BACKGROUND PAPER

Climate Change: Technology Development and Technology Transfer

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Technology Development and Technology Transfer
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EXECUTIVE SUMMARY

The preamble of the United Nations Framework Convention on Climate Change (UNFCCC) notes: "… the global nature of climate change calls for the widest possible cooperation by all countries and their participation in an effective and appropriate international response, in accordance with their common but differentiated responsibilities and respective capabilities and their social and economic conditions."

The Bali Action Plan highlights the urgency of tackling climate change. Climate change poses a fundamental threat to sustainable development. The poor are the most vulnerable, and the impacts will be borne by many generations to come.

The Bali Action Plan emphasizes the critical importance of technology development and transfer and the provision of financial resources and investment as means to the end of climate change mitigation and adaptation. This background paper for the Beijing High-Level Conference on Climate Change focuses on how governments, the private sector and other actors can facilitate and accelerate the development and transfer of environmentally sound technologies. It considers the current state of technology development and transfer, the major barriers and possible mechanisms for overcoming them through public and private actions, including partnerships.

The aim of the Conference is to support the UNFCCC process, particularly the forthcoming COP14/CMP4 of the UNFCCC in Poznan. It will not be a forum for negotiations. Instead, its aim is to serve as an opportunity for Member States and other stakeholders to discuss openly, removed from any constraints that come with sitting at the negotiating table.

The UNFCCC states in Article 4.5 that "[t]he 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." The Bali Action Plan calls for "[e]nhanced action on technology development and transfer to support action on mitigation and adaptation" (para. 1 (d)). More specifically, it points to the need for the development of mechanisms and financial incentives for "scaling up of the development and transfer of technology to developing country Parties" (para. 1 (d) (i)) and asks for measurable, reportable and verifiable actions in this regard (para. 1 (b) (ii)).

Technology development requires investment from both the public and private sector. Public sector R&D has played an important catalytic role in developing some of the key technologies of the 20^{th} century, including aeronautics, electronics, and nuclear power. It will also need to play a role in the transition to low-carbon energy technologies. The bulk of the environmentally sound technologies (including technologies to reduce greenhouse gas emissions) have been developed in response to explicit and strong government support, in the form of tax incentives, R&D grants, favorable regulatory frameworks, and government expenditure policies. On the one hand, the large public stake in these technologies could provide the governments with sufficient leverage to disseminate them more broadly in the larger public interest. On the other hand, however, these policies were generally aimed at enhancing national competitiveness, which may run counter to the goal of facilitating technology transfer to developing countries.

In the future as well, further quantified greenhouse gas emissions reduction objectives by developed countries will be critical to stimulating private sector investment in R&D. By lowering costs, large-scale deployment of low carbon technologies in developed countries will be critical to overcoming one of the most serious barriers to technology transfer to and adoption by developing countries. Such deployment would also serve to demonstrate a technology's feasibility. Given the potential stake of the public sector in the emerging technologies, global agreements could be oriented towards technological cooperation at the very outset, instead of leaving such cooperation entirely to private sector entities.

The UNFCCC technology transfer framework defines five key elements for meaningful and effective actions: (1) technology needs and needs assessment; (2) technology information; (3) enabling environments; (4) capacity building, and (5) mechanisms to facilitate institutional and financial support to technology cooperation, development and transfer.

While UNFCCC agreements contain many references to technology transfer to developing countries, the focus of implementation has generally been on creating conditions in developing countries conducive to foreign investment and building capabilities to absorb and utilize imported technologies. Less emphasis has been placed on measures which governments of technology supplier countries can and should take to facilitate and accelerate technology transfer. Nor, until now, have there been effective methods of measuring and verifying the extent of environmentally sound technology transfer.

Technology transfer involves more than hardware supply; it can involve the complex processes of sharing knowledge and adapting technology to meeting local conditions. Domestic technical and managerial capacities, institutions and investments in technological learning all influence the effectiveness with which technology can be absorbed and adapted. These considerations complicate the measurement problem.

Human resource and institutional development are crucial to facilitating technology utilization. Institutional development includes capacities for technology and business assessment, incubation, and technology testing and demonstration.

The mitigation and adaptive capacities of countries can be enhanced when climate policies are integrated into national sustainable development strategies.

Technology partnerships and networks can be means of sharing knowledge, enhancing technological capabilities, fostering innovation, improving market access and strengthening competitiveness.

Enhanced collaborative R&D is necessary between developing and developed countries to improve R&D strengths in specific areas of low-carbon technology. This can be seen as an opportunity for developing countries to acquire technological expertise in key emerging energy technologies as a basis for building competitive industries. R&D collaboration among developing countries is also an option.

Technologies, technology transfer and barriers

A broad spectrum of technologies already exists for mitigation and adaptation. In addition, there are state-of-the-art technologies nearly ready for large-scale deployment, and technologies still under research and development.

In the case of mitigation, technologies can be further grouped by area of application: energy supply (the most prominent being wind, geothermal, integrated gasification combined cycle, concentrated solar energy, biomass/biogas and hydrogen systems); end-use (industry, transport and buildings) and infrastructure; carbon dioxide (CO_2) capture and storage; and reducing other greenhouse gas emissions. While a significant number of feasible technologies are available in each of these groups, they are not all commercially competitive without government subsidies or other support.

Technologies requiring significant additional R&D and demonstration at scale include second-generation biofuels, hydrogen fuel cells for cars, grid-connected solar photovoltaics, and CO_2 capture and storage.

Table 1 enumerates the major mitigation technologies according to how soon they are expected to be ready for large-scale deployment.

A concerted effort is necessary to diversify the energy matrix in favor of renewable energy and low-carbon technologies. Technological progress can create new opportunities to harness the vast renewable energy potential. Renewable energy can replace conventional fuels in power generation, hot water and space heating, transport fuels, and rural (off-grid) energy. In developing countries, the key challenge is to bring the cost of the resultant services to levels at which they would be affordable by low income households.

Considerable investment is necessary to increase the efficient conversion and use of energy in all sectors of the economy. Improved efficiency in energy demand and supply can make a major contribution to the reduction of GHG emissions. International cooperation with public and private partners creates synergies in the development of efficient and low-carbon technologies.

Adaptation technologies may require new hardware or different implementation approaches (‘software’). Five main areas of adaptation technology application are: regional and local climate modeling and early warning, coastal zone management, water resources, agriculture and public health. **Table 2** provides an indicative list of adaptation technologies in these five areas.

Technological progress can take place through: scientific innovation and invention, the adoption and adaptation of pre-existing but new-to-the-market technologies, and the diffusion of technologies. Enormous gaps remain, especially in the case of the least developed countries.

Technology development and transfer can be either accelerated or slowed depending on market conditions, fiscal and regulatory policies, availability of finance, access to information, the legal and institutional framework, human resource capacities, and the condition of infrastructure.

Each country needs to conduct its own assessment of the most important domestic barriers to clean technology development and transfer. In addition, there are also barriers relating to international trade and associated rules, for example, with respect to intellectual property rights.

Financial constraints are most often cited as a barrier to adoption of environmentally sound technologies in those non-Annex I countries which have conducted technology needs assessments. Capital shortages and high capital costs are still commonplace in many developing countries. Underdeveloped financial sectors and inhospitable investment environments are key reasons. These constraints may be tightened by the current global financial crisis. Small domestic markets for low-carbon technologies are another oft-mentioned barrier to technology adoption. Limited information about the availability of technologies and technology suppliers was another frequently cited barrier to technology acquisition. However, the biggest obstacle is that existing technologies are too expensive, making the resulting services unaffordable for the bulk of the populations of non-Annex I countries.

Government policies can support or hinder low-carbon energy technology development and transfer. Supportive legal and regulatory frameworks may include energy-efficiency codes for buildings, fuel efficiency standards for motor vehicles and mandates for renewable energy use. Given cost disadvantages still faced by many non-conventional energy sources, government subsidies, feed-in tariffs and other support can facilitate adoption, but these may require international support. Rapid adoption of alternative energy technologies is hindered by subsidized conventional energy prices. However, removal of the subsidies without an increase in income or the availability of other affordable energy services could be both inequitable and socially unacceptable.

Mechanisms for enhancing technology development and transfer

Mechanisms for technology transfer are designed to facilitate the support of financial, institutional and methodological activities. The Parties of the Convention have assigned operation of the financial mechanism to the Global Environment Facility (GEF). The Kyoto Protocol also recognizes the need for the financial mechanism to fund activities by developing country Parties. One relevant mechanism under the Protocol is the Clean Development Mechanism (CDM). Also, the Parties have established three special funds: the Special Climate Change Fund (SCCF) and the Least Developed Countries Fund (LDCF), under the Convention; and the Adaptation Fund (AF), under the Kyoto Protocol.

Studies of technology transfer under CDM, based on an analysis of project design documents, suggest that CDM has made some contribution to financing emission reduction projects using technologies not currently available in the host country. Still, the one-off, project-specific nature of CDM raises questions about how much cumulative technological learning it can promote.

The existing financing mechanisms are widely considered to be inadequate to the task of mobilizing resources and effecting technology transfer on the scale required to address the climate change challenge. There is the need for strengthening, streamlining and reducing the transaction costs of the CDM. Even then, the project-oriented focus of the mechanism makes it difficult to mobilize financing for large-scale public investment in low-carbon energy infrastructure and/or public transport infrastructure.

The World Bank has set up strategic Climate Investment Funds and programmes "to scale-up financing available for policy reforms and investments that achieve sustainable development goals through a transition to a low-carbon development path and a climate-resilient economy." The two initial CIFs are the Strategic Climate Fund and the Clean Technology Fund. These are to operate as trust funds collecting donor contributions; pledges thus far amount to US$ 6.1 billion.

Foreign direct investment (FDI) and trade are also channels for the transfer of low-carbon technologies. The easing of restrictions on FDI has contributed to technology diffusion within developing countries. Some countries have encouraged joint ventures rather than wholly owned FDI in an effort to maximize technology transfer to local firms. Still, the extent of low-carbon technology transfer depends, in large part, on the strength of host country policies and market signals that encourage adoption of such technologies.

A number of innovative financing proposals have been advanced by various countries (or groups of countries) in the climate change negotiations to address financing gaps for mitigation and adaptation. This includes proposals from the "Group of 77 (G77) and China," Ghana, Mexico, Norway, the Republic of Korea and Switzerland. A number of proposals call for the establishment of global technology funds. The main differences are in the methods of financing and replenishing such funds (e.g., assessed contributions, auction of carbon allowances, carbon taxes or other means) and in the methods of governance. Few proposals are specific on mechanisms, beyond those for financing, for promoting technology transfer. Criteria which can help in evaluating the various proposals include: newness and additionality to ODA, predictability, fairness in terms of both revenue raising and resource allocation, and governance structure. The main proposals are summarized in **Table 3**.

Intellectual property rights (IPRs)

Intellectual property (IP) comes in a variety of forms, only some of which are legally protected. Countries have different legal approaches to intellectual property protection, based in part on their level of technological capabilities and on the degree to which strict IPR protection is perceived as an aid or an obstacle to economic development and the building of a technological base. Patents and trade secrets are the two most important models of IPR protection with regard to environmentally sound technologies.

The Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement of the World Trade Organization (WTO) establishes minimum standards of IP protection. Despite some flexibilities, the overall framework is in favour of the rights of the IP holders. At the same time, the Agreement explicitly promotes environmental, public health, and development goals and gives Members some discretion to determine when those goals should override the normal TRIPS restrictions.

TRIPS severely restricts the potential for invoking competition policy to negate abuse of the rights of IP holders. Compulsory licensing is one option available to a developing country when a patent is filed in the country but the patent holder refuses to license the technology. Its application is subject to strict limitations, however.

Article 31 of TRIPS, which covers the case of national emergencies, has provided an avenue for compulsory licensing by governments to ensure that the exclusive rights of patentees do not prevent access to medicines and technologies for public health. This exception is primarily meant to serve the domestic market, though the WTO decision on public health allows for limited export of products made under compulsory license.

To make TRIPS more conducive to the transfer of environmentally sound technologies, one possibility is to explore the rationale and feasibility of a waiver for transfer of environmentally sound technologies similar to that for public health issues, expanding the scope of the Doha Declaration accordingly. It may also be possible to exploit other mechanisms outside of TRIPS to facilitate technology transfer. For example, an agreement on information access and benefit sharing could curtail excessive patenting and improve prospects for innovation in both developed and developing countries.

A variety of other proposals have been put forward for facilitating environmentally sound technology development and transfer. These are summarized in **Table 4.**

These and other proposals deserve critical scrutiny to assess their effectiveness in lowering costs to developing countries of technology access and deployment.

Public-private roles for innovation and technology transfer

The development of new, low-carbon technologies responds to both supply-push and demand-pull factors. Government financing for science and technology development is one key push factor. The policy-induced price of carbon is a key demand factor.

The roles of government and business differ depending on the stage of a technology's development. Normally, government plays a vital role in basic research on the science underpinning low-carbon technologies. Firms are more active in research, development and demonstration (RD&D) and in the actual commercialization of new technologies.

There is a gap between the RD&D phase, when a technology is advanced enough that its application can be demonstrated, and the stage when the deployment of the technology or product takes place on a sufficiently large scale to make it viable on the market. This gap is referred to as the "valley of death". Significant hurdles can slow or block the move from one stage to the other. These hurdles include cost, infrastructure, slow capital turnover, market organization, information and financing.

Centres for low-carbon energy technology innovation could have an important role to play. The centres are designed to overcome many of those hurdles, and to promote both supply-push and demand-pull. These centres can be set up as public-private North-South partnerships in which public funds (in the form of endowments and grants) are used to leverage significant private sector investment. In the case of developing country centres, donor funding could be a significant portion of the public financing. Analytical work would identify the key country-specific barriers to technology development and adoption, while the detailed understanding of an individual country's energy needs, resource endowments and technological capabilities would inform the technology and product focus of a given national centre's activities.

The activities of such centres could cover various stages of the innovation chain, from technology and product development to market deployment. Among possible activities are: applied research and development; technology demonstration through field trials; business incubator services; enterprise creation; early-stage funding for low-carbon technology ventures; technical advice and finance for the deployment of existing energy efficiency technologies; skills training and capacity building; policy and market analysis.

The mix of donor, domestic public and private funding for the innovation centres will vary across countries and over time. In the establishment phase, public (including donor) funding will need to be a substantial portion, with at least five years of secure funding at launch. National centres would be linked in an international network to facilitate knowledge sharing and R&D collaboration.

This model involves foreign donor funding but the role of foreign private partners is less clear. For what kinds of environmentally sound technologies is the model apt to be most appropriate? What other models exist for public-private and public-public partnership to promote technology and transfer to developing countries?

Table 1. Technologies for Mitigation

	Near-term	Mid-term	Long-term
	ENERGY SUPPLY		
Fossil fuels	IGCC[1]commercialization Solid oxide fuel cells Cleaner coal plants	Hydrogen (H_2) co-production from coal/biomass	
Hydrogen	Integrated stationary fuel cell systems Demonstration H_2 production from renewable sources	Low cost H_2 storage and delivery. H_2 from renewable sources. Renewable H_2-powered fuel cell vehicles	H_2 and electric economy
Renewable energy	Lower cost wind power Demonstration cellulosic ethanol Photovoltaic (PV) clad buildings. Cost-competitive solar PV First-generation bio-refinery	Low-wind speed turbines Advanced bio-refineries Cellulosic biofuels Community-scale solar systems Water photolysis Energy storage options	Widespread renewable energy utilisation Genetically engineered biomass Biologically inspired energy and fuels
Nuclear fission & fusion	Advanced reactor and fuel cycle technology	Generation IV nuclear plants. Fusion plant demonstration	Advanced concepts for waste reduction. Fusion power plants
	END USE AND INFRASTRUCTURE		
Transportation	Hybrid and plug-in hybrid electric vehicles Alternative and flex-fuel vehicles Improved energy storage Power electronics	Fuel cell vehicles and H_2 fuels Efficient and clean heavy trucks Cellulosic ethanol vehicles Intelligent transport systems Low-emissions aircrafts	Zero-emission vehicle systems Optimized multi-modal inter-city and freight transport Engineered urban designs and regional planning
Buildings	High-performance integrated homes High-efficiency appliances Insulation control windows	"Smart" buildings. Solid-state lighting. Ultra efficient HVACR[2] Neural-net building controls	Energy managed communities Low-powered sensors with wireless communications
Industry	High-efficiency boilers Greater waste heat utilisation Bio-based feedstocks	Superconducting electric motors. Efficient thermoelectric systems	High-efficiency all-electric manufacturing. Widespread use of bio-feedstocks
Electric grid and infrastructure	Distributed generation. Smart metering and controls for peak shaving. Long-distance direct current (DC) transmission	Neural-net grid systems Energy storage for load levelling	Superconducting transmission and equipment Wireless transmission
	CO_2 CAPTURE, STORAGE AND SEQUESTRATION		
CO_2 capture	Post- combustion capture Oxy-fuel combustion Oxygen separation techniques	Novel capture technologies Biomass coupled with CO_2 capture and storage (CCS)	Novel in-situ CO_2 conversion technologies
Geological sequestration	Reservoir characterization Enhanced hydrocarbon recovery. CO_2 injection for coal-bed methane production	Mineralization of solid carbonates Well sealing techniques demonstrated	Sufficient effective CO_2 storage capacity
Terrestrial sequestration	Reforestation Soil conservation	Sequestration decision support tools. Bio-based and recycled products	Biological sequestration Carbon and CO_2 based products and materials
Marine sequestration	Effective dilution of directly injected CO_2	Carbonate dissolution/alkaline addition	Safe long-term marine storage
	EMISSION REDUCTION OF OTHER GHGs		
Methane from energy production and waste	Bioreactor land-fill technology New drilling techniques for recovery of coal-bed methane	Advanced land-fill gas utilization. Ventilation-air methane technologies	Integrated waste management systems
Methane and N_2O from agriculture	Anaerobic digesters for heat and electricity production	Utilisation of soil microbial processes	Zero-emission agriculture
High global warming potential gases	Advanced refrigeration technologies. Advanced aluminium smelting processes	Alternative refrigeration fluids	Solid-state refrigeration and air conditioning systems
N_2O from combustion	Catalytic reduction of N_2O in nitric oxide plants	Catalysts that reduce N_2O to elemental nitrogen in diesel engines	Advanced vehicles and non-carbon based fuels

[1] Integrated gasification combined cycle.
[2] Heating, ventilation, air-conditioning and refrigeration.

Table 2. Technologies for Adaptation

MAJOR AREAS	TECHNOLOGIES AND PROCESSES
Extreme weather, climate and sea-level events	Climate models and systems for monitoring and early warning Climate-proofing infrastructure
Coastal zone management	To protect: tidal barriers, dune and wetland restoration, and afforestation To retreat: establishing set-back zones and creating upland buffers To accommodate: improved drainage technologies and early warning and evacuation systems
Water resource management	Desalination techniques Reservoirs and levees for flood management Advanced recycling and efficient technologies in industrial cooling.
Agriculture	New varieties of crops Advanced irrigation systems Efficient wind breaks Advanced erosion control techniques
Public health	Advanced urban planning to reduce heat island effects Improved public transport Disease vector control, and vaccination

Table 3. Summary of main financing and institutional proposals

Sponsor	Proposal	How would it be financed?	How would revenues be allocated, used?	Governance mechanisms	Issues to consider
G77 and China – financial and technology mechanisms	New linked financial mechanism and technology mechanism under the UNFCCC Technology mechanism modeled broadly on Montreal Protocol: – institutional mechanism designed to address all aspects of cooperation on technology research, development, diffusion and transfer; – comprises an Executive Body, technical panels focusing on key technologies/sectors.	Multilateral Climate Technology Fund (MCTF): "new and additional" financial resources over and above ODA. Raised from: – environmental and energy taxes, – revenue from permit auctions – public budgets – international organizations.	The funds would support R&D, deployment and transfer of technologies as well as the enhancement of developing countries' domestic capacity. Promote public-private partnerships (PPPs), active private sector participation Could support a range of activities: – joint EST design, R&D & technology demonstration – market development; – covering incremental costs of investment through, e.g., subsidies, export credit guarantees; – capacity-building.	MCTF operates as a single window facility within the UNFCCC financing mechanism; Fully accountable to the COP of the UNFCCC; Equitable and balanced representation of all Parties; Direct access to funding by the recipients. Policies relating to the MCTF guided by the technology mechanism.	Financing mechanism complementary to technology mechanism. Funds provided outside the UNFCCC would not count as fulfilling developed countries' commitments. This is a potential political hurdle.
Ghana – international framework agreement for technology development and transfer	International framework agreement would address both mitigation and adaptation. Two mechanisms: – Technology Development and Transfer Board (TDTB) and – Multilateral Technology Fund (MTF)	Funding would come from Annex II countries, in accordance with their commitments under the UNFCCC as per Article 4.3. Additional sources of funding, including market-based mechanisms and private sector financing.	Not specified.	TDTB: would be a standing body under the UNFCCC responsible for the development, deployment, diffusion and transfer of ESTs and know-how. MTF: would operate under the authority and guidance of and be fully accountable to the COP. (Essentially same model as in G77 and China)	Provides an institutional framework in addition to a financing scheme, which allows for a more integrated approach. Details of revenue raising mechanism not fully specified.

Sponsor	Proposal	How would it be financed?	How would revenues be allocated, used?	Governance mechanisms	Issues to consider
Mexico – World Climate Change Fund (Green Fund)	The proposed Fund could establish linkages between mitigation, adaptation and technology transfer and development.	All countries would contribute to the Fund. Contributions would be based on levels of GHG emissions, population, and gross domestic product. All contributions to the Fund would be subject to a double levy: – first levy for the Adaptation Fund – the second levy for a Clean Technology Fund.	Fund would be designed to: (a) significantly increase funds available for mitigation , (b) support adaptation efforts, (c) promote transfer and diffusion of ESTs, (d) contribute to financing global climate change arrangement under UNFCCC. Portion could go to LDCs. Developing countries that choose not to join the Fund would be excluded from its benefits, without any penalty.	All contributing nations, whether developed or developing, would participate in the governance structure that would be established for the Fund. The structure would also be open to representatives of all beneficiaries.	Assessed contribution based on criteria of fairness, efficiency and ‘polluter pays’ Areas of possible contention: – formula for determining contributions – opt out for d’ing countries; if dev’ed countries want same option, could undermine Fund.
Norway – auctioning a share of national emission allocations	Auctioning a portion of the assigned amounts (national emission allowances) to raise revenues for global climate change action	The percentage or the number of allowances auctioned could be set to reach revenue target. Could generate significant financial resources – estimated $15-25 billion per year.	The revenues could be used to finance adaptation activities in the first instance, but could also be used to finance mitigation.	A designated international institution would conduct the auction; governance of revenues unspecified.	Unresolved questions include: the number/ share of allowances to be auctioned; criteria for use of the resources raised by the mechanism; governance principles of the fund.
Republic of Korea – carbon credits for NAMAs	Issuance of carbon credits for verifiable mitigation associated with Nationally Appropriate Mitigation Actions (NAMAs) taken by developing countries as per Bali Action Plan Decision 1(b)(ii).	Sale of carbon credits generated by NAMAs in international carbon markets	The proposal recommends that details on operating the scheme, including criteria and extent of credit issuance, could be worked out at the fifteenth session of the COP.	Under UNFCCC; other details not specified	Provides a vehicle for private sector participation in mitigation financing, technology transfer to developing countries. Does not address the adaptation challenge.

Sponsor	Proposal	How would it be financed?	How would revenues be allocated, used?	Governance mechanisms	Issues to consider
Switzerland – global carbon levy and adaptation fund	Global levy on fossil fuel emissions linked to funding scheme for adaptation Based on the principle of common but differentiated responsibilities and on the polluter-pays principle	Uniform global tax of $2/tCO_2$ on all fossil fuel emissions. Basic emission allowance per inhabitant exempted from tax; would result in countries with higher emissions per capita paying higher taxes. Developed countries would deliver a significantly larger fraction of their carbon tax revenues to the MAF than would developing countries.	Major portion of revenues allocated to a Multilateral Adaptation Fund (MAF) Would finance **adaptation policies and measures** under: – a "prevention pillar" involving climate-change impact risk reduction; – an "insurance pillar" that involves, inter alia, insuring against climate-related risks not covered by private insurance companies. A portion of revenue channeled into a National Climate Change Fund.	The function of MAF would initially be taken on by the Kyoto Protocol Adaptation Fund (AF) until a significant number of countries have joined the scheme, at which point the function is meant to be taken over by a new international institution, complementary to the AF.	Designed to ensure fairness in its implementation as countries with higher per capita emissions would contribute more to the fund. Proposed uniform tax rate may not be politically acceptable if seen as failing to acknowledge different economic circumstances and historical responsibilities. Implementation challenge of global levy

Table 4. Innovative mechanisms to promote technology development and transfer

Mechanism	Rationale	Issues to consider
Publicly-supported centres for technology development and transfer	Green revolution model of technology diffusion; makes technologies available to developing countries without IPR protection	Similar to proposal for innovation centres in section on 'public-private roles'; suitable for mitigation or only for adaptation technologies?
Technology funding mechanism to enable participation of developing countries in international R&D projects	Resultant IPRs could be shared; patent buyouts could make privately owned technologies available to developing countries	Is there sufficient incentive for participation by developed country private sector technology leaders?
Patent pools to streamline licensing of inventions needed to exploit a given technology	Developing country licensees won't have to deal with multiple patent holders	What are the incentives to patent holders? Would government regulation be needed?
Global R&D alliance for research on key adaptation technologies	Model of research on neglected tropical diseases	Is such an approach suited to mitigation technologies?
Global clean technology venture capital fund	Fund located with a multilateral financing institution which will also have the rights to intellectual property	Will new technology ventures be viable commercially if they don't own intellectual property?
Eco-Patent Commons for environmentally sustainable technologies	Approach initiated by the private sector to make certain ESTs available royalty-free on a "give-one, take-one" model	Voluntary; private incentives appear weak. What about those companies without a patent to contribute?
Blue Skies proposal of European Patent Office: differentiated patent system with climate change technologies based on a licensing of rights	Complex new technologies based on cumulative innovation processes need to be treated differently from, e.g., pharmaceuticals	Appears to address similar concerns to patent pool proposal: more specifics needed on implications for technology access
More favourable tax treatment in developed countries for private sector R&D performed in developing countries	More pro-active, technology-push approach by developed country governments	May face domestic political constraints
Technology prizes	Reward innovation without awarding IPRs to innovators	Require a well-specified research objective

I. INTRODUCTION

The **Beijing High-Level Conference on Climate Change: Technology Development and Technology Transfer** is being convened to support the work of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC), particularly with regard to the agenda item of the fourteenth session of the Conference of the Parties (COP) to the Convention in Poznan on facilitating and accelerating the development and transfer of environmentally sound technologies. It will not be a forum for negotiations, but rather will provide an opportunity for Member States and other stakeholders to engage and openly consider the current state of technology development and transfer, the major barriers and possible mechanisms for overcoming them through public and private actions, including partnerships.

