and institutions to promote and encourage technology transfer to least-developed countries (Article 66.2). The WTO Fourth Ministerial Conference held in November 2001 in Doha reaffirmed that these provisions are mandatory and requested the TRIPs Council to monitor its implementation.

The Agenda 21, in its article 34.18, suggests inter alia the “Purchase of patents and licenses on commercial terms for their transfer to developing countries on non-commercial terms as part of development cooperation for sustainable development, taking into account the need to protect intellectual property rights”.

There is no unique set of provisions for dealing with IPR in the IEA implementing agreements (except for protecting the IEA copyright): they are left to the implementing agreements themselves, in particular as they do not all gather the same countries, or may even be different in the different “tasks” of the various IAs. Many such agreements stipulate that participants are free to publish all information they get from the agreement, but not with a view to make profit. Patents owned by participants that are needed for use in a task shall be licensed to participants responsible for that task at no cost. Arising inventions shall be owned in all countries by the inventing Participant, and information regarding inventions on which patent protection is to be obtained shall not be disclosed by others for six months. Moreover, some IAs suggest that each participant should license arising inventions to other participants, their governments and their nationals royalty-free for use in their country only, and on “reasonable terms and conditions” for use in all other countries.

Another example of an elaborated set of guidelines to deal with IPR in (bilateral) energy research and development international agreements can be found in DoE, 1999. The guidelines suggest complete freedom for all parties to an agreement to translate, reproduce and publicly distribute articles, reports and book arising from cooperation. With respect to royalties arising from invention, the guidelines distinguish the case of visiting researchers, who shall receive IPR under the policies of the host institution, and the case of joint research, where each Partly shall be entitled to obtain all rights and interests in its own country, while rights and interests in third countries should be determined in the agreements themselves.

4.2 Sharing the learning investments

New technologies in general witness learning effects on costs: as their markets expand, costs go down (IEA, 2000; see earlier discussion in Philibert, 2003). Consequently, it is hoped that expanding the markets for technologies not-too-far from competitiveness could expand their niche markets towards full competitiveness – or at least competitiveness in markets where externalities are properly priced – in a decade or two. Achieving this is likely to require, alongside sustained R, D&D efforts in public-private partnerships, a somewhat subsidised or "artificial" expansion of markets. The total amount of these "subsidies" (which could take the form of feed-in tariffs in the electricity sector) would represent "learning investments".

The wind power industry has benefited from such efforts in the US in the 1980s, followed by Denmark, then Germany, Spain, the UK and progressively more countries, including India. Concerted efforts might be more productive – and the costs of future similar "learning investments" could be shared by a broader set of countries willing to cooperate. Other renewable technologies, from PV to concentrating solar to biomass power to offshore wind may benefit from such international cooperation – that would go beyond the R&D shared efforts in the IEA implementing agreements.

This is what the GEF is trying to do with its Operating Programme n°7, but the irony is that it does so with developed country money only in developing country fields. It is hard to see why such efforts are not better connected to similar efforts undertaken in various developed countries through renewable energy portfolio policies.

In the lead up to WSSD, a proposal for all countries to commit themselves to reach some agreed percentage of renewable energy sources in their primary energy supply, was partly intended to accelerate learning by doing from accelerated deployment for this necessary technologies, but failed to reach agreement. There might be effective alternatives to common percentage targets that could fulfil the same objective but be more suitable to the conditions in individual developed and developing countries. Metrics might be capacity, energy, or even physical units such as square meters (say, for PV, or solar heating). It may also be that "plurilateral" agreements on fostering renewable energy sources between like-minded countries offer better prospects for a prompt start – with the hope they be broaden progressively.

This may still leave open the question of integrating efforts undertaken in developing countries with GEF and other developed country financing – including ECAS and multilateral development banks – and those undertaken in developed countries themselves. While this may be a topic for negotiators in the UNFCCC, initiatives may also be part of the implementation of the G8 Evian Action Plan for Sustainable Development.