1. Background

Climate change is one of the most important challenges currently facing humanity and will continue to be a major problem not only due to its complex and pervasive nature but also because of its long-term impact on sustainable development. This view, supported by the Fourth Assessment of the Intergovernmental Panel on Climate Change (IPCC), has been expressed repeatedly by the United Nations Secretary-General in different fora. Finding effective and practical responses to this problem will have profound implications at the global, regional, national and community levels. Economic, environmental and social policies specifically designed to tackle this challenge are necessary since climate change affects all aspects of society. The urgency in finding solutions to this global problem will require unprecedented, bold actions from Governments, the private sector, and civil society.

A global commitment to a concerted effort under the United Nations system began in 1992 with the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) and its entry into force upon ratification by the required number of signatories in 1994. Its objective is "to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner." (United Nations 1992b)[3] In achieving this objective it was fully realised that there are different national circumstances, complexities, and responsibilities among and within nations, as articulated in the principle of common but differentiated responsibilities and respective capabilities.

A comprehensive climate change strategy encompasses coherent policies and actions with respect to mitigation and adaptation. Mitigation involves reducing GHG

[3] Article 2.

emissions and enhancing carbon dioxide (CO_2) sinks aimed at reducing the extent of global warming. Adaptation refers to the sensitivity, vulnerability and adjustment capacity of natural and human systems to climate change and its potential consequences. Technology is an essential component of this comprehensive climate change strategy. A broad spectrum of advanced technologies already exists for mitigating and adapting to climate change. In addition, new technologies will likely emerge as a result of focused research, development and international cooperative partnership initiatives.

There is an increasing recognition that technology development and transfer will play a major role in global and national strategies to combat climate change. Therefore, the effective and timely development and transfer of technologies to developing countries is essential for pursuing sustainable development goals and objectives. This view has come to the fore in discussions on the post-2012 framework for international climate policy. There is, however, a need to deepen the understanding of several issues currently affecting the development and transfer of technologies worldwide. In particular, the identification of mechanisms for overcoming barriers and obstacles to technology transfer and for enhancing international cooperation is a major priority.

It is stated in Article 4.5 of the UNFCCC that "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 organizations in a position to do so may also assist in facilitating the transfer of such technologies" (United Nations 1992b).

Agenda 21 that resulted from the United Nations Conference on Environment and Development recognizes that "there is a need for favourable access to and transfer of environmentally sound technologies, in particular to developing countries, through supportive measures that promote technology cooperation and that should enable transfer of necessary technological know-how as well as building up of economic, technical, and managerial capabilities for the efficient use and further development of transferred technology" (United Nations, 1992a). More specifically, the Johannesburg Plan of Implementation (JPOI) that resulted from the World Summit on Sustainable Development calls upon Governments and relevant regional and international organizations to take action on technology transfer, capacity-building and the diffusion of these technologies. Furthermore, the JPOI calls for efforts to accelerate the development, dissemination and deployment of affordable cleaner energy, energy efficiency and energy conservation technologies, and the transfer of these technologies to developing countries (United Nations 2002).

The thirteenth session of the Conference of the Parties (COP) to the UNFCCC (December 2007) adopted the Bali Action Plan. This Plan calls for a comprehensive global agreement by the end of 2009 through a negotiation process to enable full, effective and sustained implementation of the Convention, by addressing (Decision 1/CP.13) “1.(d) Enhanced action on technology development and transfer to support action on mitigation and adaptation, including, inter alia, consideration of: (i) Effective mechanisms and enhanced means for removal of obstacles to, and provision of financial and other incentives for, scaling up the development and transfer of technology to developing country Parties in order to promote access to affordable environmentally sound technologies; (ii) Ways to accelerate deployment, diffusion and transfer of affordable environmentally sound technologies; (iii) Cooperation on research and development of current, new and innovative technology, including win-win solutions; (iv) The effectiveness of mechanisms and tools for technology cooperation in specific sectors;” and “1.(b) (ii) Nationally appropriate mitigation actions by developing country Parties in the context of sustainable development, supported and enabled by technology, financing and capacity-building, in a measurable, reportable and verifiable manner.” In order to combat climate change, this COP also (Decision 3/CP.13) “recognizes that there is a crucial need to accelerate innovation in the development, deployment, adoption, diffusion and transfer of environmentally sound technologies among all Parties, and particularly from developed to developing countries, for both mitigation and adaptation” (United Nations 2008). Thus technology transfer has always been a key element of both the international climate change regime and the sustainable development agenda.

While UNFCCC agreements contain many references to technology transfer to developing countries, the focus of implementation has generally been on creating conditions in developing countries conducive to foreign investment and building capabilities to absorb and utilize imported technologies. Less emphasis has been placed on measures which Governments of technology supplier countries can and should take to facilitate and accelerate technology transfer. Nor, until now, have there been effective methods of measuring and verifying the extent of environmentally sound technology transfer.

Despite the renewed efforts of the international community and the growing recognition of the importance of technology, the full potential for the development, deployment and transfer of these technologies remains unfulfilled. In particular, technology transfer and diffusion have fallen short of the goals set by the Parties to the UNFCCC, as well as the expectations of developing countries. In addition, international technology cooperation and partnerships have yet to be fully utilized to accelerate wide-ranging win–win technology transfer for economic growth and poverty reduction and for climate change mitigation and adaptation.

2. Climate change and sustainable development

Further climate change and higher GHG concentrations are likely to adversely affect sustainable development especially in developing regions; however, efforts to reduce GHG emissions can be expensive and may affect economic development. Nevertheless, properly designed climate change mitigation and adaptation paths and strategies can reinforce national sustainable development strategy and goals.

Since climate change policies can have positive or negative influences on sustainable development, the preferred strategy must be to take advantage of the synergies that exist between climate change and sustainable development in order to promote both. This linkage provides an opportunity for countries around the world, especially the least-developed countries (LDCs) that did not really benefit from the gains of the industrial revolution that led to the increases in GHG concentrations, to undertake sustainable development programmes and at the same time effect climate change mitigation and/or adaptation.

All countries will need to undertake both adaptation and mitigation measures though the extent of these measures will depend on their respective national circumstances and sustainable development criteria and goals. The LDCs will be able to focus their limited resources and capacities more on adaptation than on mitigation measures. Developing countries with greater capacities and potential for mitigation will need both mitigation and adaptation measures, while developed countries will be able to focus their much larger capacities on mitigation.

Undertaking sustainable development actions requires full consideration of the three dimensions of sustainable development, namely the social, environmental and economic dimensions. Within the social sector, the following factors should be considered: poverty reduction, preservation of culture and heritage, popular consultation and empowerment to enable popular participation. Within the environmental sector, consideration should be given to reduction of pollution of all types, rational use of natural resources and development of resilience to environmental shocks. Within the economic sector, the factors for consideration are economic growth and efficiency while maintaining political stability. Issues such as inter-generational equity and equity among different social groups are of paramount importance. Equity and fairness need to be the guiding principles of such a development paradigm. Undertaking such sustainable development actions can affect success in achieving climate change stabilisation because the measures outlined above lead to a reduction in GHG emissions (IPCC 2000a).

Hence, an effective climate change strategy will require a portfolio of policies, measures and technologies that integrate development, equity and sustainability. Also, effective decision-making in a sustainable development context would require expanding the economic analysis of climate change by including all co-benefits. This is important because climate change threatens to increase the gap in the distribution of goods and services between generations, and between the rich and the poor and disadvantaged. Sustainable development can be achieved, in part, through actions aimed at climate change adaptation and mitigation.

3. Technology development and technology transfer

Technologies have been the driver of economic and social development worldwide, but not all countries have had the capacity to develop and maintain the technologies they require. Because technology is so important for achieving climate change stabilisation, the need for enhanced capabilities has made technology transfer a priority high on the international development agenda as well as in climate change negotiations.

There are a number of conceptual models that identify the stages involved in technology development and transfer. The IPCC identified the following five main stages (IPCC 2000b):

- Technology assessment,
- Technology agreement,
- Technology implementation,
- Technology evaluation and adjustment, and
- Technology replication.

A more comprehensive model that reflects endogenous capacities (Davidson 2001) contains the following stages:

- Consideration of national development plans to identify the sustainable development objectives,
- Technology needs assessment based on the sustainable development objectives,
- Technology selection using endogenous capabilities and identification of gaps that can be filled with technology imports,
- Merging endogenous capabilities with technology imports to develop technology,
- Operating technology at designed performance,
- Product or equipment modification to suit local conditions, and
- Development of technology that can compete internationally.

Technology development and technology transfer relate to existing and emerging technologies and include technology diffusion and technology cooperation with regard to equipment, know-how and software as well as their associated management systems. These transactions may occur through government-government, public-private sector or private-private sector partnerships. Technology transfer is not only about the supply of hardware across national or international frontiers, but also about the complex processes of sharing knowledge and adapting technology to meet local conditions, along with the associated management demands. The IPCC defines technology transfer as a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change among different stakeholders such as Governments, private sector entities, financial institutions, non-governmental organizations (NGOs) and research/educational institutions (IPCC 2000b).

In the past, technology transfer was generally viewed as the transfer of machinery and equipment from the producer (usually in developed countries) to the user, (in developing countries) through trade, aid and licensing or foreign direct investment (FDI). However, more recently, it has been shown that such transactions involve technology payments and that technology is embedded in social and political institutions that affect technology absorption. Also, it is now evident that technology can only be absorbed by the recipient country if there is some level of domestic capacity. Thus some countries, especially in Asia and Latin America, have not only absorbed the technology but have created the capacity to operate and modify imported technology efficiently and, in some cases, even innovating and developing new technologies. Therefore, some developing countries have been able to compete in the marketplace as a result of technology learning and mastery. Nevertheless, many developing countries lack the human and institutional capacities and the necessary infrastructure for the effective transfer and absorption of innovative technologies.

In recent years, major changes have taken place that influence technology development. These include increased knowledge intensity, the emergence of innovation-based competition through market liberalisation, globalisation of trade and growing concern for the environment. Some developing countries have been able to cope with these changes and to become integrated into the global economy because they treated technology transfer as a process of technology learning, domestic capacity building and innovation. However, the majority of developing countries have not been able to achieve technological progress.

All climate change discussions and initiatives have stressed the need for cooperation between developed and developing countries for the promotion of technology transfer. In practise, different stakeholders, whether Governments, multilateral institutions, the private sector or NGOs, have different roles in technology transfer. While Governments generally create the "enabling environment" to promote investments and technology development and transfer, it is generally the other actors that are involved in the actual transfer.

4. International issues in technology development and technology transfer

Aspects to be addressed for the effective development and transfer of technologies include:

- Human resource development,
- Institutional development,
- Information development,
- Partnership and networking, and
- Collaborative research and development (R&D).

Human resource and institutional development are the most important activities for LDCs, while partnerships and networking along with collaborative R&D may be more crucial for other developing countries. Information development is important for all countries, as it is the cornerstone of technology transfer. The developed countries are expected to facilitate and support human resource capacity building in developing countries.

Human resource development

An adequately trained workforce and technical, business and managerial staff are crucial to adapting, operating and managing technology. The experience of some developing countries has shown that adequate domestic capacities for achieving economic success and sustaining export growth can transform lagging economies into modern dynamic economies. Training is a long-term activity and should be closely monitored for effectiveness through sustained efforts by all stakeholders.

Institutional development

Strategies for developing and strengthening institutions for domestic capacity building in technology development include a number of functions, which are further detailed below.

Technology and business assessments are activities that enable the technology recipient to make appropriate decisions on technology selection based on local resources and constraints along with regional and global conditions. These activities require cooperation with business and technology R&D centres and include:

- Technology sourcing and evaluation;
- Technology testing, demonstration and certification;
- Technology forecasting and tracking;
- Managing effective information systems;
- Technology advisory services;
- Support for a reward system including patenting; and
- Business forecasting.

Technology policy research involves conducting cutting-edge research related to environmentally sound technologies, as well as policy research to assist Governments in the formulation of appropriate legislation, which is crucial for technological progress. This element is important when modeling long-term demands that take into consideration the problems of climate change (Jacobsen 2000). However, given the high rate of migration of scientists, engineers and technologists to developed countries, retention of adequate personnel is a major challenge facing developing countries. Incentive packages and mentorship programmes attractive to young and upcoming researchers can help.

Technology and business incubation centres are facilities that enhance the marketing of technologies. The absence of such centres for technology development and transfer in most developing countries leads to a waste of resources and frustration among stakeholders. The work of such an institution should consist of demand-driven activities linked to business opportunities and provide clients with such functions as:

- Evaluation of investment risks,
- Linkages to international technology and business centres,
- Linkages to local and external R&D centres,

- Technology demonstration and exposition,
- Technology investment and management advice,
- Technology forecasting needs,
- Technology upgrading, and
- Technical and financial support for near-market technologies.

Technology demonstration centres can overcome the problems, faced by developing countries, especially the LDCs, of demonstrating technology utilization potential and promoting overall technology awareness. Science and technology exhibitions, both stationary and mobile, and school and mass media programmes are necessary if the cultural aspects of technology transfer and development are to be addressed. Developed countries, where most of these demonstration facilities are located, can assist developing countries in this effort.

Information development

The role of information in technology transfer and development is crucial, and therefore capacities are needed to ensure access to the information required for adequate technological capability. There is much information in the public domain that is useful for technology transfer and development. However, the information needed should go beyond simple inventories of costs and environmental parameters, and should include specific technical data that will facilitate technology selection, development and use. Also, the scarcity of investment information impedes effective involvement of the private sector. Thus, in addition to adequate numbers of well-trained personnel in recipient countries, capacities are required for:

- Information assessment and screening,
- The development of information brokers to act as intermediaries,
- Maximal use of electronic systems, and
- The development of databases in developing countries with linkages to international databases.

Technology partnerships and networking

Technology partnerships between firms in developed countries and those in developing countries have been very effective in technology development and transfer and market development, provided they are two-way relationships involving a long-term commitment with the objective of sharing knowledge, enhancing technological capabilities, fostering innovation and strengthening competitiveness. Interaction and mutual dependency, as well as risk and cost sharing among partners, are important. Networks consist of a group of institutions or associations with the aims of enhancing the capacity to conduct research and improving training and education through interaction. Partners can therefore form a network to improve access to new ideas, methods, and information sharing and materials exchange. Both technology partnerships and networking require a certain level of technical competence among partners.

There are many such partnerships and networks among corporations in developed countries, while the number involving firms in developing countries is limited but growing. This recent trend, which is common to some developing countries, especially in South and East Asia, show that these partnerships and networks can foster technological upgrading and improvement in product quality. Similar results have been observed for countries that have received significant FDI. The success of these partnerships depends largely on how the local needs and priorities of the developing country are considered. Moreover, restrictions and conditions imposed by partners in developed countries can affect these partnerships. Though partnerships and networking are no panacea for capacity building, they can have several benefits including:

- Improvement of market access across a large number of industries,
- Contribution to the development of a competitive local industry and local expertise,
- Contribution to the mobilisation of resources and technological expertise to upgrade lagging infrastructure,
- Improvement of access to international markets, and
- Support to firms and R&D institutions for leveraging their activities and attracting new investments.

Collaborative research and development

Survival in the global economy requires increased knowledge, innovation, management and technological capabilities. In addition, a multi-disciplinary approach is needed to cope with the knowledge-based activities prevailing in international technology transactions. These advances have made the type of support needed by technological R&D institutions so expensive that very few institutions can afford them. Furthermore, the knowledge needed not only is absent in developing countries but also may require innovative approaches that can only be achieved through systematic, well-planned R&D programmes.

Since R&D activities are now becoming very competitive and expensive in terms of both financial and human resources, collaboration is necessary for coping with this challenge. Moreover, collaboration between institutions of developing countries and developed countries can be the most effective option in frontier technologies. Such international cooperation provides opportunities for sharing resources and activities, as well as for making optimal use of facilities.

The dynamics of technological change imply that, in order to address climate change strategically, technology programmes should include current technologies and those at the cutting edge. Developing countries need to increase their capacities to assess, analyse and choose technologies based on their needs and development priorities, and to adapt them to specific local conditions. Some developing countries and countries with economies in transition can use their human and institutional capacities to focus on technology partnerships and networking. International institutions and bilateral institutions in developed countries should mobilise some of their capacity to address the current environmental and sustainable development concerns of developing countries.

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II. TECHNOLOGIES, TECHNOLOGY TRANSFER AND BARRIERS

Technology is an essential component of a comprehensive climate change strategy that includes global efforts to limit and reduce GHG emissions (mitigation) and to decrease the adverse impacts resulting from climate changes (adaptation). These efforts, however, will only be effective if the deployment and diffusion of innovative technologies and the transfer of know-how take place effectively across national borders ensuring full coverage of those areas that will experience the greatest adverse impacts. Continuous advances in sustainable development on a global scale will require the use of new, cleaner, low-carbon and appropriate technologies to combat climate change.

While there already exists a range of technologies for mitigating and adapting to climate change, new technologies are likely to emerge as a result of the urgency and attention currently accorded to climate change. The mitigation and adaptive capacities of countries can be enhanced when climate policies are integrated into national sustainable development strategies and plans. Sustainable development strategies that consider climate change technologies and responses can contribute significantly to changing national development paths so as to make development more sustainable for many countries.

1. Environmentally sound technologies: mitigation and adaptation

Technology development, innovation and utilization are expected to play crucial roles in meeting the environmental and climate-change challenges of the future. Technologies to address climate change can be grouped into the two major areas for which these technologies can be utilized - mitigation and adaptation. Furthermore, technologies need to be classified according to their level of development: existing technologies (near term); state-of-the-art technologies (medium term); and technologies under development (long term).

Mitigation

Mitigation technologies are required to reduce GHG emissions and to enhance sinks aimed at reducing the extent of global warming. Mitigation technologies are designed to be applied for:

- Energy supply;
- End-use (industry, transportation and buildings) and infrastructure;
- CO_2 capture, storage and sequestration; or
- Reduction of other GHG emissions.

Table II.1 lists identified mitigation technologies in these categories for the near, medium and long terms. The technologies listed represent larger technology groups envisioned to achieve significant global adoption in the near term (by 2030), medium term (2030-2050), and long term (2050-2100).

Table II.1: Technologies for Mitigation

	Near-term	Mid-term	Long-term
ENERGY SUPPLY			
Fossil fuels	IGCC[4] commercialization Solid oxide fuel cells Cleaner coal plants	Hydrogen (H_2) co-production from coal/biomass	
Hydrogen	Integrated stationary fuel cell systems Demonstration H_2 production from renewable sources	Low cost H_2 storage and delivery H_2 from renewable sources H_2 from nuclear power Renewable H_2-powered fuel cell vehicles	H_2 and electric economy
Renewable energy	Lower cost wind power Biodiesel Demonstration cellulosic ethanol Photovoltaic (PV) clad buildings Cost-competitive solar PV First-generation bio-refinery Distributed generation systems	Low-wind speed turbines Advanced bio-refineries Cellulosic biofuels Community-scale solar systems Water photolysis Energy storage options	Widespread renewable energy utilisation Genetically engineered biomass Biologically inspired energy and fuels
Nuclear fission	Advanced reactor and fuel cycle technology New fuel forms and materials	Generation IV nuclear plants Closed proliferation-resistant fuel cycles Minimization of wastes for geological disposal	Widespread nuclear power utilisation Advanced concepts for waste reduction
Nuclear fusion	Demonstration of burning plasma Research on high-energy-density physics	Fusion power plant demonstration	Fusion power plants
END USE AND INFRASTRUCTURE			
Transportation	Hybrid and plug-in hybrid electric vehicles Clean diesel vehicles Alternative and flex-fuel vehicles Improved energy storage, including batteries Power electronics	Fuel cell vehicles and H_2 fuels Efficient and clean heavy trucks Cellulosic ethanol vehicles Intelligent transport systems Low-emissions aircrafts	Zero-emission vehicle systems Optimized multi-modal inter-city and freight transport Engineered urban designs and regional planning
Buildings	High-performance integrated homes Energy-efficient building materials High-efficiency appliances Insulation control windows	"Smart" buildings Solid-state lighting Ultra efficient HVACR[5] Neural-net building controls	Energy managed communities Low-powered sensors with wireless communications
Industry	High-efficiency boilers Greater waste heat utilisation Bio-based feedstocks	Superconducting electric motors Efficient thermoelectric systems Low-emission cement production options	High-efficiency all-electric manufacturing Widespread use of bio-feedstocks Closed-cycle products and materials
Electric grid and infrastructure	Distributed generation Smart metering and controls for peak shaving Long-distance direct current (DC) transmission Composite conductor cables	Neural-net grid systems Energy storage for load levelling	Superconducting transmission and equipment Wireless transmission
CO_2 CAPTURE, STORAGE AND SEQUESTRATION			
CO_2 capture	Post- combustion capture Oxy-fuel combustion Oxygen separation techniques	Novel capture technologies Biomass coupled with CO_2 capture and storage (CCS)	Novel in-situ CO_2 conversion technologies

[4] Integrated gasification combined cycle.
[5] Heating, ventilation, air-conditioning and refrigeration.

Geological sequestration	Reservoir characterization Enhanced hydrocarbon recovery CO_2 injection to enhance coal-bed methane production	Mineralization of solid carbonates Well sealing techniques demonstrated	Sufficient effective CO_2 storage capacity
Terrestrial sequestration	Reforestation Soil conservation	Sequestration decision support tools Bio-based and recycled products	Biological sequestration Carbon and CO_2 based products and materials
Marine sequestration	Effective dilution of directly injected CO_2	Carbonate dissolution/alkaline addition	Safe long-term marine storage
EMISSION REDUCTION OF OTHER GHGs			
Methane from energy production and waste	Bioreactor land-fill technology New drilling techniques for recovery of coal-bed methane	Advanced land-fill gas utilization Ventilation-air methane technologies	Integrated waste management systems
Methane and nitrous oxide (N_2O) from agriculture	Anaerobic digesters for heat and electricity production	Utilisation of soil microbial processes	Zero-emission agriculture
High global warming potential gases	Advanced refrigeration technologies Advanced aluminium smelting processes	Alternative refrigeration fluids	Solid-state refrigeration and air conditioning systems
N_2O from combustion	Catalytic reduction of N_2O in nitric oxide plants	Catalysts that reduce N_2O to elemental nitrogen in diesel engines	Advanced vehicles and non-carbon based fuels
Ozone precursors and black carbon	Particulate matter control technologies for vehicles Reflective roofs to reduce heat-island effect	Jet fuel additives to minimize black carbon and soot emissions	

Source: US DOE 2006.

Table II.2 lists a number of clean energy technologies and their mitigation potential as a result of accelerated technology innovation. These technologies are perceived as strong players for future climate change mitigation.

Renewable energy technologies

A concerted effort is necessary to diversify the energy matrix in favour of renewable energy and low-carbon technologies for electricity, heating and cooling. Technological progress can create new opportunities to harness the vast renewable energy potential. Fuel switching in the transport system through the use of alternative fuels such as biofuels represents a major opportunity for climate change mitigation. In developing countries, the key challenge is to bring the cost of the resultant services to levels at which they would be affordable by low income households.

Considering traditional biomass, large hydropower, and “new” renewable energy sources (small hydro, modern biomass, wind, solar, geothermal, and biofuels), renewable energy supplies 18 per cent of the world’s current final energy consumption (REN21 2007).

Table II.2 Clean energy technologies and mitigation potential

TECHNOLOGY	STAGE OF DEVELOPMENT	MITIGATION POTENTIAL BY 2050 (Gt CO_2/y)	COMMENTS
Supercritical	R&D-Commercial	0.3	• Supercritical is commercial; ultra supercritical requires more development, especially in the area of high-temperature materials. • Enabling technologies for CCS
IGCC	R&D-Demonstration	0.2	• Enabling technology for CCS
CCS	Demonstration	5.5	• Cost barriers • Needs successful demonstrations of full system integration • Challenges for regulatory and legal systems
Hydropower	Scaled-up-Commercial	0.5	• Large-scale is commercial • Mini- and micro-scales are demonstration/scale-up
Solar	R&D-Commercial	0.5	• PV is commercial in certain off-grid applications • Grid applications are in R&D phase; large cost reductions required • Concentrating solar power is in demonstration phase.
Ocean energy	R&D	0.1	• Early stages of development
Geothermal	Commercial	0.3	• Large potential for cost reduction in certain regions
Wind	Scale-up	1.3	• Development policies have significantly reduced costs
Bioelectricity	Commercial	0.5	• Large potential for BIG-GT[6], IGCC, and bio-refineries but they are in R&D/demonstration stage.
Hydrogen fuel cells for transport	R&D	0.8	• Very significant cost barriers.
Second-generation biofuels	R&D-Demonstration	1.3	• Significant cost barriers.
End-use energy efficiency • Vehicles (engine, non-engine, and hybrid technologies) • Heating and cooling • Electrical end-use • Other	 Scale-up-Commercial Commercial Scale-up-Commercial Scale-up-Commercial	 5.4 2.6 4.6 1.8	• The primary barriers facing end-use efficiency technologies relate to market barriers, inadequate regulations, capital constraints and lack of information. • Where the non technical barriers can be overcome, private industry is normally ready to conduct technical work to bring the bulk of products to commercialization.
Nuclear power generation • II and III generation • IV generation	 Commercial R&D	 1.8 1.9	• Barriers to public acceptance, and political, regulatory, environmental, safety and financial issues of reactor safety, waste disposal, and nuclear proliferation. • Large cost barriers

Sources: World Bank 2008a and IEA 2006.
Notes: Figures indicate additional abatement potential of each technology relative to the baseline scenario, not total potential for CO_2 emission reduction. This potential can be realised through increased energy R&D, more extensive demonstration and deployment programmes, and a set of policies that lead to the adoption of technologies that reduce CO_2 emissions at US$ 25/tonne.

[6] Biomass integrated gasification-gas turbine.

Traditional biomass, primarily for cooking and heating, represents about 13 per cent and is declining in most regions or still growing slowly in others as biomass is used more efficiently or replaced by modern energy forms. Large hydropower represents 3 per cent and is growing modestly, primarily in developing countries. The new renewable energy sources represent 2.4 per cent and are rapidly growing in developed countries and some developing countries. Growth in the utilisation of new renewable energy sources is important because of their large future potential, and the critical need for policy support in accelerating their commercial use.

Renewable energy replaces conventional fuels in four distinct sectors: power generation, hot water and space heating, transport fuels, and rural (off-grid) energy. Currently, in power generation, renewable sources provide about 5 per cent of global power-generation capacity and, excluding large hydropower, are responsible for 3.4 per cent of the global electricity supply. Hot water and space heating are supplied by biomass, solar, and geothermal sources for tens of millions of buildings. Biomass and geothermal energy also supply heat for industry, homes, and agriculture. Biofuels for transport make small but growing contributions in some countries and regions (e.g., USA, Brazil and the European Union (EU)). The installed capacity of such renewable energy systems as wind power, solar hot water, geothermal heating and off-grid solar photovoltaics (PV), grew globally at rates of 15–30 per cent annually for many technologies during the five-year period 2002–2006. These growth rates can be compared with global growth rates for fossil fuel production of 2–4 per cent in recent years (higher in some developing countries) (REN 21 2007).

Renewable energy policies exist in at least 66 countries worldwide. By 2007, at least 64 countries had a national target share for renewable energy supply, including all 27 EU countries. Most national targets are for shares of electricity production, typically 5–30 per cent, but ranging overall from 2 to 78 per cent. Other targets are for shares of total primary or final energy consumption, specific installed capacity, or total amounts of energy produced from renewable sources, including heat.

Energy efficiency

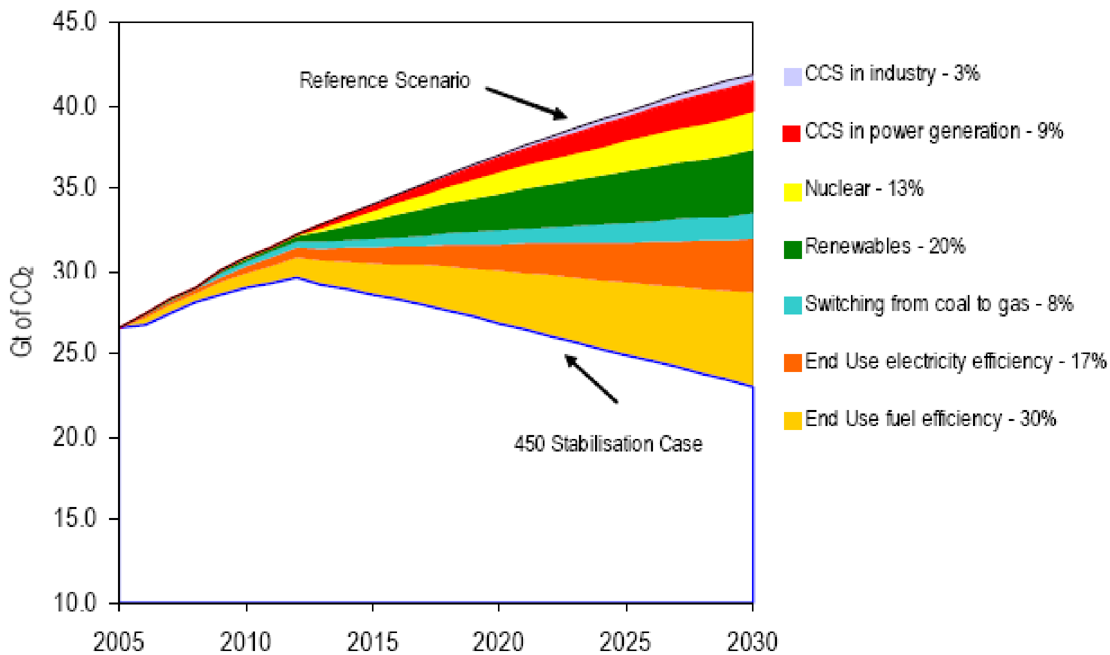
In all countries, considerable investment is necessary to increase the efficient conversion and use of energy in all sectors of the economy. Close and active international cooperation with public and private partners creates synergies in the development of efficient and clean technologies. Policies that provide a real or implicit price for emitted carbon could create incentives for producers and consumers to significantly invest in low GHG technologies and processes.

Improved efficiency in energy demand and supply can make a major contribution in the reduction of GHG emissions. A scenario illustrating the potential for technologies to reduce worldwide emissions of CO_2 by 2030 is shown in Figure II.1. The scenario is based on the “450 Stabilization Case” developed by the International Energy Agency (IEA) to reduce annual energy-related CO_2 emissions to 23 gigatonnes by 2030 (IEA 2007). The chart shows that end-use electricity efficiency and fuel efficiency have the potential to reduce expected 2030 emissions by 47 per cent. Renewable energy sources, in general, could reduce 2030 emissions by 20 per cent.

Adaptation

Adaptation involves different forms of technology, which include not only equipment and materials but also a variety of implementation processes and methods. Many of these methods have been tried and tested already but some are newer and involve innovative sciences or technologies. One of the main challenges is to ensure that these methods and technologies are put into practice in those areas where they are most needed, especially in developing countries and in the most vulnerable communities such as those in which the population lives in contact with nature and stands to lose the most as a result of climate change.

Figure II.1: Potential CO_2 emission reduction by technology area



Source: IEA 2007.

The technologies needed for adaptation can be either those that require new hardware or science (hard types), such as new irrigation systems, or those that require different implementation approaches (soft types), such as crop rotation patterns. Adaptation technologies can be implemented in five major areas: regional and local climate modelling and early warning, coastal zone management, water resources, agriculture and public health (See Table II.3). Actions to implement adaptation technologies can be of two types: anticipatory actions such as constructing dykes, and reactive actions such as moving buildings to safer areas.

Climate models and early warning systems are useful for providing public officials with the information to avert the worst impacts of changes or disasters. Technologies as well as monitoring and modelling systems are essential for the timely assessment of impacts related to altered frequencies and intensities of extreme weather, climate and sea-level events.

Technologies for adaptation to sea-level rise in coastal zones can be used to protect, retreat or accommodate. Protective measures can involve the construction of tidal barriers, wetland restoration or afforestation. Retreat activities include establishing set-back zones and creating upland buffers. Examples of accommodation include improved drainage technologies and early warning and evacuation systems.

Water resources are expected to be affected due to changes in precipitation patterns, increased drinking, irrigation and industrial water demand and increased evaporation. Water resources can be expanded by employing desalination techniques, building reservoirs and levees for flood management, and using advanced recycling and efficient technologies for use in industrial cooling.

Agricultural productivity and food supply can be highly affected even by minor climate variations. Some adaptation options in agriculture include: new varieties of crops, advanced irrigation systems, efficient wind breaks and advanced erosion control techniques.

Climate change can directly or indirectly affect human health. Some of the effects can be negative such as increased potential for heat strokes and accelerated transmission of infectious diseases. Technical options to reduce the negative impacts on health include: advanced urban planning to reduce heat island effects; increased efficient use of air conditioning; improved public transport; disease vector control; and vaccination.

Table II.3: Technologies for Adaptation

MAJOR AREAS	TECHNOLOGIES AND PROCESSES
Extreme weather, climate and sea-level events	Climate models and systems for monitoring and early warning. Climate proofing infrastructure
Coastal zone management	To protect: tidal barriers, dune and wetland restoration and afforestation. To retreat: establishing set-back zones and creating upland buffers. To accommodate: improved drainage technologies and early warning and evacuation systems.
Water resource management	Desalination techniques. Reservoirs and levees for flood management. Advanced recycling. Efficient technologies for use in industrial cooling.
Agriculture	New varieties of crops. Advanced irrigation systems. Efficient wind breaks. Advanced erosion control techniques
Public health	Advanced urban planning to reduce heat island effects. Improved public transport. Disease vector control. Vaccination.

Mitigation and adaptation synergies and tradeoffs

Mitigation and adaptation are linked in many ways. In the long term, more mitigation implies less adaptation and vice versa, and yet to date mitigation and adaptation technologies and policies have been developed separately. As adaptation receives increasing recognition, it is important that the synergies and tradeoffs between the two be clearly delineated (Sathaye et al. 2008). In forestry and soil management, the vulnerability of land can be decreased and carbon stocks protected at the same time. In construction, the design of buildings and urban areas can take into account both energy efficiency and thermal comfort. Water management plans can combine hydropower with water retention for drought periods. But if adaptation takes place without considering GHG emissions, trade-offs can result. Important examples are increases in cooling, irrigation, and energy consumption through protective infrastructure. Synergistic technologies and policies that help address both aspects simultaneously should be identified and given preference in their transfer to countries needing assistance.

2. Technology transfer

In developing its definition of the term "technology transfer", the IPCC explained that: "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. It comprises the process of learning to understand, utilize and replicate the technology, including the capacity to choose and adapt to local conditions and integrate it with indigenous technologies" (IPCC 2000).

Technological progress can take place through scientific innovation and invention, through the adoption and adaptation of pre-existing but new-to-the-market technologies, and through the spread of technologies across firms, individuals, and the public sector (World Bank 2008a).

Principal channels by which developing countries are exposed to external technologies include: (1) trade, (2) FDI, (3) contacts with highly skilled nationals working abroad, and with other information networks including (4) academia and (5) the media (World Bank 2008b).

Status

In general, some developing countries have made progress in closing the technology gap with advanced countries in recent decades. However, despite rapid improvement in technological achievement in some developing countries, major gaps remain.

Changes in the regulatory environment and in the nature of technologies partly explain the acceleration in the rate at which technologies have penetrated in some developing countries. Technological diffusion among middle-income countries has been accelerated by advances in communications and transport technologies that have given rise to the growth of global production networks and facilitated increased trade and technological advances.

However, there is no international effort to track the flow or transfer of environmentally sound technologies (ESTs). In fact, little is known about how much climate-relevant equipment is transferred -- and even less about the transfer of know-how, practices and processes. Thus, most international analyses must rely on proxy variables. International financial statistics only reflect the quantity and not the quality of FDI (IPCC 2007).[7] Financial flows, often used as proxies, allow only a limited view of technology transfer trends over time. Higher efficiency products should have the incremental cost of reduced emissions considered but the relevant information is not readily available. Renewable energy supply is easier to track.

In the past decade, there have been broad changes in the types and magnitudes of the international financial flows that drive technology transfer between countries. The trend of official development assistance (ODA) was downward during the 1990s, both in absolute terms and as a percentage of funding for projects with a significant impact on technology flows to developing countries. In the last several years, however, the ODA has been fluctuating and experienced a net increase during the 2000-2007 period. Sources and amounts of development finance, some portion of which goes for technology transfer, vary widely from region to region.

Levels of FDI, commercial lending, and equity investment all increased over this period. As a result, private sources have supplied more than three-fourths of the total net resource flows from member countries of the Organisation for Economic Co-operation and Development (OECD) to developing countries compared to only one-third in 1990 (IPCC 2000). FDI, loans, and equity are the dominant means by which the private sector makes technology-based investments in developing countries and in countries with economies in transition, often in industry, energy supply and transportation. Private sector investment in the form of FDI in developing countries has favoured East and South East Asia, and Latin America.

Table II.4 shows the total cumulative lending by multilateral development banks during the period 1995–2005 for all reported climate-relevant sectors. The miscellaneous sectors shown in the last row are excluded from the analysis.

[7] Chapter 2, p. 62.

Table II.4: Lending by multilateral development banks in developing countries for all sectors in selected years (billions of 2005 US dollars)

Sector				Annual average	Share (percentage)
	1995	2000	2005	(1995-2005)	
Education	3.405	1.750	2.550	2.463	6.1
Health	1.262	1.446	1.328	1.395	3.5
Water supply and sanitation	2.967	1.496	2.645	2.125	5.3
Transport and storage	4.585	4.209	6.969	5.550	13.8
Communication	0.441	0.080	0.248	0.220	0.5
Energy generation and supply	4.422	2.707	2.707	3.095	7.7
Agriculture	2.672	3.360	2.464	2.559	6.3
Forestry	0.101	0.053	0.125	0.134	0.3
Fisheries	0.085	0.006	2.120	0.067	0.2
Industry	0.845	0.747	2.414	1.089	2.7
Mineral resources and mining	0.025	0.342	0.405	0.222	0.6
General environmental protection	5.614	1.014	0.319	0.696	1.7
Urban and rural development	1.380	0.883	1.439	1.235	3.1
Reconstruction, relief and rehabilitation	0	0.269	2.497	0.569	1.4
Disaster prevention and preparedness	0	0	0.660	0.060	0.1
Emergency response	0.122	0.189	0	0.226	0.6
Miscellaneous	37.389	32.733	37.273	18.620	46.2
TOTAL	**65.316**	**51.285**	**66.162**	**40.326**	**100**

Source: OECD 2007

Because of the limited ability to compare trends in technology transfer on the basis of financial flows, other indicators and data to quantify the level and flows of environmentally sound technologies are needed to better inform Governments about their policy choices. In addition, technology performance benchmarks for different sectors could be compiled to give an indication of the real degree of implementation of these technologies and the potential of technological improvements. It would be useful to have simple and agreed criteria for measuring the transfer of such technologies.

Another more direct way of examining the trend in technology transfer is to correlate it with the amount of investments dedicated to environmentally sound projects. An estimated US$ 71 billion was invested in new renewable energy capacity worldwide in 2007, compared to US$ 55 billion in 2006 and US$ 40 billion in 2005. Technology shares of the US$ 71 billion annual investment were mostly for wind power (47 per cent), solar PV (30 per cent), and solar hot water (9 per cent), followed by smaller shares for small hydropower, biomass power and heat, and geothermal power and heat. An additional US$ 15–20 billion continues to be invested annually in large hydropower (REN21 2007).

Investment in renewable energy is still mostly in OECD countries, with USA and the EU together accounting for more than 70 per cent of this investment in 2006. However, investment in developing countries is growing rapidly with 21 per cent (US$ 15 billion) of the global renewable energy investment in 2006 as compared to 15 per cent (US$ 4.2 billion) in 2004.

In addition to renewable energy capacity investment, there were substantial capital investments in new manufacturing plants and equipment during 2006-2007. Investment in solar PV plants and equipment was expected to reach US$ 10 billion in 2007, up from US$ 8 billion in 2006. Investment in new biofuels production capacity worldwide has also been growing rapidly, and was expected to exceed US$ 4 billion in 2007. The value of biofuels production plants under construction and announced for construction through 2009 exceeded US$ 4 billion in USA, US$ 4 billion in Brazil and US$ 2 billion in France (REN21 2007).

Considering investments in renewable energy capacity additions (excluding large hydropower), new manufacturing capacity, and research and development spending (estimated at over US$ 16 billion in 2006 from both public and private sources), there is no doubt that more than US$ 100 billion was invested in renewable energy in 2007—marking a significant global milestone. While most of this investment is taking place in China, USA and the EU, some markets are capturing increasing shares of investment in new capacity, manufacturing facilities, and R&D, notably Brazil and India (REN21 2007).

Financing for renewable energy in developing countries has grown with the involvement of many public and private domestic banks, government funds, and rural microcredit lenders. India's Renewable Energy Development Agency (IREDA) is a good example of a national public source of funds. Brazil's PROINFA programme, which started in 2002, saw major investments come on line during 2006-2007, mostly from domestic banks. Throughout Latin America and the Caribbean, new wind projects, for example in Jamaica and Costa Rica, are receiving private financing. Thailand has been financing small power producers from public funds, with over 1,500 MW of renewable capacity installed by mid-2006—mostly biomass and biogas projects (average capacity about 20 MW). Many examples of rural microcredit throughout Asia and Africa can now be found, with well-known initiatives, both public and private, in Bangladesh, India, Sri Lanka, Uganda and elsewhere (REN21 2007).

UNFCCC technology transfer framework and national technology needs

The COP to the UNFCCC defined a framework for meaningful and effective actions to increase and improve the transfer of and access to environmentally sound technologies and know-how.[8] This technology transfer framework defines five key elements for meaningful and effective actions: (1) technology needs and needs assessment, defined as a set of country-driven activities to determine technology priorities through widespread stakeholder consultations; (2) technology information; (3) enabling environments, defined as government actions, including the removal of technical, legal and administrative barriers to technology transfer, sound economic policy and regulatory frameworks to create a conducive environment for private and public sector investment in technology transfer; (4) capacity building, which is a process for building, developing, strengthening, enhancing and improving existing scientific and

[8] Annex to Decision 4/CP.7 contained in UNFCCC/CP/2001/13/Add.1.

technical skills, capabilities and institutions in developing countries to enable them to assess, adapt, manage and develop environmentally sound technologies; and (5) mechanisms to facilitate the support of financial, institutional and methodological activities to enhance coordination among stakeholders, to engage stakeholders in cooperative efforts to accelerate the development and diffusion of these technologies and to facilitate the development of projects and programmes to support these ends.

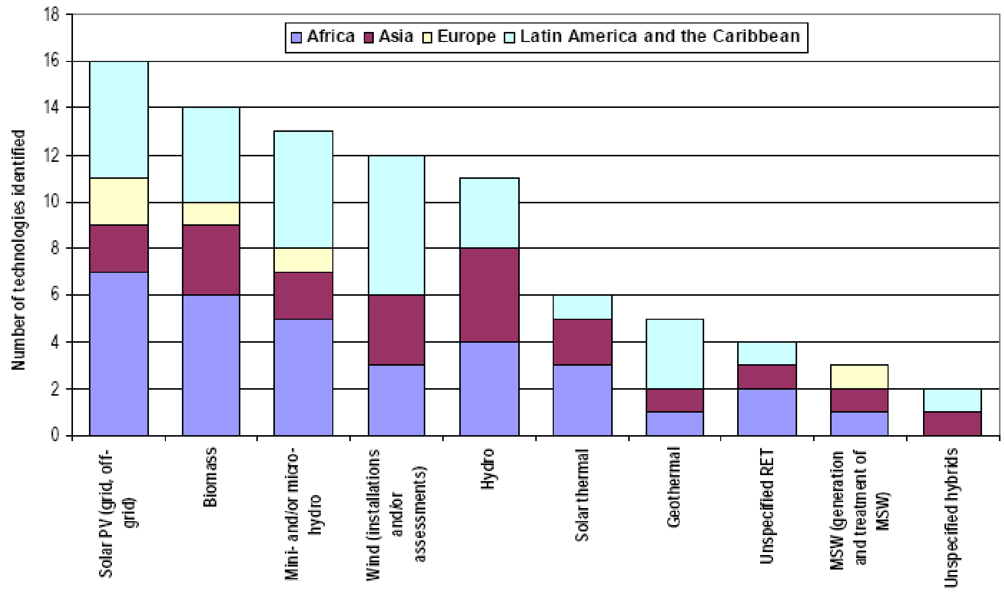
At the same time, the COP established the Expert Group on Technology Transfer (EGTT) under the Subsidiary Body for Scientific and Technological Advise (SBSTA) for the purpose of enhancing implementation of this framework and to advance technology transfer activities under the Convention. The COP reconstituted the EGTT in 2007 with the objective of "advancing the development, deployment, adoption, diffusion and transfer of ESTs to developing countries, taking into consideration differences in accessing and applying technologies for mitigation and adaptation."[9]

At its fourth session, the COP invited non-Annex I Parties to submit their prioritized technology needs, especially those relating to key technologies, for addressing climate change. A synthesis of key results of the technology needs assessments undertaken by 23 non-Annex I Parties and information from 25 initial national communications of non-Annex I Parties that specifically addressed the issue of technology needs was published in 2006 (SBSTA 2006). This report highlights priority technology needs identified in various sectors to reduce GHG emissions and facilitate adaptation to adverse impacts of climate change.

The priority technology needs on a regional basis are presented in Figures II.2 and II.3. They show the commonly identified renewable energy technology needs and energy efficiency technology needs in the building and residential subsectors, respectively. Overall, the priority technology needs for renewable energy technology were found to be for solar PV, biomass, hydro (mini- and micro-scale) and wind systems, with solar thermal systems also important for Africa and Asia, municipal solid waste treatment systems for Europe, and geothermal systems for Latin America and the Caribbean. The priority needs found overall for energy efficiency were for lighting, solar water heating, and stoves and ovens, with solar driers also important for Africa and air-conditioners, heaters and refrigerators for Asia.

[9] Decision 3/CP.13 contained in UNFCCC/CP/2007/6/Add.1.

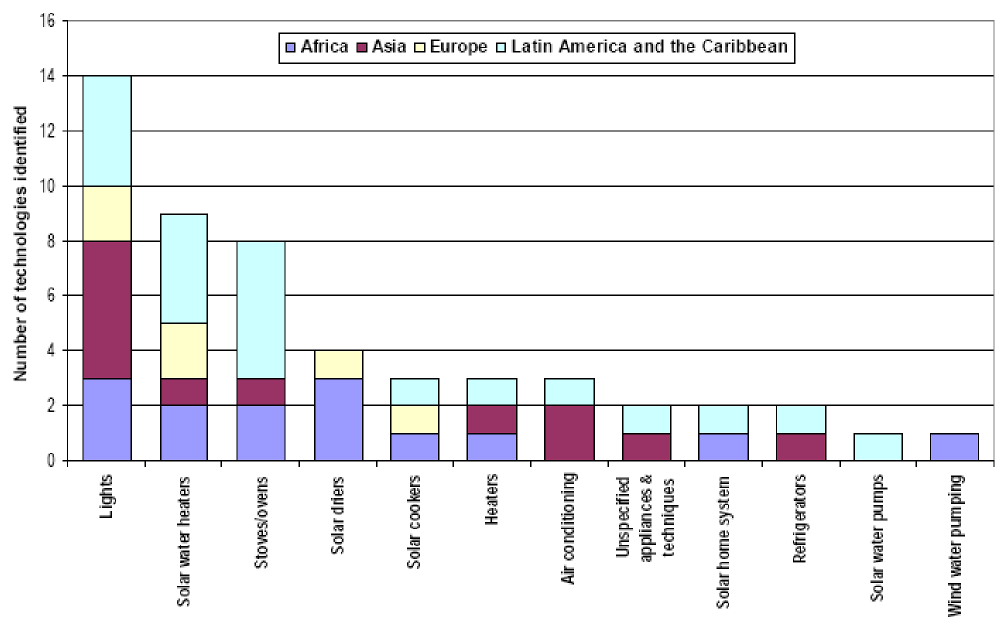
Figure II.2: Commonly identified renewable energy technology needs



Note: Solar PV - solar photovoltaic; MSW - municipal solid waste; RET - renewable energy technology

Source: SBSTA 2006.

Figure II.3: Commonly identified energy efficiency technology needs in the building and residential subsectors



Source: SBSTA 2006.

3. Barriers

Technological change occurs within a larger context of socioeconomic factors. Prices of energy or the underlying infrastructure can play important roles in shaping technological change and in determining the types of technologies that become commercialized. There are several important elements or dimensions of this context with regard to technological change (IPCC 2000):

- **Market conditions,** including: ease of market entry for new firms and technologies; availability of capital; the degree of internalization of social and environmental concerns through taxes, subsidies, insurance and other mechanisms; and the degree of competitiveness, including any oligopolistic practices or informal arrangements between government and the private sector;
- **The legal system,** including: the system of intellectual property rights (IPRs); the allocation (e.g., among firms or between the public and private sectors) of liability for past and future environmental damage; freedom of speech and information; and ease of litigation;
- **The physical infrastructure,** including: the design of cities and other settlements, transport systems and utilities; and their flexibility in permitting the adoption of alternative technologies, lifestyles and production systems;
- **Social and political structures,** including: the role of the public in decision-making; the location of power in institutional and social relationships; the presence of formal or informal alliances involving government, industry and the media; and the allocation of roles within households and communities;
- **Culture,** including: cultural diversity; the role of technology and material consumption in establishing individual identity, status and social bonds; and tendencies towards competition and cooperation, conformity and distinction; and
- **Psychology,** including: awareness, understanding, and attitudes relating to energy efficiency, its causes and potential impacts, and to changes in technology and lifestyles.