4.3 Technology "agreements", norms and standards

A number of recent proposals have been made for technology-based international agreements as successors to the Kyoto Protocol. Scott Barrett (2001) suggests the negotiation of a new climate agreement focusing on R&D funding. While such an agreement might complement the current Kyoto Protocol, Barrett maintains that over time it could fully replace it. Under his proposal, base-level contributions would be determined on the basis of both ability and willingness to pay, and could be set according to the United Nations scale of assessments. To provide incentives for participation, each country's contribution to the collaborative effort would be contingent on the total level of participation. The research emphasis would be on electric power and transportation. This would be a "push" programme for R&D – a dimension absent from the Kyoto approach.

However, Barrett also proposes a complementary "pull" incentive to encourage compliance and participation. He suggests that the most attractive approach would be to agree on common standards for technologies identified by the collective R&D effort, and established in complementary protocols. As examples, energy efficiency standards could be established for automobiles, requiring the use of new hybrid engines or fuel cells, or standards for fossil fuel fired power plants might require capture and storage.

A standards-based approach was also advocated by Edmonds (1999, 2002) and Edmonds & Wise (1999). Under their hypothetical protocol, any new fossil fuel electric power plant and any new synthetic fuels plant installed in industrialised countries after 2020 would be required to capture and dispose of any carbon dioxide from its exhaust stream or conversion processes. Developing countries would undertake the same obligations when their per capita income equals the average for industrialised countries in 2020 in purchasing power parity terms.

The most problematic aspect of such a strategy might be one of credibility – a problem inherent in approaches based on still-to-be-developed technologies. No less important is the cost issue. Edmonds & Wise themselves recognise that the cost of achieving a given concentration level with such a protocol would be 30% higher than the economically efficient cases of taxes or tradable permits. This estimate may even be too low, as the structure of the agreement would not encourage some of the most cost-effective energy efficiency improvements. In addition, the politics of some technology proposals may make them difficult to implement – particularly if they tend to disadvantage specific – and politically powerful – segments of the economy. Thus, for example a technology proposal that calls for phasing out coal may meet the same problems as faced in England and Germany where closing down even money-losing coal mining operations is a process that takes decades.

However, there are a number of areas where standards prove efficient and cost-effective – and international collaboration already helps promote them. One such example is the least lifecycle cost strategy for energy efficiency improvements in the area of domestic appliances that has been suggested by the IEA (2003c). Based on a least lifecycle cost assessment for most domestic appliances, effective policies in OECD countries could result in twenty years emission reductions of about 322 million tonnes CO_2/year by 2010, 470 Mt CO_2/y by 2020 and 572 Mt CO_2/y by 2030 – or roughly 30% of OECD Member countries' targets under the Kyoto Protocol. This would be achieved at no cost for the society and consumers – or, more precisely, a cost for government but much larger benefits for consumers. Figures would be even higher if the "least lifecycle cost" were to include a price for avoided carbon emissions (and/or other positive externalities).

Effective policies would use a variety of means, from awareness raising campaigns to procurement programmes, so as to give appropriate incentives at all relevant levels, from manufacturers to retailers and other "market intermediaries" to end-use consumers. Most likely, these policies would make a significant use of labels or minimum efficiency standards or both – which have already been proved effective.

With increasing globalisation of appliance and technology markets, however, international cooperation on appliance policy is becoming an essential element of product markets. It can generate greater transparency and comparability in appliance standards, test procedures and labelling which would bring benefits for producers, consumers and governments alike. It would reduce costs for product testing and design, enhance prospects for trade and technology transfer, assist governments and utilities in efforts to design, implement and monitor efficiency programmes.

It is not clear, however, to what extent international cooperation should aim at harmonisation. The IEA (2003c) sees harmonisation of test protocols as almost always positive, while harmonisation of labels and standards offer a more contrasted picture. Difference in climate, electricity prices, consumers' attitudes and others may make harmonisation very difficult but also meaningless in some cases. Harmonisation of labels and standards makes most sense for products whose characteristics and usage patterns do not vary greatly from country to country and where the level of efficiency economically justifiable is rather insensitive to energy prices.