Of these dimensions, most attention seems to have been paid to the role of markets and legal systems. Existing market and legal incentives can pose barriers to some kinds of technological change, but they can also provide opportunities for innovation. The need to address local pollution through government regulations may stimulate innovation that can contribute to energy efficiency improvement and also reduce GHG emissions. For example, waste water pollution regulations have provided an incentive to US industry to reduce its water consumption, which also reduces energy consumption for water heating/cooling while retaining the same level of industrial output. Whether such regulations have benefited industrial competitiveness or have encouraged innovation that is only narrowly aimed at regulatory compliance is a subject of debate, but its energy and environmental benefits are not disputed.[10]

[10] Porter and Van der Linde (1995) argued that environmental regulation of industries could also promote their competitiveness through accelerated innovation, although this has been disputed by Palmer *et al.* (1995), who argue that most evidence is that regulation, as historically practiced, has not fostered

The effects of physical infrastructure have been less studied, being harder to measure than the effects of prices and regulations. Infrastructure often acts as a constraint on changes in technology and behaviour: existing road systems and settlement patterns in many countries tend to encourage car dependency; and the existing supply networks for domestic and transport fuels make it difficult for individual households or firms to adopt alternatives.

The social capital passed on from one generation to the next offers an opportunity for diffusion of energy efficient technologies in traditional and modern societies alike. Societies in which trust and civic cooperation are strong have significant positive impact on productivity, especially human capital productivity, and provide stronger incentives to innovate and to accumulate physical capital. More investment in consultation and participation of the local population in decision making about energy efficiency and pollution control contribute both to information sharing, to building trust, and civic cooperation. The former may contribute to changes in beliefs, norms, and values if participants are convinced that they are better off after effecting the change.

Reliance on market mechanisms alone without an appropriate institutional framework that performs a coordinating function among sectors is inadequate and may be destructive of social capital. Policy attention to learning by doing, and network externalities, together with policy stability and enforcement, favour the diffusion of energy efficient technologies.

Addressing the last three dimensions listed above thus involves understanding human psychology, relationships, communities, institutions and the process through which social norms and decisions are established.

Major identified barriers

Therefore, on the basis of the foregoing discussion of the dimensions of technology change and the reported national assessments of technology needs, barriers to technology transfer include:

Market

- Unstable market situations which hinder international technological investments;
- Difficulty of market entry for new firms and technologies;
- Low level of competitiveness;
- Small size of markets; and
- Low income consumers;

Financial

- Lack of financial resources;
- High level of debt;

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competitiveness, and has encouraged innovation only narrowly aimed at regulatory compliance (Berman and Bui 2001 and Xepapadeas and de Zeeuw 1999).

- Incompatible prices, subsidies, tariffs, taxes and insurance;
- Lack of incentives;
- Lack of access to credit;
- High up-front and transaction costs; and
- Low economic productivity;

Informational
- Lack of access to information;
- Lack of access to relevant technical data;
- Lack of awareness about climate change related issues, options for mitigation and adaptation and advanced technologies; and
- Lack of information about potential donors and project developers;

Legal
- Inappropriate systems of IPRs;
- Inappropriate allocation of liabilities for environmental damage; and
- Inappropriate litigation systems;

Regulatory and policies
- Existing laws and policies that may not be compatible with climate change mitigation and adaptation related measures; and
- Lack of necessary policies, regulations, standards and codes;

Human resources
- Lack of skill/expertise in dealing with various aspects of climate change related projects; and
- Lack of skilled personnel for the installation and operation of environmentally sound technologies;

Infrastructural
- Lack of minimal technological infrastructures;
- Inflexible city and settlement designs; and
- Infrastructure obsolescence;

Organizational and Institutional
- Lack of compatible or adequate organizational and institutional frameworks (legal, financial, regulatory, enforcement, etc.); and
- Lack of coordination among activities of existing organizations and institutions;

Social and cultural
- Social practices, beliefs and norms that prevent acceptance of climate change mitigation/adaptation options;
- Lack of awareness of environmentally sound technologies and energy efficiency benefits; and
- Inefficient life-styles; and

Political
- Lack of public mechanisms that support technology transfer;
- Ineffective governance; and
- Lack of freedom of speech and information.

The identification, analysis and prioritization of barriers are part of a country-specific process for formulating particular actions and strategies. It is important to recognize that strategies to overcome the identified barriers should take into consideration the sustainable development criteria and goals as well as the interests and influences of the various stakeholders.

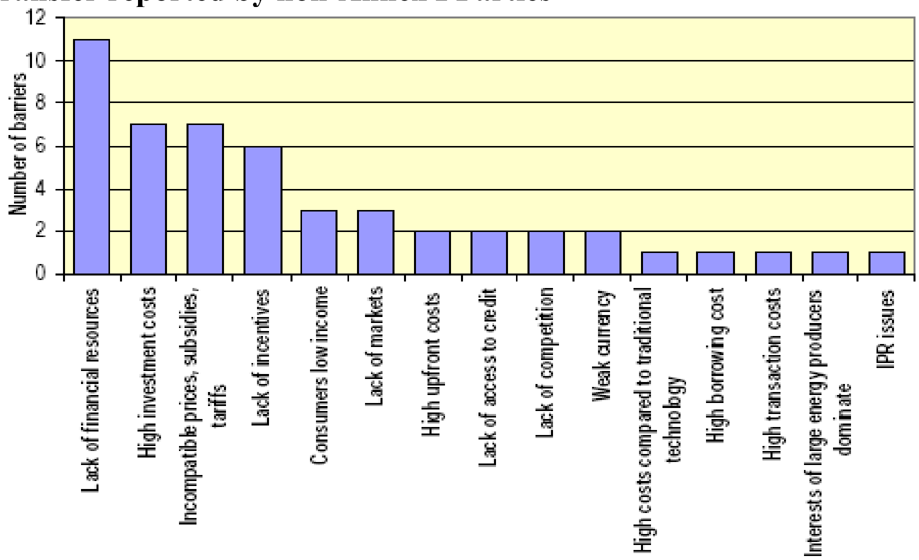
Market and financial barriers are frequently present due to a shortage of financial resources and a lack of developed markets for the technology. Shortage of financing is very common in developing countries and caused by poor macroeconomic conditions, which can include underdeveloped financial sectors, high import duties, high or uncertain inflation or interest rates, uncertain stability of tax and tariff policies and investment risks. Difficulties in accessing capital due to inadequate financial strength usually pose serious obstacles to the private sector mainly to small and medium enterprises. Markets may not exist due to lack of financial institutions or systems to ensure that investments are made for the use of the transferred technology, lack of confidence in economic, commercial or technical viability, lack of manufacturers, and lack of consumer awareness and acceptance of technology, the latter being largely driven by cultural habits (IPCC 2000).

Important regulatory, institutional and informational barriers include: lack of supporting policies and frameworks, including codes and standards for the evaluation and implementation of environmentally sound technologies; lack of support for an open and transparent international banking and trading system; low, often subsidized conventional energy prices resulting in negative incentives to adopt energy-saving measures and renewable energy technologies; inadequate vision about and understanding of local needs and demands; shortage of information that can be caused by limited access to media resulting in lack of data, knowledge and awareness, especially about emerging technologies; and lack of access to relevant and credible information on potential partners to allow for the timely formation of effective relationships which can enhance the penetration of environmentally sound technologies.

Other important barriers are: lack of understanding the role of developed and developing countries and international institutions in the failures and successes of past technology cooperation arrangements; insufficient human and institutional capabilities; inability to access, select, import, develop and adapt appropriate technologies; lack of science, engineering and technical knowledge available to private industry; insufficient R&D because of lack of R&D investments and inadequate science and educational infrastructure; and institutionalized corruption in both developed and developing countries (IPCC 2000).

Using the available information from the analysis carried out for 25 reporting non-Annex I countries (SBSTA 2006), it is possible to identify the barriers to technology transfer most commonly mentioned. Figure II.4 provides the frequency of reported barriers by type for the countries which conducted the technology needs assessments. The most frequently identified barriers cited were: lack of financial resources; high investment costs; incompatible prices, subsidies and tariffs; and lack of incentives.

Figure II.4: Frequency of economic and market barriers to technology transfer reported by non-Annex I Parties



Source: SBSTA 2006.

The information available on barriers affecting the transfer to and the adoption by developing countries of environmentally sound technologies is clearly limited. More research is essential to allow a better understanding and a more comprehensive assessment of all the relevant factors. In particular, it is very important to assess the main barriers to widespread transfer and adoption of currently available technologies that could significantly improve energy efficiency in developing countries. Also, it is necessary to determine more specifically the key barriers to more rapid development and deployment of state-of-the-art technologies and the measures and mechanisms that can accelerate these processes.

4. Case Studies

Case Study 1: Increase of FDI in China – the wind sector

FDI in China has risen rapidly over the past twenty years, with China being the current lead recipient of FDI among all developing nations and second only to the United States among Asia-Pacific Economic Cooperation countries. A small, yet growing interest of FDI in China is focused on the production of "clean" technologies or products (e.g., for pollution control, energy efficiency, or renewable energy).

Although China only contributes a small share of installed wind energy capacity globally, in 2005 the largest national annual capacity addition was in China. This was spurred by the government target to produce 30 GW by 2020 and other policies and initiatives to encourage the market for wind power development. One of these is the wind concession programme. This government-run bidding programme encourages domestic and international companies to develop wind projects and was first utilized to promote large-scale wind farms. The programme grants companies the right to develop the selected project site and includes a 25-year power purchase agreement, guaranteed grid connection, financial support for grid extension and access roads, and preferential tax and loan conditions. However, one aspect of the programme that frustrates some international investors is a 70 per cent local content requirement. Another stimulus is the 2005 Renewable Energy Law, which creates incentives for and a requirement that 10 per cent of China's energy be from renewable sources by 2020. The law includes measures to promote the use of bidding to set prices for renewable energy development projects, although feed-in-tariffs have been used in some wind power cases. This law extends the 70 per cent local content requirement to all renewable energy projects throughout China, although many companies have found ways around this requirement.

Various Models of FDI in the Wind Sector

In one study of wind power in China, foreign and domestic companies involved in the Chinese wind turbine industry were examined and the extent of technology transfer was compared in four case studies (Lewis 2006) (See Table II.5). Among these four cases there were three types of ownership models, which greatly impacted the extent of technology transfer: (1) Limited joint venture: all materials and technology are developed and owned by the foreign company but manufactured with Chinese labour and materials (e.g., NEG Micon/Vestas and GE Wind); (2) Joint venture: a foreign company develops the technology, which is then owned by a Chinese company and components are made with Chinese labour and materials (e.g., Xi'an-Nordex); and (3) Chinese owned: a Chinese company develops and owns the technology and oversees the production of the materials (Goldwind-China).

Table II.5: Ownership, design, manufacturing and IPRs

	Company ownership	**Turbine design**	**Majority of turbine content**	**Turbine IPR ownership**
NEG Mitcon/Vestas	Denmark	Denmark	Denmark	Denmark
Xi'an-Nordex	Germany-China	Germany	China	China
GE Wind	USA	USA–Germany	China	USA
Goldwind-China	China	Germany-China	China	China

Source: Lewis 2006.

Regardless of the ownership model, very few foreign companies have transferred wind power technology, in great part due to the local content requirement and concerns about IPRs.

Foreign-owned companies have not challenged the local content requirement because they have been able to do well in the market and retain control of their intellectual property (IP). Notably, the Chinese Government is considering the implementation of local IP requirements for wind power in an attempt to push international companies to transfer more technology. Such stipulations on IP requirements could be contested by international companies under the World Trade Organisation or by simply limiting new FDI in this sector.

The Chinese Government has been trying to promote strong independent Chinese wind power companies with some success. Among Chinese wind power enterprises, several manufacturers produce equipment that is up to 30 per cent cheaper than their foreign counterparts, but they generally are not as advanced in design. For example, Chinese firms rely on 600-750-kW capacity turbines, while General Electric offers 1.5-MW and Vestas provides 2-MW turbines. The manufacturing capacity of China is changing fast with the nation on track to exceed the 30-GW target by 2020.

It has been suggested that instead of mandating IP requirements, there should be a focus on finding policies to support demonstration, testing, and certification of locally manufactured technologies (Lewis 2006). Goldwind, a Chinese company, is one of the few local manufacturers with commercially available turbines, but many new Chinese turbine manufacturers are entering the market. Many of the Chinese turbines are new models that have not been tested. Thus, there is a need for a standardised testing programme, not only to help reduce risks associated with these new turbines, but also to promote the distribution of certified designs. Chinese companies must also develop channels for informal knowledge transfer, such as through the establishment of R&D centres. In this regard, the model adopted for Suzlon, a new wind power company in India, is impressive. Although a latecomer to the renewable energy market, Suzlon has become the world's fourth largest maker of wind turbines, surpassing some Danish manufacturers. Its founders created a unique model in which they established R&D centres throughout Europe to improve their production of turbines in India.

Case Study 2: Brazil's sugarcane-based ethanol industry[11]

Brazil's ethanol industry started in the 1930s. With more sugar than it could use, the Government directed that sugarcane be used for ethanol production and made the addition of ethanol to gasoline a mandatory automobile fuel. As a result of the international oil crisis in 1973 that doubled Brazil's expenditure on oil imports, the industry made significant progress. With the need to consider alternative sources of energy to decrease its dependency and spending on fossil fuels, the Government launched the National Alcohol Programme (Pro-Álcool) in 1975 to increase ethanol production as a substitute for gasoline. It invested in increasing agricultural production, modernizing and expanding distilleries, and establishing new production plants. It also introduced subsidies to lower prices and reduced taxes for ethanol producers.

Over the next 15 years, production of ethanol increased from 0.6 billion litres in 1975 to 11 billion litres in 1990. During the first phase of the programme in 1975–1978, one part of ethanol was added to four parts of gasoline and there was an additional

[11] This section is based on Almeida 2007.

processing stage to remove water from the fuel. By 1979, production had been streamlined to focus on hydrous ethanol (containing six per cent water) that could be used in cars fuelled entirely by ethanol. At the programme's peak in 1986–1989, 90 per cent of all new vehicles sold in the domestic market were ethanol-fuelled.

Behind the success of the programme there were important scientific and technological advances in agriculture and industry. The production of 40 tonnes of sugarcane per hectare was more than doubled through investments in research and improvements sponsored together by the Government and the private sector. Using traditional breeding techniques, researchers produced varieties adapted to different soil and climate conditions, with shorter production cycles, better yields, and tolerance to water scarcity and pests (such as the devastating fungus that caused sugarcane rust in the 1980s). New grinding systems were developed and the fermentation process adapted to use different microorganisms and enzymes to produce more ethanol at a faster pace. The Sugarcane Technology Centre, a privately-funded research institute in São Paulo, was key to improving ethanol production technology, having invested about US$ 20 million per year in research at the peak of the programme. Researchers at the Centre and other institutions also found ways to use sugarcane fibre residue, known as bagasse, to produce energy, building on existing methods of burning bagasse to power steam turbines for electricity generation and using the remaining heat from the turbines for the distillation process. They developed cauldrons operating at greater pressure so that more energy could be produced, allowing many ethanol plants to become self-powered. This contributed significantly to keeping ethanol production costs low.

The infrastructure developed and advances made enabled the programme to survive a turbulent period at the end of the 1980s, when the Government cut public investment after a drop in the price of oil. Although this had a short-term impact, demand remained high and almost five million ethanol-fuelled cars were in circulation by the 1990s.

Today, Brazil is the second biggest producer of ethanol in the world (20 billion litres) after USA (24 billion litres). Close to 80 per cent of this is for the domestic market; the fuel used in 45 per cent of Brazilian vehicles is ethanol. Part of the demand is due to the success of flex-fuel cars, which can run on gasoline, ethanol or a mixture of both. The cars were developed by engineers at Bosch, a German company, in São Paulo and released in 2003. The engine works differently depending on the quantity of oxygen produced by the type of fuel burned, which is measured by a sensor. Flex-fuel cars renewed consumer interest in ethanol and intensified demand for this biofuel. According to Brazil's National Association of Vehicle Manufacturers, ANFAVEA, 85 per cent of cars — some four million vehicles — sold in Brazil today are flex-fuel. The success of flex-fuel and the need to reduce CO_2 emissions have inspired a search for new applications of ethanol. Researchers at the Delphi Technology Centre in São Paulo have developed a fuel system for motorcycles that can also use ethanol–gasoline blends in any proportion. The first ethanol-powered bus, developed at University of São Paulo, has been undergoing road tests since December 2007 to assess its economic viability. The

Brazilian aviation company, EMBRAER, has had an ethanol-fuelled agriculture monoplane in use since 2004.

As a result of poor harvests in key producing countries and a fast-growing demand for grains and other crops used for biofuels (among other reasons), world agricultural prices rose sharply during the 2006-2008 period. The price boom was led by maize and wheat but high market volatility was observed for most food and feed commodities. However, the Brazilian biofuel industry is based on sugarcane conversion which is considered a very efficient process. Furthermore, the Brazilian biofuel industry uses the extensive land available in that country with only a small fraction of the arable land being used for ethanol production.

With international demand for renewable sources on the rise, Brazil has many challenges to face if it is to continue at the forefront of the ethanol market. One major challenge is to increase its already significant production without further negative environmental or social impacts.

Producing ethanol from sugarcane bagasse and straw would be a step in the right direction. These components are rich in cellulose and turning these into ethanol would allow the entire sugarcane biomass to be used with no wastage. One tonne of bagasse can produce 186 litres of ethanol. But there are doubts about the economic viability of the current process, which requires more water and produces more polluting byproducts like liquid vinasse. Large production of ethanol, however, is no guarantee of market superiority for Brazil nor of success of the ethanol industry internationally.

Brazil is offering its expertise to nations worldwide, especially to developing countries that could produce biofuels but still depend on oil. Brazil also hopes to expand its ethanol market. Many countries have already shown an interest in the trade. In 2008, Brazil signed agreements with countries in Africa, the Caribbean and Latin America. Most of these agreements involve the transfer of Brazil's ethanol production technology. For example, in Benin, Brazil will use its expertise to help develop production capacity and, in Angola, Angolan and Brazilian oil companies are planning a facility to produce sugar, bioenergy and ethanol from sugarcane. This facility is designed to produce 150 million tonnes of sugar, 50 million litres of alcohol and 140 megawatts of electricity per year. Construction was scheduled to begin in 2008 and the joint venture involves an investment of US$ 200 million. The sugar, ethanol and power produced by this project are expected to cover domestic demand rather than exports, due to shortages of these commodities in Angola.

Case Study 3: Transfer of publicly funded technologies

Governments devote varying budgetary amounts to sponsoring or in some manner supporting a broad array of research activities in fields ranging from medicine to energy and the environment. These activities can take place in government-owned facilities, private companies, or universities or some combination thereof. Such pursuits may result in the identification of patentable technologies or processes, as well as copyrightable computer programmes or other publications worthy of IPR protection. Although the precise arrangements vary from country to country, there is a high degree of commonality in the manner in which the property rights to these publicly-sponsored results are assigned. Except in the case of "pure research" such as genomic sequence data that is immediately shared with the public at large, the property rights are assigned to one or more of the participants in the research process.

To better understand the issues associated with publicly-financed/ publicly-owned technologies versus those in the public domain, the OECD in 2000-2001 conducted a review and survey of several countries' procedures for handling the rights and titles to IP (OECD 2003). The detailed survey covered data and information on patenting and licensing at public research organizations (PROs).[12] Its goals were to (i) document and assess the legal and regulatory frameworks for commercializing IP generated with public research funds, (ii) measure and analyze the patenting and licensing activities of PROs in member and selected non-member countries, and (iii) identify areas for policy action. The analysis of the survey noted an important trend regarding IP ownership. The granting of ownership of the IP to the research organization and ensuring that benefits are shared with inventors has emerged as common practice in many OECD countries. As noted in a recent report, the management of IPRs has evolved from an Open Science model to a Licensing Model (EC 2004). Information on selected countries shows that institutional ownership of the IP is the norm, and as described for the US and Republic of Korea (ROK) examples, several stakeholders may share in its monetary rewards (Sathaye et al. 2005). The EC report also provides data on licensing income derived from technology transfer in Canada, the UK and USA (UNICO-NUBS 2001).

A second important trend reported in the OECD survey, which is relevant to the discussion of technology transfer under the UNFCCC, is that since its signing in 1992, laws and regulations governing an IP regime in member countries have evolved significantly. In the ROK and Canada, for example, the need to foster technology innovation and incubation has led to the devolvement of IPRs to non-government institutions. PROs may create incubators to foster rapid transfer of technologies to industry. These have played a key role in the growth of small R&D enterprises located in communities that have been established around the PROs. As a result, a much larger fraction of the IPRs now belong to public and private research organizations than was the case when the UNFCCC was signed and came into force.

In the US, until 1980, the IP derived from government-funded research was owned by the Government for its use and for licensing to the private sector. Dissatisfied with the slow rate of technology transfer, Congress passed the Bayh-Dole Act in 1980, which gave non-profit organizations (primarily universities) and small businesses the right to retain ownership of their inventions, and to patent them, and license them to firms. The United States has over 700 government-owned national laboratories, most of which are government-operated, and the rest are contractor-operated.

[12] Public research organizations (PROs) include universities, and non-university entities such as national laboratories and other publicly supported research institutions.

The Lawrence Berkeley National Laboratory (LBNL) is one such contractor-operated facility that is managed by the University of California for the US Department of Energy (DOE). There are two primary ways that industry can access technologies funded by the US Government at the laboratory. One approach is to seek licenses to technologies that were developed at the LBNL, and another is to conduct research jointly with laboratory scientists in a public-private partnership (PPP). Under the second approach, the DOE and industry jointly sponsor a research project. Costs, personnel, facilities, equipment or research capabilities may be shared for mutual benefit. This provides industry with a way to leverage their research activities. There are four ways to protect IP that result from such activities: patents, copyrights, trademarks and trade secrets. LBNL and other laboratories and universities, are generally concerned with the first two ways to protect IP.

Both exclusive and non-exclusive licenses may be accessed by US and foreign companies. The LBNL does not discriminate between US and non-US entities in its selection of companies that will be permitted an exclusive or non-exclusive license. All other things being equal, however, small US businesses get a preference, and exclusive licenses to non-US entities are referred to the DOE, which in turn may consult with the Office of the US Trade Representative to ensure the other country also offers US companies similar IP access and compliance within the export control regime.

Aside from the ways that IP transfers occur for government-sponsored research, collaborative research with non-staff scientists has been a time-honoured tradition at most universities, including that at the LBNL. Scientific divisions at the LBNL often sign memoranda of understanding, cooperative R&D agreements, and other agreements with both US and foreign entities. Such agreements permit short and extended visits to both countries, foster collaborative research funded by either country, and often lead to new inventions, discoveries, and jointly partnered publications. The most productive outcomes for the LBNL have been the researcher-based collaborations and/or bi-lateral relations that grew out of such partnerships. While no figures are readily available, it appears that these partnerships may lead to just as much or more of a payoff than that earned through direct licensing of technologies and software, since these include a capacity-building element that might be lacking in the former type of exchange.

Thus, while the transfer of technologies for mitigation and adaptation applications between countries is one element of the UNFCCC, IPR environment and practice have evolved significantly since the Convention was drafted. IPRs now involve many stakeholders that may not include the Government. Sustaining such an arrangement over long periods requires sufficient incentives to keep all the relevant participants fully engaged in the process. Nevertheless, while the technology outcomes may become applied worldwide, such diffusion would typically follow a pathway of licensing or royalty payments rather than use without restriction in the public domain. The implementation of technology transfer components of the UNFCCC needs to take these realities into consideration.

However, it is not suggested that all technology transfer requires monetary compensation. From the UK and US experiences with developed and developing country partners, it appears that the larger technology transfer benefit may be derived from on-going joint research between institutions of higher learning in partnering countries (Sathaye et al. 2005). Such exchanges build capacity, foster complementary contributions by researchers from different countries, and can lead to jointly developed, and even jointly held, patents and licenses. In particular applications, mechanisms of this type may be more fruitful avenues for the future development and transfer of innovative environmentally sound technologies.

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III. MECHANISMS FOR ENHANCING TECHNOLOGY DEVELOPMENT AND TRANSFER

1. Mechanisms under the UNFCCC

Currently operational mechanisms for the development and transfer of environmentally sound technologies can be classified into financing, institutional and methodological mechanisms. Financing mechanisms include mechanisms under the Global Environment Facility (GEF) and the Clean Development Mechanism (CDM). Institutional and methodological mechanisms include the Expert Group on Technology Transfer (EGTT) and the performance indicator system.

Financing Mechanisms

The Parties to the Convention have assigned operation of the financing mechanism to the GEF on an on-going basis subject to review every four years. The Kyoto Protocol also recognizes, in Article 11, the need for a financing mechanism to fund activities by developing country Parties. One such mechanism under the Kyoto Protocol is the CDM.