Neither harmonisation nor even collaboration need always be global. On the contrary, the search for exhaustive geographic coverage may prove counterproductive in delaying real work and outputs. The evaluation of the trade-off between rapidity and exhaustiveness will probably have to take into account some spillover effects – as happens when a sufficiently large number of countries adopt standards that soon become world class standards. This has been the case with many safety standards in various domains.

4.4 Developing flexibility mechanisms

Another way of accelerating technology transfer to developing countries is their participation in a global emissions trading framework, possibly under options such as non-binding and/or dynamic targets, which may make integration into global emissions trading regime more palatable to them (Philibert & Pershing, 2000; IEA, 2002a). As with CDM, such a regime would encourage entities from industrialised countries (governments or companies) to pay for the incremental costs resulting from technology improvements incorporated in new investments.

One advantage of emissions trading over project-based mechanisms interpreted in a narrow sense (a project being one single investment, or “plant”) would probably be a sharp reduction in transaction costs, since the baseline would be established once and for all (at least for a “commitment period”) for a whole sector or country (see, e.g., Ellis et al., 2004, on some difficulties experienced with the CDM). Another advantage would be to reduce fears about leakage and fair competition and trade amongst “regulated” and “unregulated” areas – fears that have proven adverse to the undertaking of plurilateral, but not global, quantitative commitments on emissions.

However, such schemes may still be possible under the current Kyoto framework through sector-wide, unilaterally-funded CDM projects – a concept that would have to demonstrate acceptability in this context, but has not been explicitly rejected thus far. Outside the Kyoto framework, however, or before its entry into force/first commitment period, there is nothing to prevent countries implementing a domestic or plurilateral emissions trading regime and linking it with other countries. In the case of developing countries, agreements could include either CDM-like project-based mechanisms or sector or country wide non-binding targets.

Given the current constraints on public spending in most countries, using flexibility mechanisms may be, at least in the long run, one of the most effective methods of promoting climate-friendly technology transfer to developing countries.

5. CONCLUSION

In sum, increased international cooperation might facilitate and accelerate technology innovation, development and diffusion – though formal negotiating processes can sometimes slow the process. Cooperation between governments should not preclude competition between firms, but rather help level the playing field, as both competition and cooperation have their role to play in accelerated technical change.

Strengthened international technology cooperation to mitigate climate change can potentially reduce R, D&D costs while possibly increasing R&D public and private resources, speed technology diffusion and transfer, and help engage more countries into action. It could take various avenues, such as:

- Strengthening and greening investment and trade, through continuing the market reforms at a controlled pace; guidelines for export credit agencies and multilateral financing institution have recently been updated, but other policy options might be considered to further influence ECAs work in a more climate-friendly manner;

- Sharing the learning investments necessary to bring climate-friendly technologies in the market place by an increased coordination of efforts in industrialised and developing countries altogether;

- Further developing testing procedures and consumer information on end-use technologies, as well as performance standards, with some efforts toward international harmonisation when appropriate;

- Further developing flexibility mechanisms by offering new options to developing countries willing to take part to international emissions trading schemes.

The three first options are unlikely to be best dealt with through the Convention process.

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7. APPENDIX: IEA IMPLEMENTING AGREEMENTS: HIGHLIGHTS ON RECENT ACHIEVEMENTS

Fossil Fuels

Clean coal technologies and carbon capture and storage options remain high on the agendas of the six Implementing Agreements that deal with fossil fuels. The IEA **Greenhouse Gas R&D Programme** focuses on CO_2 capture and storage projects and on informing policy-making on climate-change mitigation options by disseminating results. These topics figured large at the Programme's 6th Conference on Greenhouse Gas Technologies (GHGT-6) in Kyoto (Japan) in 2002, which brought together 500 delegates from more than 30 countries and featured presentation of some 240 papers.

The **IEA Clean Coal Centre** Implementing Agreement organised an event, *Clean Coal Technologies for Our Future*, in Sardinia (Italy), in October 2002, which attracted more than 200 participants from industry, governments and local communities. The Clean Coal Centre is one of the world's foremost providers of information on efficient coal supply and use. Each year, it produces some 15 reports on the technical, economic and environmental performance of coal technologies. A topical publication during 2002 was *The Kyoto Protocol in 2002 – Opportunities for Coal*.

For its part, the IEA Implementing Agreement on **Clean Coal Science** works with mechanisms for sharing coal combustion technology information, notably through technical sessions and workshops. An important part of the programme's work is its "International Register of Experimental Furnaces Associated with Combustion and Combustion Related Processes", which contains 73 entries from ten countries, including non-IEA countries.

Also in the fossil-fuel group is the IEA's Implementing Agreement for Cooperation in the Field of **Fluidized Bed Conversion (FBC) of Fuels Applied to Clean Energy Production**. Key recent events have been two workshops in 2002. In Vienna in May, sixteen papers were presented at a technical session on "Fuel Interaction & Future Fuel Mix". In November 2002, a meeting in Prague addressed the issues of "Difficult Fuels, Opportunity Fuels and Fuel Mixtures in FBC".

Renewable Energy

Nine IEA Implementing Agreements cover of the broad spectrum of renewable energy technologies. Markets for renewables are expanding and these Implementing Agreements are contributing valuable policy-oriented analysis to establish links between technology R&D and deployment. In 2002, the IEA **Bioenergy** programme launched a series of policy-oriented position papers. The first, *Sustainable Production of Woody Biomass for Energy,* discusses sustainability issues and economic, environmental and social factors. Also on its 2002 publications list were: *Fast Pyrolysis of Biomass: A Handbook, Volume 2*; *Bioenergy for Sustainable Forestry: Guiding Principles and Practice*; and a publication aimed at a wide audience, *Handbook of Biomass Combustion and Co-firing.*

In the domain of solar energy, the IEA **Photovoltaic Power Systems (PVPS)** Programme produced more than 50 reports, books and databases in 2002. A large volume of new information became available on completion of two work programme elements dealing respectively with "Design and Grid Interconnection of Building Integrated and other Dispersed Photovoltaic Systems" and "Photovoltaic Power Systems in the Built Environment". Marking its 10th anniversary, the Programme held an international conference in Osaka (Japan) in May 2003, which enabled stakeholders from around the world to exchange views on PV policies and markets. A new project to be launched during 2003 will work on "Large Scale Deployment of PV in Urban Environments".

Another solar-focus Implementing Agreement, the IEA **SolarPACES** programme, deals with concentrating solar power (CSP). It has been one of the co-ordinators in bringing together a partnership, accepted as a World Summit on Sustainable Development Type II Initiative, to facilitate CSP uptake in favourable markets. Ten investment opportunities have been pinpointed. Algeria recently joined the Solar PACES Programme and possibilities have been opened up for trans-Mediterranean bulk solar electricity exports from North Africa.

In the field of energy software used in building design, the IEA **Solar Heating and Cooling** Programme (SHC) has become the recognised source for pre-normative research on standard tests methods. Five buildings constructed in Germany, Denmark, Canada and the Netherlands have tested its guidelines, methods and tools and demonstrated successful integration of solar technologies in large buildings. The deployment of technologies for drying agricultural products is another area of SHC Programme work.

Worldwide wind energy generating capacity increased to 31 gigawatts in 2002. Ongoing tasks of the IEA Implementing Agreement for Co-operation in the Research and Development of **Wind Turbine Systems** are addressing issues that slow expansion of wind power generation. In addition to maintaining databases on wind characteristics, enhanced field rotor aerodynamics and the performance of wind turbines in cold climates, the programme has initiated three new research co-ordination projects. They will deal with aerodynamic models for wind turbine design, the impact of wind farm generation on utility transmission and distribution systems and wind energy market acceleration.

The IEA Implementing Agreement on **Ocean Energy Systems –** a relatively new programme – is playing an important role in co-ordinating development activities, drawing on the findings of a key report produced in March 2003, *Status and Research Priorities for Ocean Energy Technology*.

Hydropower produced 17% of the world's electricity in 2000. To address the economic, social and environmental issues that nevertheless arise in construction of new hydropower plants, the IEA's **Hydropower** Implementing Agreement has conducted a major study, involving more than 100 specialists from 16 countries. Its findings are currently being disseminated to industry, civil society groups and the general public.