In addition to providing guidance to the GEF, the Parties have established three special funds: the Special Climate Change Fund (SCCF) and the Least Developed Countries Fund (LDCF), under the Convention; and the Adaptation Fund (AF), under the Kyoto Protocol.

The SCCF finances projects related to: adaptation; technology transfer and capacity building; energy, transport, industry, agriculture, forestry and waste management; and economic diversification. The LDCF was established to support a work programme to assist LDC Parties, inter alia, in the preparation and implementation of the national adaptation programmes of action (NAPAs). The AF was established to finance concrete adaptation projects and programmes in developing countries that are Parties to the Kyoto Protocol. The Fund is to be financed with a share of proceeds from the CDM project activities and to receive funds from other sources. The share of proceeds amounts to 2 per cent of certified emission reductions (CERs) issued for a CDM project activity.

The Global Environment Facility

Since the creation of the GEF, about US$ 2.4 billion have been allocated to projects in the climate change focal area and resulted in the reduction of over one billion tons of GHG emissions (GEF 2008a). The GEF reported to the COP at its twelfth session that almost all climate change projects funded from the GEF Trust Fund are concerned with either the initial introduction of modern technologies in developing countries or the dissemination and broadening of their application. It estimates that 80-100 per cent of GEF climate change mitigation funding fits the technology transfer definitions used by the Convention (GEF 2006).

As part of the GEF-4 replenishment process, the focus of technology transfer activities is placed on stimulating increased market penetration for energy-efficient technologies, practices, products and materials. A specific programme for the transfer of technologies was set up under the SCCF, which follows a technology- or sector-specific approach. As of April 2007, US$ 10.7 million was available from the SCCF for the programme on technology transfer (GEF 2008b). Moreover, the GEF was requested by the COP at its thirteenth session to elaborate a strategic programme to scale up the level of investment for technology transfer to help developing countries address their needs for environmentally sound technologies.

The Clean Development Mechanism (CDM)

The COP has requested that CDM projects lead to the transfer of environmentally sound technologies in addition to requirements under other provisions.[13] The CDM project design documents include information about technologies to be employed in projects, as well as descriptions of how technologies and related know-how are to be transferred to the host Parties. The CDM can contribute to technology transfer by financing emission reduction projects that use technologies currently not available in the host countries.

The CDM is intended not to promote technology innovation, but the deployment (including international transfer) of existing low-carbon technologies. There have been a number of analyses examining the propensity for technology transfer in CDM projects. One study (Seres 2007), which examined a comprehensive data set of CDM projects and proposals, indicates that about 40 per cent of the projects examined claimed some form of technology transfer (i.e., either a transfer of equipment, knowledge, or both). Since large projects were more likely to involve technology transfer, about two-thirds of the overall projected emissions reductions utilized transferred technologies. Notably, five project categories – hydrofluorocarbons, N_2O, landfill gas, fossil-fuel switching, and wind – accounted for about 75 per cent of the technology-transfer-based emissions reductions.

In trying to understand national differences among CDM projects, it has been suggested (Pueyo Velasco 2007) that the host country's investment climate is a very significant variable determining its attractiveness for transfers of new technologies through the CDM. In fact, the probability of technology transfer is much higher for countries with higher openness or if the project is developed in the subsidiaries of Annex-I country firms (Dechezlepretre et al. 2008).[14]

There are also indications that technology transfer in CDM projects is well-correlated with GDP growth and, in key sectors such as energy and chemicals, with the presence of strong technological capabilities (Dechezlepretre et al. 2008). In addition, it has been noted that transfer of technologies through private channels is higher for

[13] Including FCCC/CP/2000/5/Add.3.

[14] The CDM does help create actors who reduce the barriers of lack of information and of access to capital, but it does not change the institutional framework of the recipient countries (Schneider et al. 2008).

countries in more advanced stages of development (Ellis et al. 2007).[15] These findings suggest that activities such as the CDM will be more successful in transferring technologies to countries that already have a relatively-high technological base. Furthermore, the individual and scattered nature of the projects impedes the accumulation of learning as well as technical and implementation capacity that can drive down costs (although the "programmatic" CDM approach may help in this regard).

The existing financing mechanisms are widely considered to be inadequate to the task of mobilizing resources and effecting technology transfer on the scale required to address the climate change challenge. There is a need to strengthen, streamline and reduce the transaction costs of the CDM. Even then, the project-oriented focus of the mechanism makes it difficult to mobilize financing for large-scale public investment in low-carbon energy infrastructure and/or public transport infrastructure.

Institutional Mechanisms

Expert Group on Technology Transfer (EGTT)

The EGTT was established as an institutional arrangement to facilitate the implementation of the technology transfer framework provided by the Marrakesh Accords. The EGTT informs Parties on the status and progress of its work in annual reports and, over the years, has produced targeted and instructive products that Parties can use in formulating specific climate change mitigation and adaptation technology strategies.

According to its terms of reference, the EGTT organizes workshops and prepares technical papers, reports and handbooks to analyze and identify ways to facilitate and advance technology transfer activities. Also, based on these activities, the EGTT makes recommendations to the SBSTA.

One of the emerging work areas of the EGTT related to mechanisms for technology transfer is innovative options for financing the development and transfer of technologies. A major output of this work is a practitioners' guidebook to assist project developers in developing countries to prepare project proposals that will meet the standards of international finance providers.

Another important work area is in the development of tools that can support countries in meeting their special needs for adaptation to climate change. A major output is a background paper containing lessons learned in specific sectors (coastal zones, water resources, agriculture, public health and infrastructure) with 15 case studies. The report highlights potential policy recommendations to strengthen the transfer of technologies for adaptation.

[15] The share of total high-technology goods to low-income countries doubled between 1970 and 2001, while lower-middle income developing countries increased their share sevenfold (Schneider et al. 2008, citing Hoekman et al. 2004).

With its reconstitution at the thirteenth session of the COP to promote the Bali Action Plan, the strengthened EGTT has elaborated a programme of work for 2008-2009 that includes the identification of mechanisms for technology transfer including innovative financing, cooperation with relevant conventions and intergovernmental processes, endogenous development of technology, and collaborative R&D of technologies.

Methodological Mechanisms

Performance Indicators System

The EGTT has conducted a review of the implementation of the technology transfer framework, assessed the progress of work in various areas under each key theme of the framework, and identified gaps and barriers to its implementation. Following this work, the COP[16] requested the EGTT to develop, as part of its future programme of work, a set of performance indicators that could be used by the Subsidiary Body for Implementation to regularly monitor and evaluate the effectiveness of implementation of the framework for meaningful and effective actions to enhance the implementation of Article 4.5 of the UNFCCC. The work is divided into three tasks: developing a set of candidate performance indicators, testing the set of performance indicators, and preparing recommendations for their use (EGTT 2008). The performance indicator system will serve as a methodological mechanism for evaluating and monitoring the development and transfer of environmentally sound technologies.

2. Other mechanisms being implemented by international organisations and partnerships

Environmentally sound technologies are also recognized as crucial elements for addressing the climate change challenge by other multilateral international cooperation mechanisms such as the World Bank's technology funds, the Asia and Pacific Partnership on Clean Development and Climate Change (APP), and the IEA's energy technology agreements and initiatives. Other important partnerships include the International Partnership for a Hydrogen Economy, the Carbon Sequestration Leadership Forum and the Renewable Energy and Energy Efficiency Partnership.

Climate Investment Funds (CIFs) of the World Bank

The CIFs which were created by the World Bank in July 2008 are a collaborative effort among the multilateral development banks (MDBs) and some countries to bridge the financing and learning gap until a post-2012 global climate change agreement comes into effect (World Bank 2008a).

[16] Decision 3/CP.13, Annex.

The CIFs have two distinct funds related to technology: the Clean Technology Fund (CTF) and the Strategic Climate Fund (SCF). The CTF will provide new, large-scale financial resources to invest in projects and programmes in developing countries which contribute to the demonstration, deployment, and transfer of low-carbon technologies. The projects or programmes must have significant potential for long-term GHG emissions reductions (World Bank 2008b). The SCF will promote collaboration and synergies among the MDBs, identify and promote targeted programmes for scaling up efforts, promote and channel increased financing, and support the sharing and dissemination of lessons learned. These new funds build on the experience gained from the World Bank's Clean Energy Investment Framework, which identified the need for financial resources to scale up clean energy investments and to integrate climate resilience into development assistance.

Additionally, the World Bank manages ten carbon funds and two related facilities comprising public and private participants (World Bank 2007). The funds include:

- The **Prototype Carbon Fund** which has pioneered the market for project-based GHG emission reductions while promoting sustainable development;
- The **Community Development Carbon Fund** which provides carbon finance to projects in poorer areas of the developing world that combine community development with investment in clean energy;
- The **Bio-Carbon Fund** which focuses on projects that sequester or conserve carbon in forests and agro-ecosystems, while promoting biodiversity conservation and poverty reduction;
- The **Netherlands CDM Facility** which supports projects in developing countries that generate potential credits under the CDM framework of the Kyoto Protocol;
- The **Netherlands European Carbon Facility** which purchases emission reductions from Joint Implementation (JI) projects located in countries with economies in transition;
- The **Italian Carbon Fund** which facilitates opportunities for the private and public sectors in Italy to participate in projects that generate cost-effective emission reductions and the transfer of clean technology;
- The **Danish Carbon Fund** which purchases emission reductions that generate potential credits under the CDM and JI arrangement of the Kyoto Protocol;
- The **Spanish Carbon Fund** which promotes projects that contribute significantly to the sustainable development of developing countries and countries with economies in transition;
- The **Umbrella Carbon Facility** which is an aggregating facility that pools funds from World Bank-managed carbon funds and other participants to purchase emission reductions from large projects; and
- The **Carbon Fund for Europe** which assists European buyers of emission reductions in meeting their compliance needs, is jointly managed by the World Bank and the European Investment Bank, and purchases emission reductions that generate potential credits under the CDM and JI arrangement of the Kyoto Protocol.

The Bank's Board of Executive Directors recently approved two new carbon facilities, which are both aimed at the post-2012 period and are set up as partnerships between the sellers (Governments and private entities from Bank client countries) and the buyers of emission reductions:

- The **Carbon Partnership Facility (CPF)** which focuses on supporting programmes that generate emission reductions from long-term investments, mainly in the post-2012 period; and
- The **Forest Carbon Partnership Facility (FCPF)** which focuses on helping developing countries with tropical and subtropical forests to tackle deforestation and forest degradation.

The Asia-Pacific Partnership on Clean Development and Climate (APP)

The APP is an international non-treaty agreement among Australia, Canada, China, India, Japan, the ROK, and USA announced in 2005 at an Association of South East Asian Nations (ASEAN) Regional Forum meeting and launched in 2006 at the Partnership's inaugural meeting in Sydney.

The aim of the Partnership is to collaborate on the promotion and creation of an enabling environment for the development, diffusion, deployment and transfer of existing and emerging cost-effective, cleaner technologies and practices, through concrete and substantial cooperation so as to achieve practical results. The Partners also cooperate on the development, diffusion, deployment and transfer of longer-term transformational energy technologies that will promote economic growth while enabling significant reductions in GHG emissions.

The Partnership has established eight government and business task forces on cleaner fossil energy, renewable energy and distributed generation, power generation and transmission, steel, aluminum, cement, coal mining, buildings and appliances[17].

Cooperation between the UNFCCC and other multilateral environmental agreements (MEAs) and intergovernmental processes

Enhanced cooperation between the UNFCCC and other multilateral environmental agreements and intergovernmental processes is an important goal promoted by the Parties to the UNFCCC. Thus, at the thirteenth session of the COP, the Parties made recommendations for technical cooperation including: sharing information and experiences related to the transfer of technologies; encouraging Parties to take into consideration the objectives of other MEAs when formulating climate change strategies, programmes and projects; identifying areas for potential cooperation; and formulating clear objectives for cooperation.

[17] APP website: www.asiapacificpartnership.org.

Other MEAs and intergovernmental processes represent complements to the Convention. The World Bank with sufficient operational experience and financial expertise provides very valuable technical support for the establishment and operation of technology-related financial mechanisms according to the objective of technology development and transfer approved under the UNFCCC process.

The design of technology transfer mechanisms under the UNFCCC can benefit from some of the lessons learned from other MEAs. One good example is the Montreal Protocol on Substances that Deplete the Ozone Layer. Box III.1 provides a summary of lessons learned from the implementation of the Montreal Protocol.

Box III.1 Lessons learned from implementation of the Montreal Protocol

The Montreal Protocol on Substances that Deplete the Ozone Layer was agreed in 1987 and entered into force in 1989 after scientists showed that some man-made substances were contributing to the depletion of the Earth's ozone layer which protects life from damaging ultraviolet radiation.

The Montreal Protocol requires that Parties eliminate emissions of most ozone-depleting substances (ODS). Environmentally safe substitutes and related technologies have been used to achieve this objective. Since many of these technologies were widely available only in a relatively few countries and since the global market had been slow to bring these technologies to some parts of the world, deliberated and active international technology transfer programmes have been needed to eliminate ODS emissions (Strelneck and Linquiti 1995).

In order to ensure the completion of the Montreal Protocol and the transfer of the "best available environmentally safe substitutes and related technologies", the Multilateral Fund was established by the London Amendment to the Protocol in 1990. The main objective of the Multilateral Fund is to assist developing country Parties to the Montreal Protocol, whose annual per capita consumption and production of ODS is less than 0.3 kg, to comply with the control measures of the Protocol (http://www.multilateralfund.org/).

The fund covers the incremental costs associated with technology transfer, including the costs of on-site engineering, equipment purchase and installation, training, and start-up. Capacity-building projects, such as the establishment of national ozone offices and regional ozone network offices, are also eligible for funding (Andersen et al. 2007).

As of April 2008, the contributions made to the Multilateral Fund by some 49 developed countries (including countries with economies in transition) totaled over US$ 2.3 billion. The implementation of the projects using these funds will result in phase-out of the consumption of more than 249,577 tonnes and the production of about 174,206 tonnes of ODS. Of these totals, about 215,462 tonnes of ODS consumption and 158,737 of ODS production have already been phased out from projects approved as of December 2006 (http://www.multilateralfund.org/).

The Montreal Protocol is considered one of the most successful global environmental agreements and stimulated the development and worldwide transfer of technologies to protect the stratospheric ozone layer. Lessons have been identified from implementation of the Montreal Protocol that may be of interest to the climate change process (Andersen et al. 2007). The lessons relevant to technology transfer include: developing visionary technology assessments; empowering the financial mechanism to be a proactive instrument for technology transfer; developing and implementing training programmes; and using regulations and policies to promote technology transfer.

3. Effectiveness of traditional commercial mechanisms for technology transfer to developing countries[18]

Over the past two decades, developing countries' exposure to foreign technologies has increased. Their imports of capital and intermediate goods (which permit the production of technologically sophisticated goods and services) now represent between 6 and 14 per cent of their GDP, an increase of more than 80 per cent since 1994. The ratio of high-technology imports to GDP more than doubled during the same period (see Figure III.1). In the case of lower middle-income countries, high-technology goods represent broadly the same 23 per cent share in total imports as in high-income countries (15 per cent if China is excluded). The easing of restrictions on FDI also has contributed to technology diffusion within developing countries. FDI is a source of process technology and learning-by-doing opportunities for individuals in developing countries.

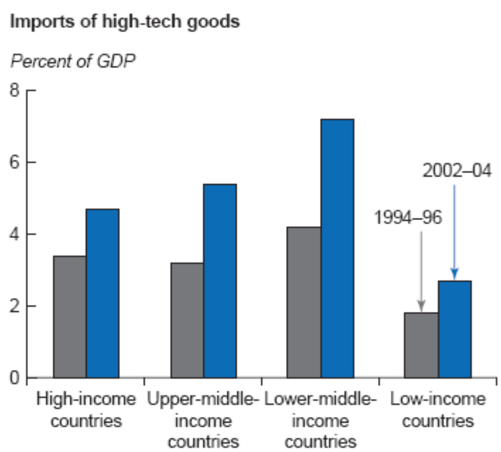

Figure III.1: Imports high-technology goods
Source: World Bank 2008c

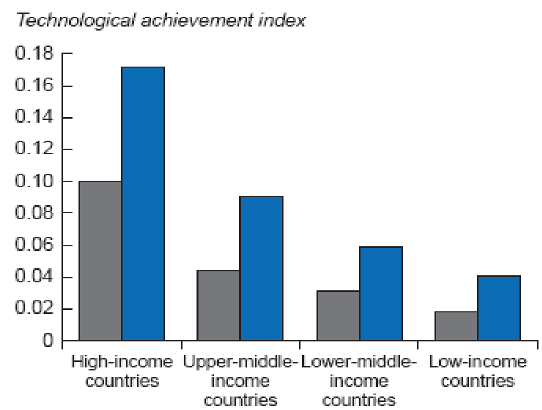

Figure III.2: Technology gap among countries
Source: World Bank 2008c

Over the past 15 years, FDI flows to developing countries have almost doubled as a percentage of GDP. In addition, foreign firms are making important contributions to the technological capacity of host countries, performing more than 40 per cent of the total R&D in some countries. At the same time, the competition, standards and knowledge of foreign markets that foreign firms bring to the domestic market can have important spillover effects. Finally, some firms in developing countries have increased their access to cutting-edge technology by purchasing technologically sophisticated firms domiciled in high-income countries.

In addition to dismantling barriers to foreign investment, some middle-income countries have encouraged greater FDI flows by implementing specific regimes governing IPRs. A few countries have encouraged joint ventures rather than FDI to maximize technology transfers to local firms. However, this strategy seems to work only for countries with substantial market power.

[18] Drawn mainly from World Bank 2008c.

However, the technology gap between the developed countries and the developing countries remains extremely wide, as reflected by the Technology Achievement Index (see Figure III.2)[19]. Moreover, some of these technologies are very expensive and their adoption in many countries is not economically feasible.

4. Innovative proposals for the development and transfer of technologies

Traditional commercial mechanisms, such as FDI and international trade, contribute in a limited manner to the effective development, transfer, diffusion, and deployment of environmentally sound technologies in developing countries. Additionally, the existing special technology transfer mechanisms are limited for supporting the immediate and urgent needs for technology development, deployment, diffusion and transfer to developing countries. In order to overcome barriers to technology transfer and fill the gaps between the needs for such technologies and the degree to which these technologies are adopted in developing countries, it is important to consider the enhancement of existing mechanisms. Enhanced mechanisms should be designed to accelerate, widen and enlarge international technology cooperation. Effective technology transfer will support improvement of the well-being of the poor, increased profitability of local enterprises and consequently better economies.

Analysis of experience with technology transfer and of the currently operational mechanisms for development and transfer of environmentally sound technologies highlights the need for consideration of financing and institutional arrangements and IPRs.

Financing and institutional arrangements

The total existing funding includes US$ 3.3 billion from the GEF for the 1991-2010 period, US$ 90 million in the SCCF of the UNFCCC, US$ 180 million in the LDCF (including new pledges) and an estimated US$ 3 million in the AF of the Kyoto Protocol Adaptation Fund. These existing resources do not appear to be sufficient to satisfy the estimated financial needs for developing countries which include: US$ 19 billion per year for building upgrades, US$ 14 billion for low-carbon industrial production, US$ 36 billion for transport and US$ 28 billion for agriculture, plus additional funding needed for R&D (UNFCCC 2007). IEA also estimates that US$ 1.1 trillion per year[20] would be necessary for technology substitution and upgrading to reduce CO_2 emissions by 50 per cent from current levels by 2050 (IEA 2008).

Although the CDM has allowed developing countries to benefit from investment flows while developed countries get access to lower cost abatement opportunities than they might have in their domestic markets alone, its capacity is limited and the investment flows it has stimulated have been a modest US$ 7.4 billion to date (Capoor

[19] The Technology Achievement Index (TAI) aims to capture how well a country is creating and diffusing technology and building a human skill base, reflecting capacity to participate in technological innovation.
[20] IEA Blue Scenario.

and Ambrosi 2008). This is a small fraction of the financial flows that are needed. Hence, the existing CDM system will need to be scaled up if it is to accelerate more effective development and transfer of environmentally sound technologies.

Following the call by the Ad Hoc Working Group on Long-Term Cooperative Action (AWG-LCA) on specific proposals for the enhanced provision of financial resources and investments to support action on mitigation and adaptation, and technology cooperation[21], proposals were prepared by invited Parties. From the number of proposals contributed, only those which had something significantly new or different to offer were selected for summarization below.

Proposals from the G-77 and China on financing and technology mechanisms

The Group of 77 (G-77) and China have put forward both a financial mechanism and a technology mechanism for consideration. These proposals, which are complementary to each other, are designed to enhance technology cooperation.

The first is a new financial mechanism and "architecture" under the UNFCCC to manage the transfer of financial resources to assist developing countries in addressing the climate change challenge. The G-77 and China identified the following basic principles under which they would like to work in the context of enhanced financial resources[22]. The mechanism would:

- Operate under the authority and guidance of and be fully accountable to the COP to the UNFCCC;
- Have an equitable and balanced representation of all Parties within a transparent system of governance;
- Enable direct access to funding by the recipients; and
- Ensure recipient country involvement during the definition, identification and implementation of actions.

The proposal specifies that funds provided to organizations outside the Convention would not be counted as fulfilling developed countries' commitments under the UNFCCC to providing financial resources to developing countries to assist them in taking action on climate change.

Funding Sources for technology (as well as for other central functions of the financial mechanism, such as supporting adaptation) would be "new and additional" financial resources over and above ODA. The major source of funds would be derived from the public sector, which may be supported by market-based and private sources as agreed by the Parties[23]. Details related to **funding** include:

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[21] FCCC/AWGLCA/20008/8.

[22] Drawn from the workshop on investment and financial flows held in Bonn in June 2008, an official meeting of the AWG-LCA.

[23] Drawn from the Statement of the Group of 77 and China on 7 June 2008 to the second session of the AWG-LCA held in Bonn.

- The Governments of developed countries would use capital from their various environmental and energy taxes, from revenue from the auction of pollution rights and from the public finance budget. These funds would be used as the driving force to establish the international technology cooperation fund to ensure the development and transfer of environmentally sound technologies;
- The fund must attract resources from international organizations, and search for new financial resources through international negotiations and dialogue, as well as effective international cooperation mechanisms; and
- The most crucial issue is to make use of public financing as a driving force to promote public-private partnerships (PPPs), encourage the active participation of the private sector including R&D institutions and enterprises, thereby bringing along more private capital and technology and effectively combining the public and private funds.

The funding mechanism could target a single or multiple sectors, and could support any of a range of **activities**, such as:

- Supporting joint design, research and development or large-scale commercial applications of the environmentally sound technologies;
- Providing services and convenient conditions such as technology demonstrations, technology information and reduction of market development risks, and adoption of new technologies for technology co-partners;
- Offering incentives and compensation for the incremental cost to developing countries of addressing climate change through subsidies, export credit guarantees, the provision of technical services, etc.; and
- Launching a series of capacity-building activities which are mainly about human resource development, institution building and the removal of market barriers.

Details related to **governance** include the following:

- The fund would operate as a single window facility within the UNFCCC financing mechanism and would support R&D, deployment and transfer of technologies as well as the enhancement of developing countries' domestic capacity;
- The policies relating to the Fund, including the uses to which the funds are put, would be guided by the Technology Architecture (i.e., the Subsidiary Body on Technology, the Strategic Planning Committee and the Technical Panels, and by the Technology Plan of Action); and
- The funding needs of the mechanism could be evaluated independently. Parties could agree to regular replenishments of the mechanism to ensure the adequacy and predictability of the flow of funds for technology transfer and an appropriate burden sharing among developed countries.

The Technology Mechanism being proposed by the G-77 and China is an institutional mechanism designed to address all aspects of cooperation on technology research, development, diffusion and transfer in accordance with Articles 4.1(c), 4.3, 4.5

and other relevant articles of the Convention, in order to enable mitigation and adaptation under the relevant paragraphs of Decision 1/CP.13. The technology mechanism is expected to operate under the guidance and authority of the COP and be accountable to it.

The institutional arrangements of this mechanism comprise an Executive Body and a Multilateral Climate Technology Fund (MCTF). The Executive Body would be supported by a Strategic Planning Committee, Technical Panels, a Verification Group and a Secretariat. The Committee would have major functions related to strategy, guidance, evaluation and updates of a Technology Action Plan. The Panels would be in charge of generating and compiling expert information on capacity building, policies, cooperation, monitoring and other relevant topics.

The MCTF would provide technology-related financial requirements as determined by the Executive Body. It would operate under the COP as part of the enhanced multilateral financial mechanism proposed by the G-77 and China and described above.

A Technology Action Plan would be prepared to serve as a starting point for the work of the Executive Body. The Plan would include clear actions and dates for the first three years and would be updated for successive three-year periods. The Plan would support the following stages of the technology cycle: research, development, transfer and diffusion. The Plan would define specific policies, actions and funding requirements for all relevant technologies including public domain technologies, patented technologies and future technologies.

The Technology Mechanism would cover technologies in all relevant sectors and endeavor to remove barriers to effective technology development, deployment, diffusion and transfer. This mechanism would articulate with the overarching financing mechanism of the Convention to secure necessary financing.

Proposal from Ghana on an international framework agreement for technology development and transfer[24]

Using the Bali Action Plan as a basis, Ghana has proposed the creation of an international framework agreement for technology development and transfer that would address both mitigation and adaptation. This framework agreement would include an institutional mechanism, the Technology Development and Transfer Board, and a financing mechanism, the Multilateral Technology Fund (MTF).

An international institutional mechanism would be established in addition to national institutional mechanisms. At the international level, the Board would be a standing body under the UNFCCC responsible for the development, deployment, diffusion and transfer of environmentally sound technologies and know-how. Such a Board would have the power to decide, advise, and/or make recommendations and also

[24] Drawn from "Ghana's proposal on options for effective mechanisms and enhanced means for technology development and transfer" as an input to the discussions of the AWG-LCA, 2008.

report directly to the COP on scientific, technical, financial and implementation issues related to the development, deployment, diffusion and transfer of these technologies to developing countries.

To increase its effectiveness, the international institutional mechanism would be linked to effective and robust national institutional mechanisms in developing countries. Consequently the framework agreement reached would ensure that national systems of innovation that are supportive of the technology development cycle are established and resourced in all developing country Parties to the UNFCCC. The presence of effective national institutional mechanisms in developing countries would foster the early uptake of technologies in these countries.

As a financing mechanism, the MTF would operate under the authority and guidance of and be fully accountable to the COP, have equitable and balanced representation of all Parties within a transparent system of governance, enable direct access to funding by developing countries, and ensure recipient country involvement in the stages of identification, definition and implementation of relevant technology development programmes or processes.

Funding for the MTF would come from Annex II countries, in accordance with their commitments under the UNFCCC as per Article 4 paragraph 3. Additional sources of funding, including market-based mechanisms and private sector financing, could also support the Fund.

Proposal from Mexico on a World Climate Change Fund[25]

Mexico has proposed the establishment of a World Climate Change Fund (Green Fund). This Fund would be designed to: (a) significantly increase the funds available for mitigation actions, (b) support efforts to adapt to the adverse effects of climate change and the impacts of response measures, (c) provide technical assistance and promote the transfer and diffusion of clean technologies, and (d) contribute to the financial underpinning of the new global climate change arrangement based on the UNFCCC.

It is expected that all countries would contribute to the Fund in strict accordance with the principle of common but differentiated responsibilities and respective capabilities. Thus, their contributions would be based on their levels of GHG emissions, population and gross domestic product. An objective formula would be used to determine each country's contribution, incorporating such criteria as (a) the-polluter-pays principle, (b) equity (c) efficiency, and (d) payment capacity. The most objective formula for determining contributions would be that reached through consensus. Mechanisms that could mobilize new financial resources for the Fund without putting excessive pressure on public financing include auctioning permits in domestic cap-and-trade-systems in some developed countries, and taxing air travel.

[25] Drawn from the Statement by Mexico on 13 August 2008 to the AWG-LCA.

Developing countries that choose not to join the Fund would be excluded from its benefits, without any penalty. The creation and operation of the Fund should not represent a disadvantage to any developing country.

To avoid imbalances, an upper threshold is proposed for withdrawals by any single developing country. Developed countries would only be entitled to use a fraction of their contributions, so that developing countries may have access to financial resources much larger than their own contributions as an incentive for their participation in the Fund. A part of the total contributions to the Fund could be set aside for the benefit of the LDCs.

The proposed Fund could establish linkages between mitigation, adaptation and technology transfer and development. To that end, it is proposed that all contributions received by the Fund would be subject to a double levy, to be determined through negotiations. The first levy would be for the Adaptation Fund and the second levy would enable the development of a Clean Technology Fund.

Proposal from Norway on auctioning allowances[26]

Norway has proposed that financial needs under the UNFCCC could be financed through the auctioning of a share of the assigned emissions units of all Parties. Auctioning is seen as a promising option to generate adequate, predictable and sustainable financial resources because of its international character.

In an emission trading system, the auctioning of emission quotas is a possible source of revenue, and in a cap-and-trade system, allowances are considered assets. The number of allowances to be issued would follow from the overall long- and mid-term emissions. A small percentage of this asset value could be auctioned directly.

The percentage or the number of allowances auctioned would be set to generate the amount of funding needed for the purpose in question. A predefined number of allowances, a fixed percentage of the total amount or a revenue requirement can be used. A process can also be established to decide the exact amount at a later stage.

This proposal needs further development on a number of issues, including: determination of the number of allowances to be auctioned; for what purpose financial resources would be raised by this mechanism; and the principles under which the fund would be established and organized.

Proposal from the Republic of Korea for a financing and technology transfer mechanism[27]

[26] Drawn from the Statement by Norway on "Finance – AWG-LCA, Norway's submission on auctioning allowances," 2008.
[27] Drawn from the proposal from the Republic of Korea to the AWG-LCA, 2008.

The proposal submitted by the Republic of Korea to the AWG-LCA is based on the use of carbon credits resulting from the verifiable mitigation of Nationally Appropriate Mitigation Actions (NAMAs). The proposal recognizes carbon credit as a sustainable source of finance and technology transfer for mitigation actions of developing countries. Under the proposal, developing countries are expected to take NAMAs as agreed and contained in Bali Action Plan Decision 1(b)(ii).

The proposal rationale acknowledges that although mitigation actions of developing countries have to be supported by financial flows and technology transfer, the Annex I Parties can only play a limited role since most of the financial resources and technologies are in the hands of the private sector. Therefore, public funds which are being proposed are not sufficient.

The proposal indicates that the carbon credit for NAMAs would be able to engage the private sector into playing an active role. Parties can concur on the principle of recognizing carbon credits for the verifiable mitigation of NAMAs as part of the agreed outcome of the fifteenth session of the COP.

Proposal from Switzerland on a funding scheme[28]

Switzerland has proposed a funding scheme focused on adaptation. The proposal involves a global carbon levy, based on the principle of common but differentiated responsibilities and on the-polluter-pays principle, with a low levy on CO_2 emissions, to cope with the huge gap between financing for adaptation and financing for mitigation.

The proposal calls for a uniform global levy on all fossil fuel emissions so that all countries would assume a fair share of the responsibilities for addressing climate change issues. The scheme would incorporate a basic tax exemption per inhabitant. This free emission allowance would result in countries with higher emission levels making a higher contribution to the Fund relative to low-emission countries. As countries with higher emissions tend to be the countries with high levels of per capita income, this would lead to a considerable net transfer of resources from developed to developing countries.

Of the revenues raised through the uniform global carbon levy, a major portion would be allocated to a multilateral regime, the Multilateral Adaptation Fund (MAF). Payments from the MAF would be used for financing adaptation policies and measures based on a "prevention pillar" involving climate-change impact risk reduction through appropriate policies and measures with funds disbursed to the relevant programme rather than to individual projects, and an "insurance pillar" as a form of climate impact response that involves relief, rehabilitation and recovery by investing financial resources to safeguard public goods, in particular insuring against climate-related risks which are not covered by private insurance companies.

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[28] Drawn from the proposal from Switzerland on a "Funding scheme for Bali Action Plan" to the AWG-LCA, August 2008.

Another part of the revenues generated by the carbon levy would be channeled into a National Climate Change Fund (NCCF) for each country for financing, according to the country's specific needs and legal framework, adaptation, technology transfer and/or mitigation measures. These national funds would also operate as partner institutions to the Multilateral Adaptation Fund (MAF) and would be encouraged to address the priorities of national climate change programmes.

Developed countries would deliver a significantly larger fraction of their carbon tax revenues to the MAF than would developing countries. In contrast, developing countries would keep the largest share for their NCCF and deliver only a small fraction to the MAF. Medium-income countries would occupy an intermediate position.

Consideration of the proposals

These innovative financial and institutional arrangements, which are being proposed to accelerate the development and transfer of technologies to implement the UNFCCC, demand consideration and analysis in the climate change debate.

The G77 and China proposal includes considerable details on the principles, governance and implementation of the financing mechanism. The proposal stresses the need for recipient country involvement and the equitable participation of all the Parties. Additionally, the proposal addresses the importance of public financing in promoting private participation and PPPs, and the need for the fund to provide support in technology adoption and market related issues. There is also the recognition that capacity-building activities are essential components of technology transfer and need to be funded by the mechanism. In relation to funding arrangements, the proposal specifies that funds provided to organizations outside the Convention would not count as fulfilling developed countries' commitments. It is uncertain how this arrangement would impact other existing or future funding schemes related to climate change and technology transfer.

Ghana's proposal provides, in addition to a financing scheme, an institutional framework which allows for a more integrated mechanism. The proposed Technology Development and Transfer Board would provide the assessment of strategies and technologies that would guide the efforts of the Multilateral Technology Fund. The proposal, however, does not fully describe how contributions to the Fund would be made, except that they would come from the developed countries for the benefit of the developing countries.

The Mexican proposal bases government contributions to a proposed World Climate Change Fund on the countries' level of GHG emissions, GDP and population. Therefore, the scheme incorporates criteria that would reflect fairness, efficiency and the principle that the polluter pays. Nevertheless, the specification that the formula for determining contributions should be reached by consensus could inject uncertainty and political pressure to the process. Also, the option for developing countries to not participate, either as contributor or benefactor, could be a source of controversy, in particular for those developed countries that might also want the same freedom to opt out, which would undermine the Fund.

The auctioning of carbon emission allowances proposed by Norway represents an interesting approach that would imply the creation of a market for such instruments that would converge to equilibrium at the marginal abatement cost. The mechanism could allow the generation of significant financial resources but perhaps not enough to finance the global climate change challenge. It is important to note that this scheme assumes that all Parties would agree to a cap-and-trade system. Several complex issues are not defined in this proposal, including principles to define the fund’s operation and levels of allowance.

The proposal from the Republic of Korea provides a vehicle for promoting the participation of the private sector in the financing and technology transfer process for mitigation in developing countries. Private participation is indeed considered essential for the effective development, transfer and diffusion of environmentally sound technologies to developing countries. The proposal, however, does not address the adaptation challenge and provides no details on how this mechanism would be implemented. Furthermore, the proposal recommends that details on operating the scheme of carbon credit for NAMAs, including criteria and extent of credit, could be worked out at the fifteenth session of the COP.

Switzerland’s proposal stresses the need to address adaptation in a more coordinated and effective manner given the enormous challenge faced by many developing countries in this respect. The proposal of a global carbon levy is designed to ensure fairness in its implementation since countries with higher per capita income (which in general are the ones with higher emissions) would contribute more to the fund. Additionally, the scheme aims to establish an optimal carbon price that would attempt to correct the market failure resulting from the externalities related to climate change. Difficulties may develop, though, in the implementation process of such a scheme because of the need to establish an effective global levy system based on a proposed uniformed tax rate.

5. Intellectual property rights (IPRs)

Patents and trade secrets are the two most important models of IPRs protection for environmentally sound technologies. Although patent statistics are available from many national and international agencies, there are theoretical and methodological issues in deriving meaningful conclusions from these sources. The main reason is that these technologies are spread over many fields and not all are useful for dealing with climate change concerns. There is no agreed definition of climate-friendly technologies or special category for environmentally sound technologies related to climate change, with the result that different assumptions and methodologies are in use.

According to statistics from the World Intellectual Property Organization (WIPO), of about 5.6 million patents in force in 2005, 49 per cent were owned by applicants from two developed countries, Japan and USA. The major European countries are also strongly represented in ownership of patent rights to these activities.

Figure III.4 shows the distribution of patent ownership of renewable energy and motor vehicle abatement technologies among the countries with the most relevant patents. Applicants from the European Union as a whole and Germany, Japan and USA are the main owners of the technology patents. In comparison, applicants from China and other developing countries own a small share of the patents for such technologies.

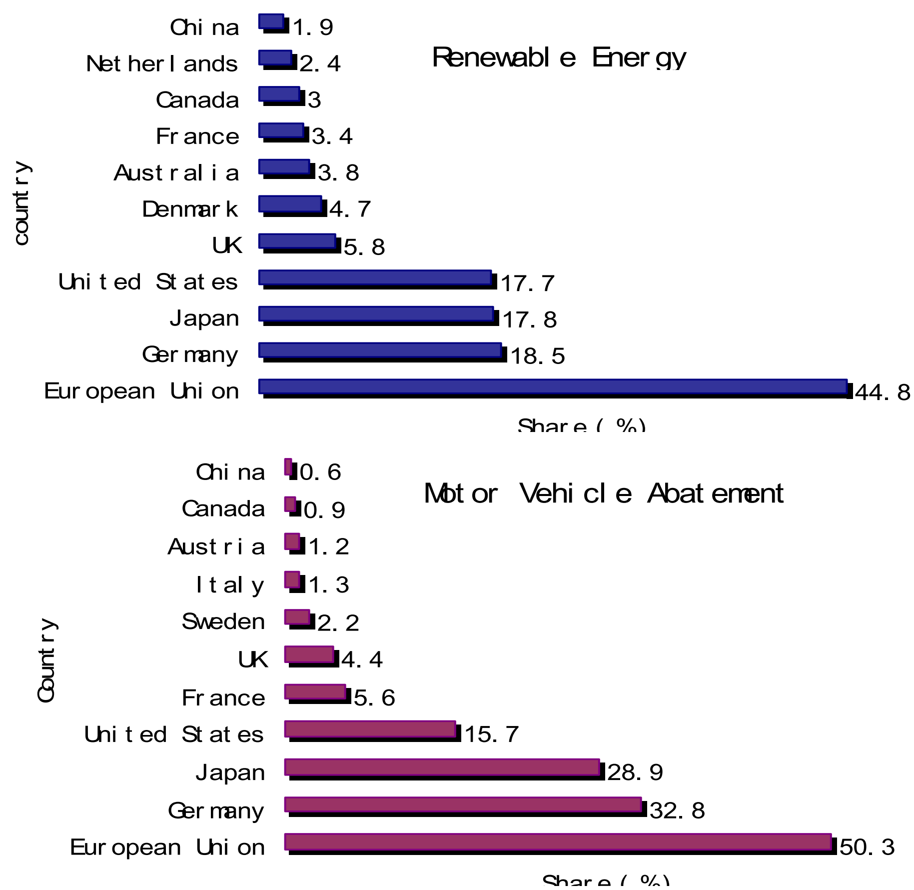

Figure III.4: Patent ownership in selected countries 2000-2004

Source: OECD 2007.

The potential trade-off between IPR protection and technology development and transfer is a very important issue in the context of climate change. Overall, differing views persist as to the impacts of IPRs on innovation and technology transfer in developing countries. A major rationale for protecting IPRs is that they can serve to support markets in technology transfer – without some degree of protection, firms would be reluctant to sell and license their technologies (Maskus 2004). The argument is thus that innovative firms need protection in order to increase their willingness to provide knowledge of their production processes to firms in developing countries. On the other hand, technology importing countries are interested in obtaining access to technology at the lowest possible cost, and some argue that this objective is best met by limiting the IPR protection enjoyed by foreign firms. Caution is generally advised in drawing conclusions on the precise impact – negative or positive – of IPRs on technology development and transfer. The following is some of the available evidence from econometric studies (Maskus 2004):

- Stronger patent rights may be expected to increase considerably the "rents" earned by international firms, as patents become more valuable, with the result that protected technologies become more expensive for developing countries.
- Among middle-income and large developing countries, international trade flows, particularly in patent-sensitive industries, respond positively to strengthened patent rights. Importantly, trade flows to poor countries are not sensitive to patent rights. Again, while the evidence on FDI and patent rights is mixed, poor countries with stronger patent rights do not attract more FDI.
- There is evidence that the strengthening of patent rights shifts technology transfer from exports and FDI towards licensing.

Valuable insights can also be gained from the historical experience of individual countries. Thus, it is often mentioned that countries such as Japan and the Republic of Korea gained access to critical foreign technologies and were able to develop their economies, at least in part, as a result of maintaining less stringent IPR protection. Today, other middle-income countries look to follow the same path, with a view to absorbing free or low-cost foreign technologies, initially into labour-intensive production for export and later value-added strategies (Maskus 2004). In this context, the undifferentiated protection of IPRs, as it exists under the WTO, probably does constrain the options for industrialization. Certainly, the poorest countries, unable to pay licensing costs and with little to offer in the form of domestic markets, would be most disadvantaged.

Naturally it must also be borne in mind that IPRs are only one of a catalogue of factors that have a bearing on technology transfer. The size of the domestic market, general investment climate, governance and infrastructure are other important factors.

Key IPR issues related to technology development and transfer include the following:[29]

- The ratio of R&D investment to total cost - As the ratio of R&D cost to total cost rises, the importance of IPR protection also rises. This could limit development and diffusion of technologies to countries that are perceived as having weak IPR protection.
- Ease of IPR enforcement - Certain types of patents (e.g. method patents) are harder to enforce than others. This would influence how effective or useful patents are in capturing returns to investment.

[29] Principal source: E3G 2008.

- Patent application standards and processes - Different standards and application processes might pose an impediment to further innovation and diffusion due to cost and length of time required for approval. Patent application standards are also crucial for determining the ability of holders to defend patents against breach.
- Ease of copying - Access to the underlying knowledge is a key component for 'reverse-engineering'. For some technologies this will be easier than others, potentially reducing the incentives to innovate in the first place.
- Patent thickets - Some technologies require multiple patents. These 'patent thickets' may require cooperation from many different actors in order to successfully innovate, and can act as a barrier to diffusion.
- Tacit knowledge - Most advanced technologies involve a degree of tacit knowledge. This can act as a barrier to diffusion and further development even in situations where formal licensing agreements exist.

Some studies suggest that the relative share of patents for environment-related technologies is declining. Thus, the relative share of environment-related technologies filed with the US Patent and Trademark Office (PTO) declined from 2.5 per cent in 1977 to 1.5 per cent in 2003, although in absolute numbers there was an increase from 500 in 1977 to more than 3,500 in 2003.[30] Thus, an examination of US PTO data and Patent Cooperation Treaty Data from 1998 to 2007 concluded that the number of patents filed in the clean technology industry is increasing and is likely to continue increasing in the future.[31] Many commentators have pointed out that investment in energy R&D has decreased over the years.[32] This may be one of the reasons for the decline in the number of patents for these technologies.

The role of IPRs in environmentally sound technologies varies from technology sector to technology sector. Importantly, the situation pertaining to most of these technologies is different than that in the pharmaceutical sector, where individual patents may have a substantial impact because specific drugs may not have substitutes, and consequently the patent holder is in an exceptionally strong market position (Barton 2007). In the energy sector, however, basic technologies used in the production, distribution and transmission of energy and basic technologies in transportation have long been off-patent and are mostly in the public domain. It is particular improvements or features that are now under patent. Because of this, there is competition between a number of patented products, with the result that royalties (licensing costs) and product prices are lower than they would be in the case of a monopoly.

A technology can be covered by more than one patent and the technology described in one patent might be applicable in more than one technology sector.

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[30] Marinova 2008.
[31] Miller et al. 2008 .
[32] Prins and Rayner 2007, Kammen 2006, and Holdren 2006. See Gallagher, Kelly Sims, John P. Holdren, and Ambuj D. Sagar. "*Energy-Technology Innovation.*" Annual Review of Environment and Resources, vol. 31, pp. 193-237 (2006) for an overview of climate change, energy and innovation in technology.

Solar energy. At present the three core technologies are silicon-wafer based PV, thin-film PV and focused solar thermal power. In all three, there are a number of established players, as well as recent entrants. The basic technology is in the public domain and patents do not represent a major barrier, as licenses are likely to be available on reasonable terms, given the large number of firms in the sector. Developing country firms that have recently entered the market include Tata-BP Solar, an Indian firm in a joint venture format, and Suntech, a Chinese firm which combined its own technologies with that purchased from developed countries (Barton 2007). The application of nanotechnology in solar energy appliances and solar energy-based applications is likely to increase. Corporations in India and China are among the top-ranking firms in this sector and, at present, there do not seem to be any patent thickets or a limited number of firms monopolizing the technology.

Wind energy. The basic technology is in the public domain, but there are relatively fewer players in this sector on a global scale. Patents seem to be more important in off-shore applications. Given the nature of the technology, incremental innovation is likely to be important as the scope for radical invention in terms of breakthroughs or radical technologies is limited.

Bio-fuels. Although the basic techniques in this technology are quite old, the technological advances are expected to come from new processes and new products like enzymes and catalysts. Patents in this technology sector are likely to be based on knowledge developed in biotechnology and process engineering. The number of patents is increasing. The possibility of patent thickets and an anti-commons situation cannot be ruled out. This has many implications for technology transfer and freedom to operate.

Climate-tolerant crops. Climate change has enormous implications for agriculture in developing nations. The need for developing drought-resistant, flood-resistant and salt-resistant crops has been underscored by the centres of the Consultative Group on International Agricultural Research (CGIAR). A preliminary analysis suggests that an increase in public sector R&D in this area and redeployment of traditional varieties are advisable, so as to ensure that patents do not become barriers in this emerging technology sector.

Looking ahead, the implications of developments in nanotechnology and biotechnology require further analysis, as these two technologies are likely to form the basis for new techniques and processes in technology sectors, including solar energy, bio-fuels and climate-tolerant crops.

The extent to which IPRs represent a barrier depends in part on the stage of development or maturity of the technology, as well as the type of technology. Barriers to entry, including IPRs, may be lower in the case of solar than in the case of the most advanced gas turbine technologies, where firms from developed countries may retain control over the design and manufacture of the most sophisticated components, such as the turbine blades (Ockwell et al. 2008).

As emphasized elsewhere in this document, technology transfer involves processes and activities that go beyond the transfer of equipment and machinery. The question of whether strong IPRs facilitate technology transfer or act as barriers is a divisive one. On one hand, it is argued that there is a positive correlation between stronger IPRs and trade flows, productivity, FDI and sophistication of the technologies transferred. Thus technology-exporting countries have identified weak IPRs in major developing countries as a barrier to the export of environmentally sound technologies.[33] On the other hand, there are those who take the view that there is a negative correlation between strong IPRs and technology transfer. In particular, it is maintained that strong IPRs at initial stages of development hamper transfer and adoption of technology (UNIDO 2006). In the face of this polarization of views, one fairly robust conclusion is that the poorest countries are at the greatest disadvantage in gaining access to technology.

TRIPS, technology transfer and options under TRIPS

The WTO Agreement on Trade-Related Aspects of International Property Rights (TRIPS) effectively incorporated IPRs into the multilateral trading system. To its supporters, TRIPS establishes a critical legal framework under which firms can transact IPRs, and its effect is to increase technology transfer (Sherwood 1997). Critics regard it as a mechanism for entrenching the global market power of firms from developed countries, enabling them to act in ways that slow down technology transfer to developing countries (Correa 2005).

In brief, TRIPS establishes minimum standards for the protection of IP. Although it provides some flexibility in defining inventions, in granting exceptions to patent rights and in implementing procedures, the overall framework not surprisingly favours the rights of the IP holders. In the context of climate change, the key issues are: (1) whether, on the whole, TRIPS facilitates or acts as a barrier to the transfer of environmentally sound technologies to developing nations; and (2) whether its provisions empower Governments to use compulsory licensing for transfer of technology.

Some key features of TRIPS are the following:

- Granting of patents in all fields of technology, without discrimination with reference to place of invention, whether imported or locally produced, subject to exemptions under Article 27;
- Twenty-year term of patent protection from filing date (Article 33);
- Non-discrimination between nationals and non-nationals in IP protection;
- Granting of exclusive rights to make, sell, and import technology and products; and
- Compulsory licensing subject to certain provisions.

The above provisions mean that parties to TRIPS are required to grant 20-year monopoly rights to patent holders. During this period, the patentee gets exclusive rights

[33] OUSTR 2006.

(for use, manufacture and sale) and the right to prevent infringement (unauthorized use, manufacture and sale). The provisions also entail restrictions on what parties can do to foster domestic innovation industries (Hutchison 2006).

Compulsory or non-voluntary licensing is one option, albeit limited, available to developing countries when a patent is filed in the country but the patent holder refuses to license that technology. The guiding criterion is the public interest, for instance on grounds of national emergency, circumstances of extreme urgency and public non-commercial use. The compulsory licensing option under Article 31 is tightly circumscribed. The main limitation is that the compulsory license must serve the domestic market and that export may only be an incidental use. Disincentives for licensees to enter the market include the short duration of the licenses, and the fact that licenses are non-exclusive which means that the patent holder also can compete in the market with the licensee (Hutchison 2006).

Responding to developing countries' concern over access to life-saving medicines, the Doha Declaration on Public Health contains an attempt to clarify the flexibility embodied in the TRIPS provisions concerning the use of compulsory licenses to address public health problems (Reichman 2003). Importantly, the Declaration also confirmed that it was not necessary to declare a full-scale emergency before having legal recourse to compulsory licensing; rather, it was up to each member to determine what constituted a national emergency or situation of extreme urgency. The application of a similar approach to other areas remains an open question. However, it has been pointed out that the mere threat of compulsory licensing may obviate the need to take any further action.

Article 66.2 of TRIPS obliges developed countries to create incentives for technology transfer to LDCs. However, this provision has not resulted in substantial action, with activities confined to technical programmes to implement IP laws (Hutchison 2006).

For developing country members of the WTO, the advent of TRIPS inserted IPRs into a wider swathe of public policy. Developing country members of the WTO do not have recourse to policy options and flexibilities some developed countries had in using IPRs to support their national development. TRIPS has narrowed the scope for developing countries to pursue technological learning and the adaptation of foreign technologies. An undifferentiated IPRs system, which favours strong protection, will not work to the advantage of all countries. In particular, such an approach may be a disadvantage to those countries that are unable to license new technologies or are not benefiting from the inflows of FDI that stringent patent law promises. Consideration could be given to expand the scope of the Doha Declaration, to explore the rationale and feasibility of a waiver for the transfer of environmentally sound technologies similar to that for public health issues, and to exploit other mechanisms outside of TRIPS to facilitate technology transfer. For example, an agreement on information access and benefit sharing could curtail excessive patenting and improve prospects for innovation in both developed and developing countries.