The **Hydrogen** Implementing Agreement continues its extensive number of tasks for pre-competitive research in hydrogen production storage and transport. A major 2002 event that it co-sponsored was *BioHydrogen 2002*, an international conference in the Netherlands focusing on scientific advances during the first three years of the Programme, the current status of biological hydrogen production, progress on early-stage applied science and promising research directions.

Wide-ranging work over the past months within the IEA Implementing Agreement on **Advanced Fuel Cells** featured important technical achievements in polymer electrolyte fuel cells, as well as workshops during 2002 on solid oxide fuel cells and molten carbonate fuel cells. Market conditions and performance requirements for stationary fuel cell systems were investigated in different countries in a variety of applications, from small scale in single houses to large-scale power generation. This work served to underline the variability of market conditions between countries.

End-use Technologies

The IEA's programmes dealing with end-use technology applications cover three areas: transportation, buildings and industry.

In transportation, the **Advanced Fuel Cells** Implementing Agreement points to well-to-wheel studies that have quantified fuel economy and greenhouse gas emission benefits of fuel-cell vehicles compared with internal combustion engines and hybrids.

Three other IEA Implementing Agreements deal with transportation. The **Hybrid and Electric Vehicles** Agreement notes publication in 2003 of a report, with recommendations, analysing more than 80 government programmes to support market introduction of clean vehicles. Recent work by the Agreement on **Advanced Motor Fuels** has provided data on the characteristics of a range of future greener diesel fuels and on homogeneous charge compression ignition in four-stroke, two-stroke and free piston engines. A major focus of the Implementing Agreement on **Advanced Materials for Transportation** has been international collaboration on measurement of thermal and mechanical fatigue of advanced ceramics, also new work on evaluating selected silicon nitride material and bulk density of a complex geometry green or porous body.

Five IEA collaborative programmes work on energy end-use in the buildings sector. A completed project under the programme on **Energy Conservation in Buildings and Community Systems** produced *Principles of Hybrid Ventilation,* which describes methods to predict performance in hybrid-ventilated buildings. A current work focus is retrofitting in educational buildings.

The IEA **District Heating and Cooling (DHC)** Programme concluded work on the "Implementation of Co-operative Projects in the Field of District Heating and Cooling and Combined Heat and Power (CHP)". Results were disseminated to a large well-targeted audience at a seminar in Trondheim (Norway).

Within the programme on **Energy Conservation through Energy Storage**, developments in 2002-2003 included approval of standards for underground thermal energy storage design and installation, validation of a new thermal response test, the building of new plants and a workshop, *Cooling in all Climates with Thermal Energy*, in New Jersey (USA) in October 2002.

In the domain of the IEA Implementing Agreement on **Heat Pump Technologies**, Beijing (China) was the venue, in May 2002, for the 7th IEA Conference on these technologies. Entitled "Better by Nature", it featured presentations on heat pumps but also air conditioning and refrigeration technology. In Spain, in October 2002, an international workshop, "The Heat Pump – Present and Future" concluded that the Spanish heat pump market is developing and that more active involvement in international R&D programmes should be considered.

Work under the IEA **Demand-Side Management** (DSM) Programme included the presentation of Awards of Excellence to two photocopier manufacturers for achieving up to 75% reductions in their products' overall energy consumption. The DSM Programme has also developed a "black box" that notably acts as a gateway for information flows between household appliances and energy utilities.

Industrial energy efficiency involves five different IEA collaborative programmes, including the Implementing Agreement on **Process Integration**, which in 2002 finalised a briefing package on the most favourable conditions for increasing the thermal efficiency of integrated industrial processes.

The IEA collaboration on **Advanced Energy-Efficient Technologies for the Pulp and Paper Industry** reports on pilot and demonstration projects for converting the industry's by-products into combustible synthesis gas. International teams play an important co-ordinating role in areas such as this where expertise and research facilities are located far from each other.