Innovative approaches and ideas

Below is a selection of ideas and proposals for enabling the transfer of environmentally sound technologies (ESTs) to developing countries.

- The Montreal Protocol established a Fund to support the transfer of technology and capacity building in developing nations so that Ozone Depleting Substances (ODS) could be phased out (See Box III.1). This is a useful idea but there are some limitations. ESTs cover a far wider scope than the limited set of alternative technologies, processes and products under the Montreal Protocol.

- Using the "Green Revolution" as a model, there could be initiatives to establish centres for technology development and transfer. Under the Green Revolution many centres were established for crop development and plant breeding, and the technology was transferred without IPRs to developing countries. A similar approach to development and transfer of ESTs has been advocated so that the technologies are available in the public domain.

- Some proposals like the BASIC project deserve serious consideration. The BASIC project suggests the creation of a Technology Funding Mechanism that could be structured to facilitate participation of developing countries in international R&D projects. The project also suggests that the Funding Mechanism can be used to buy out IPRs and make privately owned technologies available for use in developing countries. A similar proposal, the Multilateral Technology Acquisition Fund, has been proposed by the G-77 and China in climate negotiations.

- Patent pools of relevant technologies could be created to cut down on transaction costs – this would enable the acquisition of licenses without having to deal with too many parties. Patent pools are widely used in the electronics and information technology industries. For instance, when the different technologies related to a single device (e.g., a digital camera) or application (e.g., Motion Picture Experts Group (MPEG) format) are held by many parties and the technology cannot be put to use unless each party licenses them, patent pools are created and cross-licensing among the parties is encouraged. Such patent pools are created by holders of IP rights, with or without government support or intervention. The technologies in the pool are available for licensing on mutually agreed terms. For ESTs, the patent pool could be technology specific or sector specific.

- Global R&D alliances, drawing on the PPP model applied to the problem of vaccines and drugs for neglected diseases, could be further explored. The suitability of this model for ESTs needs further investigation.

- Developing nations including India have made suggestions for technology development and transfer. India's paper to the Gleneagles G-8 Summit proposed a network modelled on the CGIAR, and called CLEANET, for collaboration on energy R&D, as well as the establishment of a Global Technology Venture Capital Fund.

- Another proposal is for a global pact on access to science and technology, so that WTO Agreements, particularly TRIPS, do not become a barrier to the access of science, technology and knowledge. The objective is to ensure that access to science is unhampered and the free flow of scientific and technological knowledge is ensured for the public good. This theme can be extended to ESTs as well.

- Developed countries could offer the same tax advantages for R&D performed abroad, particularly in the poorest countries, as for R&D carried out domestically.

- Grant-making bodies in developed countries could offer additional support to proposals that meaningfully involve research teams in developing countries.

- Initiatives such as the Eco-Patent Commons, which involves making patents free for use in ESTs, could be expanded.[34]

- Technology competition and prize funds have been cited as incentives to induce innovation and technology diffusion. Similar proposals have been put forth in the case of drug development and discovery for neglected diseases. These proposals include prize funds, advance purchase commitments, patent payouts, a medical R&D treaty, and open-source drug discovery. Their use could also be extended to environmentally sound technologies.

- The European Patent Office has advanced a Blue Skies proposal for a differentiated patent system, with ESTs treated differently from pharmaceuticals and governed by a regime for the licensing of rights.

These and other proposals deserve critical scrutiny to assess their effectiveness in lowering costs to developing countries of technology access and deployment. In the case of financing proposals, relevant criteria include: newness and additionality to ODA, predictability and fairness in terms of both revenue raising and resource allocation. Governance structures are important to consider for all the mechanism proposals.

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IV. PUBLIC-PRIVATE ROLES AND PARTNERSHIPS FOR INNOVATION AND TECHNOLOGY TRANSFER

The global energy technology investments needed between 2005 and 2050 have been estimated to be as high as US$ 250 trillion under a projected baseline scenario (IEA 2008). Investment requirements for a low-carbon system could be even higher. The GHG emission profile of energy technologies will need to be drastically different from business-as-usual if significant emissions reductions are to be achieved.[35] At the same time, it is increasingly urgent to embark on adaptation strategies. This, in turn, will also require the development of technologies that suit the particular needs of developing countries. Thus, the scale of the challenge is enormous; furthermore, the complexity of the challenge is underlined by the wide range of technologies involved and large differences among the countries where these technologies will be deployed.

Technology development requires investment from both the public and private sector. Public sector R&D has played an important catalytic role in developing some of the key technologies of the 20th century, including aeronautics, electronics, and nuclear power. It will also need to play a role in the transition to low-carbon energy technologies. The bulk of the environmentally sound technologies (including technologies to reduce GHG emissions) have been developed in response to explicit and strong government support, in the form of tax incentives, R&D grants, favorable regulatory frameworks, and government expenditure policies. On the one hand, the large public stake in these technologies could provide the Governments with sufficient leverage to disseminate them more broadly in the larger public interest. On the other hand, however, these policies were generally aimed at enhancing national competitiveness, which may run counter to the goal of facilitating technology transfer to developing countries.

In the future as well, further quantified GHG emissions reduction objectives by developed countries will be critical to stimulating private sector investment in R&D. By lowering costs, large-scale deployment of low-carbon technologies in developed countries will be critical to overcoming one of the most serious barriers to technology transfer to and adoption by developing countries. Such deployment would also serve to demonstrate a technology's feasibility.

1. Public and private roles and public-private partnerships

Traditional perspectives of "supply-push" and "demand-pull"

Broadly, energy innovation comprises a set of activities that include energy R&D, demonstration, and deployment. Six stages for energy-technology innovation in a market economy are suggested,[36] as illustrated in Figure IV.1:

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[35] An additional US$ 17 trillion will be needed to bring global CO_2 emission levels back to 2005 levels by 2050 (IEA 2008).

[36] The stages here represent a slightly modified version of the stages proposed by Grubb (2004).

- basic R&D;
- technology- and product[37]-specific design, development, and demonstration;
- market demonstration and technology/product selection in which potential purchasers and users ('the market') can start to evaluate technology/product options and back the most promising offering(s);
- adoption of the technology by established firms, or the establishment of firms based around the technology for effective niche markets;
- market accumulation, in which the use of the technology expands in scale, often through accumulation of niche, protected or subsidized markets; and
- diffusion on a large scale.

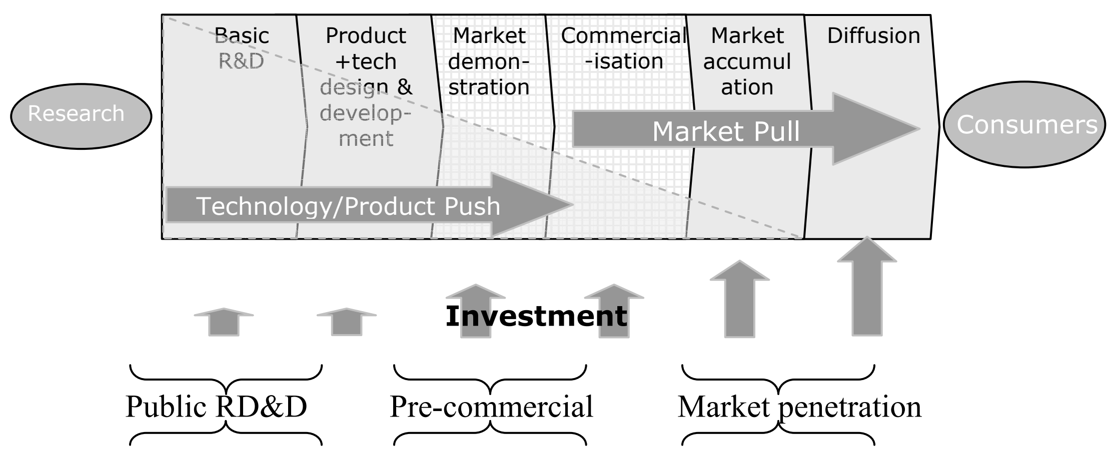

Figure IV.1: Main steps in the innovation chain
Source: Grubb 2004.

A technology or product will undergo many cycles of modification before it is commercialised (and even thereafter, numerous incremental improvements generally continue to be made). Thus, there are linkages and feedbacks among the various stages mentioned above. For example, data collected during demonstration or pilot projects may

[37] "Technology" and "product" are differentiated here. A "product" is an engineered system -- built around a core "technology" or a set of technologies -- that provides a particular energy service to the user (Sagar and Mathur 2000). For example, a solar-PV light is a "product" based on the core technology of a PV module; the same PV module can also be the basis of different products such as a solar-PV electric system that can power a house or feed into a grid. The two concepts are differentiated here because while most advanced energy technologies are produced in developed countries (e.g., gas turbines, coal gasifiers and internal combustion engines), product design can, and often does, take place in developing countries. In fact, designing a product that is appropriate for local conditions is key to its success. Thus, an improved cookstove design that is successful in Kenya may need to be modified to be successful in Sri Lanka. Note that designing a product for a specific market may also require modification and adaptation of the core technology. In other cases, a product from one country may itself be modified for use in another country.

suggest a modification of the technology; similarly, an improvement in the technology may trigger a change in product characteristics and designs. Mature technologies taken from one market or climatic zone may require significant redesign and modification to enter another market and climatic zone.

Successful energy innovation involves not just the development of new and improved technologies but also their introduction into the marketplace through specific products. Thus, the energy innovation process requires both ensuring the availability (i.e., supply) of new energy technologies and products based on these technologies, as well as creating and sustaining markets (i.e., demand) for these products.

Furthermore, the front and back ends of the innovation chain are intimately inter-related in that the kind of research, design, and development carried out to develop new energy technologies and products are shaped by the markets, i.e., the perceived needs and preferences of consumers (this is referred to as "market (or demand) pull"); on the other side, the availability of new technologies also shapes markets by changing the economics of the market or by offering new and attractive options to consumers (referred to as "technology (or supply) push").

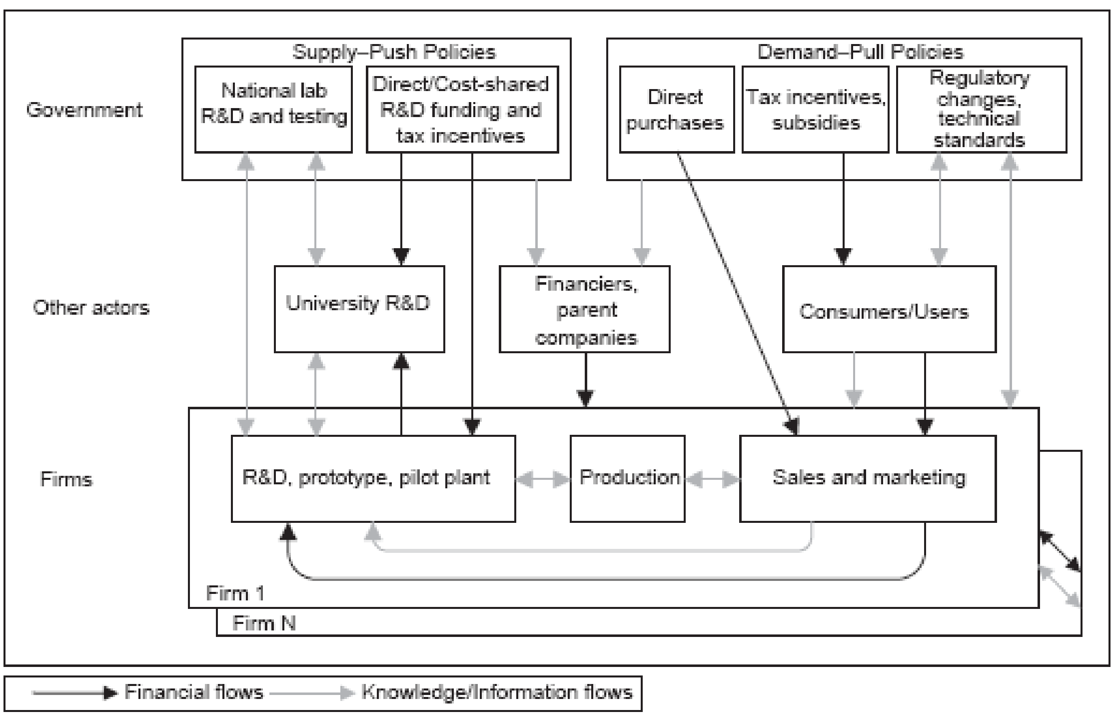

Figure IV.2: Supply-push and demand-pull policies in energy innovation
Source: Margolis 2002.

From a public-policy perspective, the main levers available to government for supply-push are direct R&D funding for various R&D performers (universities, government research laboratories and firms), as well as tax incentives to promote R&D in industry (see Figure IV.2). On the market-pull side, the main policy instruments are government procurement to create or support a market for a particular technology, regulations and standards, and tax incentives/subsidies to influence consumers' purchasing decisions.

In terms of financing, the main role of the public sector is to fund the upstream side of the innovation pipeline. This includes the basic sciences that underlie the development of energy technologies – which is increasingly important as the gap between science and technology shrinks (for example, in the area of PV). It also includes various R&D activities that translate scientific and technical knowledge into technologies that might have market potential, and demonstration projects that test the real-world deployment of technologies, at a pilot scale or even a full-sized but 'one-off' project.

The public sector also has a role to play in providing market mechanisms to encourage the deployment of renewable technologies, e.g. feed-in tariffs have supported deployment of near-market on-shore wind technology in Germany and the Renewable Obligation has supported the introduction of wind and biomass energy in the UK.

The private sector itself funds R&D activities aimed at developing and refining technologies but it also spends significantly on product development activities, where the firm's assessment of market conditions and consumer needs becomes invaluable. In most developed countries, firms account for a majority of the R&D – for example, in 2004, the private sector accounted for 75 per cent of the national R&D expenditure in Japan, 64 per cent in USA, and 51 per cent in France. Developing countries show a greater variation, with the corresponding number for China being 66 per cent, South Africa, 49 per cent, and India, 20 per cent (OECD 2007; Indian data from DST 2006). However, expenditures by the private sector for energy innovation are not available for a number of reasons[38] (Sagar and Holdren 2002). So it is not possible to make an equivalent public-private comparison in the energy area (although an NRC committee estimated that in the United States, the private sector was responsible for about two-thirds of that nation's energy R&D investments between 1978 and 1999 (NRC 2001)). But it is more than likely that the private sector will be responsible for a smaller fraction of the total energy innovation expenditures in countries where the private sector accounts for a smaller fraction of the national R&D. It is noted that where the private sector is mainly responsible for energy infrastructure investment, there has been a lack of long-term investment, leading to electric grid failures in many developed countries, and a heavy dependence on low capital cost fossil-fuel fired generation equipment as opposed to high capital cost renewable systems.

While the public sector can also play a key role in developing and supporting markets for energy technologies, it needs to attract private investment by underwriting

[38] This includes the broad range of R&D activities that are relevant to the energy sector and these activities are carried out by a wide range of institutions – government laboratories, firms (large conglomerates, other large and small manufacturers, specialized/niche players, start-ups), universities, research consortia, and non-profit organisations. Evaluating R&D expenditures within the private sector is particularly difficult, given the problems of defining energy R&D and disentangling this from other R&D activities (Sagar and Holdren 2002).

programmes that promote early deployment by creation of markets either through some financial support, regulation or helping to overcome particular barriers to deployment.

The public sector also has a particularly critical role to play in scaling up energy technology deployment. At this stage of the innovation process, the main role of government is to set in place "rules of the game" (i.e., regulations, rating systems and policies), as well as voluntary mechanisms that help internalise the environmental externalities or support the market for technologies with better environmental performance. Examples of policies that have been put in place include air pollution and fuel-efficiency standards for automobiles, energy-efficiency codes for buildings and, more recently, the European Emissions Trading Scheme (ETS) which sets a cap on carbon to encourage the uptake of cost-effective and marginal-abatement opportunities. Other examples of voluntary mechanisms supported by the public sector include the Carbon Trust's interest-free loans to provide capital to small and medium enterprises that would not otherwise purchase energy efficiency equipment (with support from the UK Government). Energy Star in USA is an example of a voluntary market mechanism being used to accelerate deployment of energy efficient appliances and goods. The Government can also use its procurement programmes (which generally are substantial) to promote the deployment of technologies with desirable energy performance, an example being the Federal Energy Management Program in the United States which promotes purchasing of energy-efficient products by the national government. Rating systems can make the energy efficiency attributes of products and systems apparent in the marketplace and improve the value of the incremental investments needed to reduce emissions.

Note that in the early stages of technology development, the private sector requires higher returns than in later stages. The reason for this is that in early-stage technologies, often the technology and the market are unproven and, therefore, the investment is a higher and less well defined risk for the private sector. Once the technology has been proven, risks are better known and it is competitive with existing technologies, the private sector's role is to deploy the technology at scale. The regulatory and market mechanisms of the kind mentioned above can help ensure a smooth transition from early-stage to large-scale deployment, e.g. renewable power planning regulations supporting deployment.

Thus, firms, as the ultimate developers and purveyors of products, are the key link between the basic scientific and technical advances in laboratories (partly funded by government) and the markets, while government policies, by shaping the rules of the game under which markets operate, play a different but no less important role in mediating the downstream part of the innovation process. Thus, successful energy innovation requires appropriate participation by both sets of actors, even if they are not actively working together.

Public-private partnerships (PPPs)

R&D early-technology development

In the world of technology development and deployment, partnerships between the public and private sectors are common, especially at the earlier stages (R&D, demonstration, and early deployment) and in particular in developed countries.

Private efforts to develop or commercialize a new technology can be impeded by several factors, e.g., project scale and cost, lack of full range of expertise in any one firm, and technical and market risk, even if the outcome may offer substantial benefits to the firm, the industry and to society as a whole. By helping firms overcome these barriers to investment, PPPs – involving cooperative R&D activities among industry, universities and government laboratories – can play a key role in overcoming these barriers and enabling or accelerating the development of industrial processes, products and services (NRC 2002).

In the US, for example, PPPs are an important facet of government policy to promote innovation (Audretsch et al. 2002). The main avenues of PPPs for technology development include (NRC 2002):

- innovation award programmes such as the Small Business Innovation Research (SBIR) Program and the Advanced Technology Program (ATP) that provide grants for technology development, which in turn can help partnerships to gain access to early-stage funding;
- cooperative R&D agreements that provide a well-established avenue for national laboratories to work with industry, academia and other organisations on cooperative R&D projects; and
- industry consortia, where R&D cooperation among firms, facilitated by government support (which may include funding or research contributions), can lower R&D costs or increase R&D efficiency. At the same time, firms continue with their own product-related R&D programmes to compete in the marketplace.

There are two types of public-private R&D partnerships under EU's Framework Programmes for Research and Development: European Technology Platforms and Joint Technology Initiatives (JTIs). The former help the industrial and academic research communities in specific technology fields coordinate their research and tailor it to a common “strategic research agenda”, which typically seeks to overcome barriers to the development, deployment and use of new technologies. These barriers could include the organisation of research, lack of suitable regulations or standards, insufficient funding, or a shortage of skills. The JTIs are long-term PPPs where the scale of resources necessitates combining private sector investment with public funding from national governments, the EU or other sources (EU 2006).

Similarly, Japan also has had various R&D programmes that have promoted inter-sectoral and inter-institutional networks. For example, the Large Scale Industrial Technology Research Development Programme of the Ministry of International Trade and Industry (MITI, now Ministry of Economy, Trade and Industry (METI)) and the New Energy and Industrial Technology Development Organization (NEDO) are intended to advance the development of technologies deemed important for the economy but too risky for private companies. It was a stated goal of the programme to promote close cooperation among public research institutes, industry, and academia. The Next Generation Basic Technology Programme of MITI and NEDO, which was directed at fundamental technologies indispensable for the next generation of technological development in key areas, also implemented its projects in cooperation between industry, government and universities (Hayashi 2003).

Demonstration and early deployment

PPPs are also helpful in overcoming the technical risk associated with the introduction of a new technology into the marketplace. In fact, cost-sharing in technology demonstration programmes is especially common for technologies that have public-good characteristics. A prominent example is the US Clean Coal Technology Program, motivated by the acid rain problem and initiated in 1986, that sought to develop and demonstrate, so as to determine their commercial feasibility, clean coal technologies in four categories: environmental control devices, advanced power generation, fuel processing and industrial applications. Here, in all, the industry contributed almost two-thirds of the costs of the projects. A study of the DOE's energy-efficiency and fossil research development and demonstration (RD&D) programmes found that "cost sharing between [the] DOE and industrial collaborators frequently improved the performance of RD&D programs and enhanced the level of economic and other benefits associated with such programs." (NRC 2001).

Infrastructural/deployment programmes

Probably the most common use of the term "public-private partnership" currently comes from the infrastructure and health services fields. In this context, PPP refers to an agreement between a government and a private firm under which the private firm delivers an asset, a service, or both, in return for payments. These payments are contingent to some extent on the long-term quality or other characteristics of outputs delivered (World Bank 2007).

There are three main rationales for these kinds of PPP: relieving pressure on government budgets by eliminating large up-front investments of often-scarce public funds, greater efficiency due to the private partners' operational expertise, or better management leading to improved services and infrastructure (Nikolic and Maikisch 2006; World Bank/PPIAF 2007). In principle, such partnerships should be able to leverage the specialized technical or managerial expertise of private players (e.g., performance-based monitoring and incentive based management) and their capability to reduce or better allocate risks (e.g., by better managing cost and schedule overruns (Nikolic and Maikisch 2006)). PPPs can involve contracting out, concessions, private financing initiatives or divestiture (see Figure IV.3).[39]

[39] Contracting-out involves publicly-financed investments aimed at improving efficiency and/or quality by awarding a service, management, construction, maintenance, equipment or hybrid contract to serve a specific need. In a concessionary arrangement, the ownership of an existing asset would stay with the Government with the private partner responsible for operation, maintenance and new investments.

International cooperation on energy technologies

International programmes on energy-technology cooperation generally take two forms: advancing technology development and accelerating technology deployment. Broadly, this may take place through various activities, including R&D partnerships, demonstration projects, making available financial instruments (such as financing or loan guarantees to support deployment of specific technologies), building human and institutional capacity and development of suitable policy frameworks (Holdren et al. 1999).

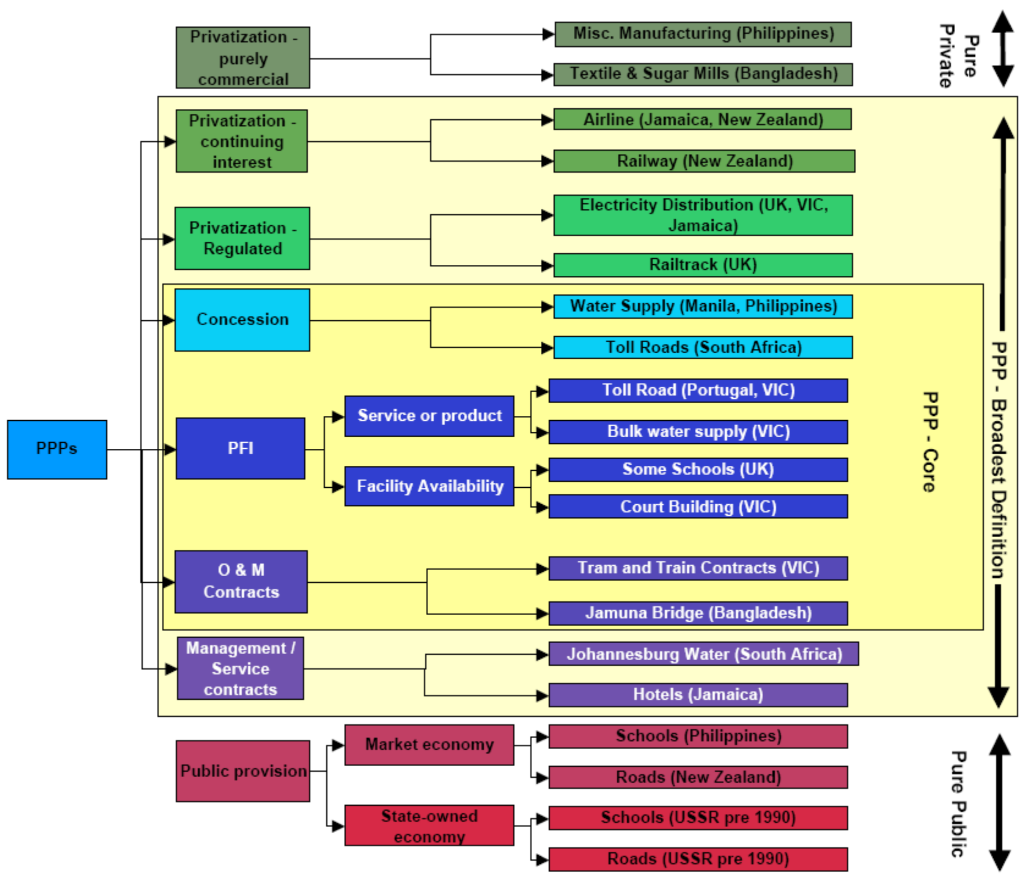

Figure IV.3: Scope of PPP arrangements

Note: VIC: Victoria, Australia

Source: World Bank/PPIAF 2007

Divestiture/privatization involves the sale of a public facility and transfer of ownership of all commercial risk to the private party (Nikolic and Maikisch 2006).

In the former category, the IEA's implementing agreements offer a flexible mechanism that allows various forms of energy technology cooperation, with funding coming through cost-sharing or task-sharing. Activities under existing agreements cover both cooperation of technical research as well as exploration of ways to lower the barriers to deployment of energy technologies (Mignone 2005).

2. Moving from R&D to market/large-scale deployment

The "valley of death" and its importance for low-carbon energy technologies

As mentioned earlier, in the discussion of the R&D phase, financial support for the development of a technology and demonstration of its technical and commercial feasibility comes from government and from the private sector. In the commercialization phase, firms are the dominant players and provide the relevant financial outlay. But there is a big gap between these two stages: the first one focuses on the development of a technology and the second requires the development of a product that then will need to compete on the market with other existing products (or in the case of an altogether new product, offer consumers sufficient reason to use the new product).

This gap is commonly called, in technology innovation studies, the "valley of death." This refers to the stage between the RD&D phase, when a technology is advanced enough that its application can be demonstrated, and the stage when the deployment of the technology or product takes place at sufficiently large scale to make it viable on the market.

Thus, moving from concept to commercial product availability (unsubsidized, with a warranty) requires overcoming the diverse range of technology, business, market and regulatory barriers. Broadly, these involve four respective 'journeys' (see Figure IV.4), all of which have to occur in order to deliver fully commercial technologies deployed at scale:

- The technology proving itself and being able to compete at cost with the market equivalent,
- The company growing into a successful business from lab-scale to many employees with manufacturing capability,
- The market being ready for the transition to the new technology, and
- Regulation being in place to support the process from the early stages of demonstration through to general application of the technology on the local market.

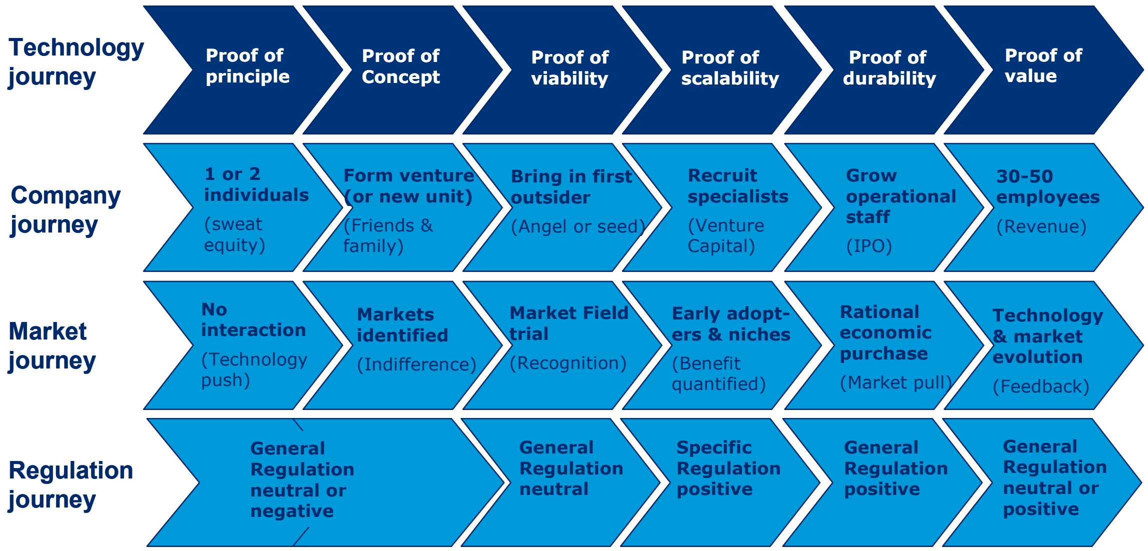

Figure IV.4: "Journeys" needed in different arenas for successful technological innovation

Source: Carbon Trust 2007.

In some technology areas, like information technology, the attraction of innovations is so compelling and rapid that the sector is almost defined by its capacity to innovate to deliver new and exciting products; typical R&D funds spent by companies is 10-20 per cent of the turnover or more. This is not the case for energy, where typical R&D expenditures are well below 1 per cent of turnover. The R&D funds spent on low-carbon technologies are very much lower still. Figure IV.5 conceptually illustrates this gap. The focus of most R&D expenditures by Governments is on technologies (or concepts) far from market applications. However, the focus of most market incentives is at the opposite extreme, providing a modest incentive towards lower-carbon investments based mainly on existing technologies. The gap arises because the market signals for energy innovation on both 'supply side' (technology-push) and 'demand side' (demand-pull) are weak – as are carbon market incentives.

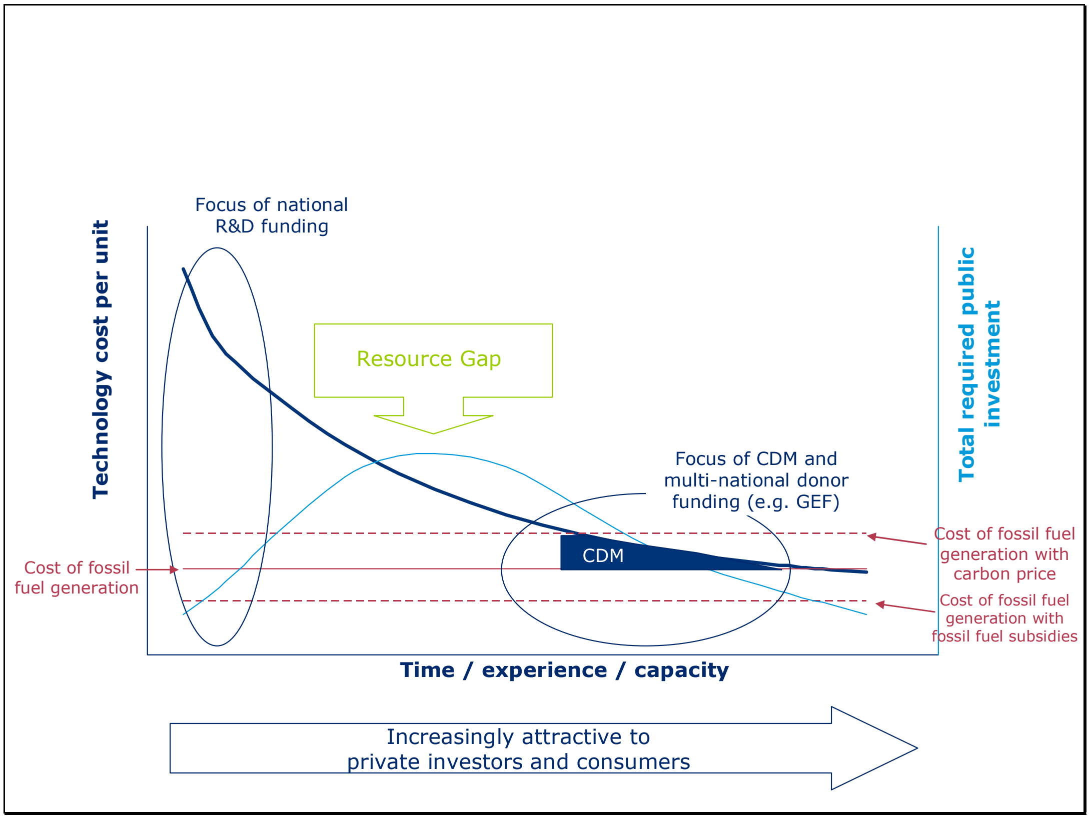

Figure IV.5: Role of public funding in the development and deployment of low-carbon technologies

Source: Carbon Trust 2007.

The demand-side relates to the development of the end-use market and includes cost, infrastructure requirements, slow capital stock turnover, market organization, and consumer information and financing options (IEA 1997, IEA 2000). This has an influence on "market-pull," the second part of the innovation model.

Both conditions need to be overcome for successful large-scale deployment: the firm must have the willingness and the resources to convert a promising technology into a product, and the market conditions must be such that the product can compete successfully and gain consumer acceptance.

Supply-side barriers in the energy sector

Supply-side barriers – those that inhibit 'technology-push' developments - are partly internal to firms and include the cultural gap between the technical and marketing personnel and the availability of resources to carry out product development (Markam 2002, Wessner 2005). Overcoming this gap requires champions, resources and formal development processes (Markham, 2002). The champion must be able to demonstrate the technical and market potential of the end product so that the firm or organization is willing to commit to its development. The firm must also make available the funding needed for technology development – these resources could come from within the firm, if it is a large entity, or from external funders (such as early-stage venture capitalists, angel investors or public programmes).[40]

Funding for developing new energy technologies is relatively difficult partly because energy is a commodity business. This severely limits the economic margins associated with innovation. Since the product is the same (e.g. electricity, heat, or liquid fuel), a new way of producing energy (or saving it) has to compete primarily by being cheaper than incumbent technologies. The rewards for innovation are thus intrinsically much smaller than in product-driven markets, and the funding consequently much less. At the same time, the nature of the energy market (i.e., slow turnover times for capital stock, large engineering requiring costly and time-consuming demonstration projects) raises the costs and risks and may make other investment opportunities more attractive, both within firms as well as for a private-capital business (Holdren et al. 1997).[41]

Demand- side barriers in the energy sector

Demand-side barriers are even more complex. Cost often is the dominant barrier to deployment of new technologies. Any new and improved technology has to compete with an established technology in cost terms, but the cost of any technology is higher in the early stages of its production, thus hampering the ability of this technology to compete with technologies already in widespread use.[42] Since energy prices do not reflect the full costs of energy, reductions in environmental, social, and other impacts of energy use are not reflected in market transactions. These price distortions further inhibit the deployment of new and improved energy technologies. At the same time, innovative energy-supply and end-use technologies are often more capital intensive (although less fuel intensive) than conventional technologies, which can deter potential users (Holdren et al. 1997). As the technology becomes more established in the market place, benefits from economies of scale and learning-by-doing[43] can help lower the costs significantly – but the scale of investment is amplified.

[40] In fact, US programmes such as the SBIR and ATP are precisely intended to address this resource gap (Wessner 2005).

[41] The situation may be changing, though, as the profile of the climate issue rises and as piecemeal policies and actions to address climate change become more common. As a result, venture capital and private equity investments in the clean energy area have been rising, up from US$ 1 billion in 2001 to US$ 13.2 billion in 2007 (UNEP/NEF 2008).

[42] Although technologies based on fossil fuels – oil, gas, and coal – traditionally have given stiff competition to new entrants because they are well-established and relatively cheap, the recent rise in the prices (and price volatility) of these fuels has given impetus to other alternatives.

[43] Cost reduction through 'learning-by-doing' takes place through improvements in manufacturing techniques and processes as well as in product design that result from the experience gained by a firm (or industry, through spillover effects). In fact, empirical data show that the total cost reductions of new technologies are related to their cumulative production, with the relationship between the two often referred to as the "learning curve".

Existing market organisation can hinder the establishment of a new product; even if it is possible to introduce a product onto the market, other factors, such as slow capital stock turnover and consumer information and financing options, contribute to reducing the rate of uptake by the market.

Carbon market barriers and technology transfer

Carbon markets, by effectively providing a subsidy for low-carbon technologies, can influence the (albeit weak) demand-pull forces towards more sustainable innovation by influencing the economics of the energy technology markets. Recent analysis suggests that the European ETS has not yet been effective at promoting innovation, partly because of design and implementation issues (that potentially could be overcome in the next generation of trading schemes) (Bleischwitz et al. 2007; Pontoglio 2008; Carbon Trust 2007) but also due to lack of stringency (Pontoglio 2008). Based on a case study of the wind industry, it has been suggested (Blanco and Rodrigues 2008) that the price of carbon will need to be much higher (€ 40/tCO_2) to support the market for wind energy technologies. Given that there still is significant uncertainty about long-term climate policies, it is difficult to imagine a clear and strong price signal in the near term that would create a strong enough "market-pull". Even in developed countries, markets remain either uninformed or skeptical about the willingness of government to impose a clear, consistent and sufficient carbon price, without loopholes, convincingly enough to justify taking sizeable risks with R&D investments.

Innovation elements of particular importance to developing countries

Products that suit developing country needs often have very different specifications from the products in developed countries. Thus, there is a specific need for product adaptation and/or development (although the core technology may remain the same) that is suitable for developing countries. There is a particular need to enhance capacity on this front.

Equally importantly, systematic steps to develop markets are key to the dissemination of energy technologies and products, especially where the markets may be fragmented or the consumers have only limited purchasing power. This might require that approaches, such as innovative delivery models, support to entrepreneurs and energy service companies, provision of information and financing, and appropriate policies, take on great significance. The development of domestic policy and market analysis capacity, of course, is a key need.

Lastly, while much focus is on deploying technology for GHG mitigation, it is important to remember that adaptation also will have technological needs. This adds further pressure on the relatively-limited technological capabilities of many developing countries.

Yet, innovation is the surest way to ensure that development and GHG mitigation do not conflict. New, lower-carbon technologies can provide not only reduced emissions, but energy systems that are cleaner in other respects, and less dependent upon volatile international fuel markets. Clean energy innovation is fundamentally supportive of development.

3. Energy and climate technology innovation centres[44]

All the evidence summarized above demonstrates a clear need for public-private partners. Energy companies and markets as they exist do not invest adequately in energy innovation, for clear and identifiable reasons. Carbon markets cannot change this underlying fact, nor do they provide sufficient incentives to drive such innovation as exists in low-carbon directions. Yet, the long history of the 'technology valley of death' demonstrates the essential need to include the private sector at the early stages of innovation, even if it is largely publicly-funded.

There are two sets of issues that are particularly pertinent to PPPs for climate change:

- Partnerships aimed at technology development and deployment generally have been targeted at specific sectors and not aimed at building a local innovation ecosystem. For such a broad-ranging challenge as the energy sector, including all the dimensions of energy efficiency, this is a fundamental problem.
- The experience with PPPs in general has been mixed, although there have been some positive outcomes, particularly in terms of improving performance (Hodge and Greve 2007). But there have been serious questions about the governance of such organisations, especially in the case of global partnerships (Buse and Walt 2002, Hodge and Greve 2007, Tucker and Makgoba 2008), including those involving NGOs as partners (Brinkerhoff and Brinkerhoff 2004, Haque, 2004).

It is therefore important to look for evidence of successful models upon which to build new proposals. Outside the energy-environment sector, one such model is the CGIAR network of agricultural innovation centres (Gagnon-Lebrun 2004). Within the energy-environment world, a recent study (UNEP/NEF 2008) examined a number of examples and identified the UK's Carbon Trust as a particularly interesting one.

Combining these antecedents, a proposal is put forward for a network of Energy and Climate Technology Innovation Centres (or Low-Carbon Energy Technology Innovation Centres) in developing countries. This would be a new combination of public-private, North-South, and South-South partnerships, intended to advance the development and availability of suitable technologies (i.e., support "technology-push"), underpin the creation and development of markets (i.e., support "demand-pull"), and carry out other enabling activities to overcome implementation barriers in developing countries (Sagar 2008; Carbon Trust 2008).

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[44] This section draws on Grubb et al. 2008 and Sagar 2008.

A network of such innovation centres could serve three goals: (1) accelerate the transition to low-carbon technology development by enabling multilateral funds to be cost-effectively deployed at the national level through encouraging PPPs; (2) advance sustainable development while making a positive contribution to climate mitigation in developing countries by enabling the development of technologies that serve the unmet energy needs of developing countries, especially for the energy poor; and (3) support climate adaptation programmes by developing technologies that are suitable for specific countries.

The main function of these Centres would be to expedite technological innovation towards these three goals by:

- Working in partnership with the private sector, which would involve using public money to reduce the risks of private sector investment, and promoting technical collaboration between public- and private-sector researchers on specific projects;

- Focusing resources and activities towards the development and/or adaptation of the most appropriate energy and climate technologies for a country, given its capabilities, resource base and needs;[45] and

- Proactively identifying and addressing technology and market barriers to move technologies up the adoption curve – this includes helping create a favourable national political and regulatory framework for the deployment of these technologies, providing information and raising awareness nationally, and exploring innovative delivery models that promote local entrepreneurship and employment.

Thus these Centres would provide appropriate, sustained and significant support to promote the development and deployment of energy technologies to meet key global energy challenges, especially climate change, energy security, and enhancing energy services for developing countries and the poor, while also meeting the goals of the UNFCCC. At the same time, they would build domestic human and institutional capacity for technical, policy, and market analysis and implementation. They also would help develop, assist, and strengthen local energy enterprises. This kind of activity will be particularly important for countries with limited technological capability, which, unfortunately, are also often the countries with the greatest energy challenges. There is also the likelihood that technology transfer is increased for a recipient country that has stronger technological capabilities (Dechezlepretre et al. 2008).

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[45] Broadly speaking, there are four categories of activity that are particularly relevant and critical:

- Adaptation and deployment of existing technologies or products, so that international incremental funding or subsidies are more effective;
- Overcoming various barriers to promote technology deployment where cost is not the key issue;
- Development of local low-carbon technology solutions and products to satisfy unmet energy needs (confluence of sustainable development and climate change); and
- Leveraging technological capabilities and critical mass for adaptation technologies.

A network of regional Energy and Climate Technology Innovation Centres located in selected developing countries could enhance the local and regional engagement with global technological developments, and catalyse domestic capacity to develop, adapt and diffuse beneficial technologies. Experience indicates that effective technological innovation needs to encompass the 'software' of commercial, institutional and financial structures, as well as the 'hardware' of the technology itself, and to benefit from learning from experience in the field. The Centres would nurture these capabilities through targeted interventions including field trials, business incubation, capacity building and seed capital (see Table IV.1). Hence these Centres would reduce technology costs through innovation, help to leverage private and public resources to bridge the clean energy financing gap that currently exists, and advance the deployment of technologies. They would play a role in all stages of the innovation process, more directly in the early stages and as facilitators for the later stages.

To achieve this, the Centres would need to be set up as PPPs that could work collaboratively with local academic organisations, businesses and governments to ensure that the most cost-effective projects are supported and to catalyse the large commercial investment required to achieve a transition to a low-carbon economy. These national Centres would be independent, but could be supported by an umbrella organisation which ensures that lessons are shared between Centres and with other countries having similar characteristics.

Based on observations about the scale of existing technology and product development laboratories and on the experience of the Carbon Trust and those active in supporting early-stage clean technologies, it is estimated that each Centre would require an investment of US$ 40-100 million per year. Overall, this would require a total investment of US $1-2.5 billion over five years to establish five regional Centres, as a first phase of activity.[46] Given the long lead times involved in energy research, development and deployment projects, a five-year funding budget is the minimum necessary to establish the network and achieve measurable progress. Future funding for additional Centres and subsequent time periods should be considered in light of success with the first phase.

Such public sector support could leverage 5-10 times as much in the form of private sector investment. It could enable up to 50 projects per year to be supported in each Centre, many of which could lead to self-sustaining technologies and businesses, given appropriate policy environments, with considerable carbon and economic benefits. Locating the first set of such Centres in representative developing countries, to develop capacities appropriate to fundamentally different kinds of operating environments, could accelerate wider international impact. Establishing such a programme thus holds the potential to make a major contribution to the combined goals of meeting the twin climate challenges of mitigation and adaptation, energy security, and sustainable development.

[46] Although some of this investment could come from the host country, this proposal would depend on securing funding that would be counted as fulfilling developed countries' commitments under UNFCCC.

Table IV.1: Types of intervention required to address specific local barriers to technology innovation and diffusion

Activity	Gap/need addressed	Benefits
Applied research and development Grant funding, open and/or directed at prioritised technologies	Inadequate support for relevant applied research for technologies where existing efforts are minimal or nonexistent because of lack of market signals or existing (technical and other) capacity	Adapt existing technologies or develop new technologies to meet local energy and climate needs, leveraging local knowledge base, if possible. Applied research and product development for potential commercial relevance. Promote North-South and South-South technical cooperation
Technology accelerators Designing and funding projects to evaluate technology performance, e.g., demonstration, field trials	Uncertainty, lack of information and skepticism about in-situ costs and performance, and lack of end-user awareness	Reduction in technology risks and/or costs by independent collection and dissemination of performance data and lessons learned
Business incubator services Strategic and business development advice to start-ups	Lack of seed funding and business skills within research/technology start-ups – the 'cultural gap' between the research and private sectors	Investment and partnering opportunities created by building a robust business case, strengthening management capacity and engaging the market
Enterprise creation Creation of new businesses by bringing together key skills and resources	Market structures, inertia and lack of carbon value impede development of start-ups or new corporate products and services	Creation of new high growth businesses to both meet and stimulate market demand Development of local commercial and technical capabilities
Early stage funding for energy and climate technology ventures Co-investments, loans or risk guarantees to help viable businesses attract private sector funding	Lack of financing (typically first or second round) for early stage technology/product development due to classic innovation barriers combined with perceived energy technology market and/or policy risks	Enhanced access to capital for emerging businesses that demonstrate commercial potential Increased private sector investment in the sector through demonstrating potential investor returns
Deployment of existing energy-efficiency technologies Advice and resources (e.g., interest-free loans) to support organisations to reduce emissions	Lack of awareness, information and market structures limit uptake of cost-competitive energy efficiency or low-carbon technologies	Improved use of energy resources through enabling organisations to implement energy efficient measures and save costs Catalyse further investment from organisations receiving support
Skills and capacity building Training of human resources in various areas related to technology innovation Designing and running training programmes	Lack of capacity to research emerging energy and climate technologies, develop appropriate products, and install, maintain and finance emerging low-carbon technologies	Enhancement of technical, policy and market analysis and implementation skills Growth in business capacity and employee capabilities to enable more rapid uptake of low-carbon and climate technologies
Domestic policy and market insights Analysis and recommendations to inform domestic policy and businesses	Lack of independent, objective analysis that can draw directly on practical experience to inform the local government and the market	Enhancing the policy and market landscape to support the development of an energy and climate technology economy

Source: Based on Grubb et al. 2008.

The activities listed in Table IV.1 provide a continuum of support from the early stages of technology demonstration to full market deployment. By combining all these mechanisms in one centre of expertise, this arrangement could create more value than stand-alone approaches: business intelligence from investors and the market informing early-stage technology support and project selection. Conversely, a deep understanding of early-stage technologies can be fed back to the market – enabling early insight to new opportunities and catalysing private sector investment.

In particular, a network of Energy and Climate Technology Innovation Centres could greatly reduce the size of the financing gap, a key barrier to successful technology innovation, in developing countries by addressing:

- High or uncertain costs of new technologies;
- Limited or uncertain suitability of technologies and products for local conditions;
- Limited business capacity or skill base to identify useful technologies, adapt them for local use, and provide installation and maintenance services;
- Uncertain market demand;
- Limited access to capital due to a conservative banking sector and very thin and highly sector-specific venture capital and private equity sectors; and
- Unfavourable regulatory and political climate (including competing priorities, vested interests, market distortions and subsidies in favour of fossil fuels).

In many developing countries, these barriers are frequently compounded by the lack of a central organisation acting as the focal point bringing together the academic, business and government communities to address the energy and climate innovation challenge in a coordinated manner.[47] Where focal points do exist, they generally lack the scale and experience needed in order to have a significant impact.

Targeted interventions can reduce the future cost of deploying low-carbon technologies, providing the conditions for increased private sector investment. For every unit of public sector investment, the Centres could leverage in up to ten times this amount in private sector investment either by creating breakthroughs in the cost and market readiness/acceptance of technologies so that they can be adopted at scale without further support, or by defining the additional public policies (local or international) needed to help stimulate their adoption. The total cost of these Centres should be relatively low when compared with other larger infrastructure projects.

The Centres could address both local and international barriers and help create a favourable domestic and international policy and regulatory framework for mitigation and adaptation technologies, avoiding lock-in to high-carbon development pathways. The network could also enable lessons learned to be codified and promulgated across developing countries to accelerate the process.

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[47] In fact, since most of the technology conversations in the climate context have centered on mitigation, there is also a need to promote a focused programme on adaptation technologies.

Suitably set up, such Energy and Climate Technology Innovation Centre could be well placed to work in ways that traditional government approaches cannot, by drawing on expertise and resources from not only government, but also business, industry associations, the energy sector, finance community and investors. As independent organisations they would be impartial, seeking the most appropriate solutions for low-carbon technology development and deployment. Their business-oriented approach would ensure that all activities would be focused on increasing the commercial potential of clean energy technologies and leveraging private sector investment alongside public funding.

The Centres could provide further benefits by collecting data from technology projects, businesses and the market, analysing the information and feeding key insights back to policy makers and to business. By identifying successes (e.g. niche markets, early adopters, particular technology installations and new business models) and the barriers that remain (e.g. regulatory hurdles, perverse subsidies, technology and market barriers), such a network of Innovation Centres could help government and business to work together to improve the market environment for clean energy.

This proposal could benefit from the development of networking arrangements among Centres to avoid unnecessary duplication and overlap and to promote synergies through joint planning, development, testing and marketing activities. Also, it might be worthwhile to spell out the regional dimensions of such a Centre, especially with regard to assessing needs, developing capacities, and involving the experts and markets of the nations of the region in which the Centre is located. Additionally, it would be helpful to know the kinds of environmentally sound technologies for which this model is apt to be most appropriate. Finally, in addition to the models and proposals already considered in this paper, it is important to consider other new and innovative approaches that can be designed for public-private and public-public partnerships for promoting the development and transfer of environmentally sound technologies for the benefit of developing countries.

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