For its part, the programme on **Energy Conservation and Emissions Reduction in Combustion** registered significant progress during 2002 in developing the understanding needed to overcome barriers to producing a practical homogeneous charge compression ignition engine, which offers an alternative to the gasoline engine combustion process. Its findings provided the first known experimental verification of previous modelling predictions.

Work under the Implementing Agreement on **Heat Transfer and Heat Exchangers** has focused on condensation in plate heat exchangers, including a state-of-the-art review, and efficient heat exchangers in gas turbine systems.

Under the **High-Temperature Superconductivity** Implementing Agreement, 2002 saw publication of *Cooling for Future Power Sector Equipment Incorporating Ceramic Superconductors*, which presents detailed information on available cryogenics and the required improvements for use of superconductors in the electric power sector.

Information Centres

Delivery of energy technology data from the two IEA Information Centres increased again substantially in 2002. Between 2001 and 2002, the number of registered users of the **Energy Technology Data Exchange** World Energy Base increased by nearly 40%. A user survey produced encouraging feedback. In 2002, more than 100 000 entries covering a multitude of energy-related subjects were added to the database.

During 2002, co-operative activities were launched between the IEA **Energy and Environmental Technologies Information Centres** (EETIC) and the UNEP Sustainable Alternatives Network (SANet). EETIC brings together two centres providing information on demonstration projects, CADDET Energy Efficiency and CADDET Renewables. These are due to merge, and work in 2002-2003 focused on consolidation and increased use of new facilities. The third EETIC component, the Greenhouse Gas Technology Information Exchange (GREENTIE), boasts more than 7 000 clean technology suppliers in its on-line directory. A key development in 2002-2003 was introduction of the Project Broker Facility that puts users and equipment manufacturers in contact via an on-line registration form.

Meanwhile, the **Energy Technology Systems Analysis Programme** (ETSAP) develops operational tools for analysts who assist decision-makers in national governments with assessing energy technologies to meet energy requirement challenges. ETSAP’s MARKAL model has been adopted for defining national energy technology strategies in a number of countries, also by the IEA Secretariat for its Energy Technology Perspectives Project.

Fusion

Three of the eight co-operation programmes on fusion power are providing valuable R&D results in relation to the **tokamak concept**. This is the chosen technology for the ITER experimental plant, to be built in the near future. A major workshop on “Implementation of the International Tokamak Physics Activity (ITPA) Coordinated Research Recommendations” was organised on 18-19 November 2002 at the Massachusetts Institute of Technology (USA). Its purpose was to discuss implementation of ITPA proposals that would benefit from coordinated, joint experiments among major world tokamaks.

Alternative fusion concepts (Reversed Field Pinch, Stellarator, Spherical Tori) are under investigation involving other IEA fusion power programmes, and R&D results are being exchanged among participants. Other elements in the IEA’s fusion power portfolio are programmes on materials for fusion technologies, components for future fusion reactors and environmental, safety and economic aspects of fusion power.

Building on its 20-year experience in the field, the IEA Implementing Agreement on **Fusion Materials** is acting as a technology incubator for the “International Fusion Material Irradiation Facility” (IFMIF) project, which is expected to become the largest international facility for fusion materials testing. During the period 2002-2003, the IFMIF Key Element technology Phase (KEP, 2000-2002), aimed at decreasing the development risks and cost of the IFMIF project, was successfully concluded.

On 28-29 April 2003, the IEA Implementing Agreements were present at the Paris venue for the Meeting of the IEA's Governing Board at Ministerial Level. Their stands at the IEA Energy Technology Collaboration Fair organised for the occasion gave Energy Ministers, their delegations and the press a well received overview of the work and achievements of the programme.

Abundant information about individual Implementing Agreements in each of the various areas is available on the individual websites of each Implementing Agreement (given in the table in the next chapter), and through the IEA Secretariat's homepage (http://www.iea.org), where details on the co-operative structure as a whole can be consulted.

As part of the effort to broaden dissemination of results achieved within the IEA energy technology network, the IEA's *OPEN Energy Technology Bulletin* was launched in 2002. By the start of 2003, this on-line newsletter had already acquired more than 3000 subscribers world-wide.