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Technological Cooperation and Climate Change

ISSUES AND PERSPECTIVES

Working papers presented at the Ministry of Environment and Forests, Government of India - UNDP Consultation on Technology Cooperation for Addressing Climate Change

23-24 September, 2011 – New Delhi, India

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23-24 September, 2011; New Delhi, India

Contents

Abbreviations

AGM	Annual General Meeting
AWG-LCA	Ad Hoc Working Group on Long-term Cooperative Action
BAT	Best Available Technique
BEMS	Building and Energy Management System
BIM	Buildings Integrated Management
BIS	Bureau of Indian Standards
BRIICS	Brazil, China, India, Indonesia, Russian Federation and South Africa
CDQ	Coke Dry Quenching
CERN	Centre for European Nuclear Research
CET	clean energy technology
CFC	chlorofluorocarbons
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical
COP	Conference of Parties
CRIDA	Central Research Institute for Dryland Agriculture
CSIR	Council of Scientific and Industrial Research
CTC	Climate Technology Centre
CTCN	Climate Technology Centre and Network
CTMMIT	Centro Internacional de Mejoramiento de Maiz y Trigo
EAGLE	Coal Energy Application for Gas, Liquid and Electricity
EGTT	Expert Group on Technology Transfer
EST	environmentally sound technology
FAO	Food and Agriculture Organization
FBC	fluidised-bed combustion
FGD	flue gas desulfuriser
GATS	General Agreement on Trade in Services
GCF	Green Climate Fund

GDP	gross domestic product
GEF	Global Environmental Facility
GHG	greenhouse gas
GJ/tcs	gajoules of primary energy per tonne of crude steel
GRPC	Genetics Resources Policy Committee
GW	gigawatt
HIF	Health Impact Fund
IBRD	International Bank for Reconstruction and Development
ICAR	Indian Council of Agricultural Research
IDC	innovative developing country
IEA	International Energy Agency
IFPRI	International Food Policy Research Institute
IGCC	Integrated Coal Gasification Combined Cycle
IITA	International Institute of Tropical Agriculture
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IPR	intellectual property right
IRRI	International Rice Research Institute
LDC	Least Developed Country
LDCF	Least Developed Countries Fund
LED	Light Emitting Diode
MOEF	Ministry of Environment and Forests
MT	metric tonne
MW	megawatt
NGO	non-governmental organisation
NICRA	National Initiative for Climate Change Resilient Agriculture
NIH	National Institutes of Health
ODA	official development assistance
ODS	ozone-depleting substances

OECD	Organisation for Economic Cooperation and Development
OSDD	Open Source Drug Discovery
PCI	Pulverised Coal Injection
PPP	public-private partnership
PRI	Panchayati Raj Institution
PV	photovoltaic
R&D	research and development
SC	super-critical
SCCF	Special Climate Change Fund
SCM	Subsidies and Countervailing Measures
SCR	selective catalytic reducer
SDC	Swiss Agency for Development and Cooperation
SIDS	Small Island Developing States
SRTT	Special Report on Technology Transfer
TAC	Technical Advisory Committee
TEC	Technology Executive Committee
TNA	Technology Needs Assessment
TOR	terms of reference
TPES	Total primary energy supply
TPT	Top Pressure Turbine
TRIPS	trade-related aspects of intellectual property rights
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USC	ultra super-critical
WGTTT	Working Group on Trade and Transfer of Technology
WIPO	World Intellectual Property Organisation
WPD	wind power density
WTO	World Trade Organisation

Foreword

Climate Change is one of the most formidable developmental challenges faced by humanity today. The consequences of Climate Change are global, affecting all. However, the impact tends to be higher for the disadvantaged, making them even more vulnerable to climate risks. While Climate Change calls into question further progress and sustainability of development gains, it also provides the opportunity to move towards a low carbon climate resilient path. The dilemma revolves around ensuring pro-poor growth and energy security, essential for human development dividends, while containing emissions and their adverse effects from rising ambient temperatures. In this regard, accelerating development, adoption and diffusion of cleaner climate friendly technologies across all countries and sectors is important.

The discussion and international negotiations around technology cooperation and the setting up of the Technology Cooperation Mechanism under the United Nations Framework Convention on Climate Change (UNFCCC) is a positive and welcome step. The operational modalities and the effectiveness of such a mechanism will be critical for shaping technology cooperation for climate change in the coming years. It is therefore important to prioritize climate technology needs for developing countries, as well as examine existing models and institutional arrangements for technology cooperation to draw lessons for the international mechanism. For this purpose, a Consultation on "Technology Cooperation for Addressing Climate Change" was organized jointly by the Ministry of Environment and Forests (MOEF), Government of India and the United Nations Development Programme (UNDP) in India. This publication comprises commissioned papers written by eminent persons which were presented and discussed at the consultation.

The publication presents critical viewpoints related to climate change technologies and technology cooperation in order to highlight associated issues, challenges and opportunities. To this effect, it brings together perspectives for enabling more informed discussions on issues of technology cooperation for addressing climate change and is a significant contribution to national and global discussions on Climate Technology Cooperation Mechanism.

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Photo © Tom Pietrasik/UNDP India

Chapter 1

Technology Cooperation for Addressing Climate Change

Preeti Soni

Introduction

Technology plays a critical role in addressing the global challenge of climate change and sustainable development. Issues related to technologies and technology cooperation have been discussed and debated at the international climate change negotiations since the Convention was being drafted. These are inherently embedded in the text of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol.

Technology cooperation, in particular, is a key strategy that can further the efforts of the global community in mitigation of greenhouse gas emissions (GHGs) and adaptation to climate change impacts. In this regard, the international community is preparing for the 17th meeting of the Conference of Parties (COP 17) to the UNFCCC at Durban where one of the agenda items is the implementation of a "Technology Mechanism" to facilitate enhanced action on technology development and transfer


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to support relevant climate change action. However several issues remain to be considered and deliberated on, along with an analysis of their proposed implications, at the international, regional and national levels.

This paper presents the context in which issues pertaining to technology and technology cooperation to address climate change are being discussed and debated. Broadly, it presents a historical review and current status of the issue of technology and technology cooperation under the UNFCCC. Against the overall international perspective, an overview of the key emergent issues and questions that are especially relevant for developing countries such as India is given. The key issues and perspectives identified here are further discussed in greater detail in subsequent chapters.

Technology Cooperation under the UNFCCC Framework

As mentioned above, technology issues are embedded in the overall framework for addressing climate change provided by the UNFCCC (see Annexure 1). The Convention stipulates that all Parties, taking into account their common but differentiated responsibilities and national and regional development priorities, objectives and circumstances, are to promote and cooperate in developing, applying and diffusing, including transferring technologies, practices and processes that control, reduce or prevent certain anthropogenic emissions of GHGs in all relevant sectors (Article 4.1 (c)).

According to Article 4.3, Annex II, Parties are to provide financial resources for the transfer of technology. Article 4.5 urges developed country Parties to 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 to developing countries, to enable them to implement the provisions of the Convention. The extent to which developing country Parties will effectively implement their commitments under the Convention will depend on effective implementation by developed country Parties of their commitments under the Convention related to financial resources and transfer of technology (Article 4.7). This commitment is echoed in similar provisions under the Kyoto Protocol in Article 10c[1].

It may be noted that these Articles of the Convention place a significant emphasis on technology development and technology transfer. Technology cooperation is a term that is preferred by some vis-à-vis technology transfer as it denotes a collaborative action. Technology "transfer" here, however, follows the Intergovernmental Panel on Climate Change (IPCC) definition which is:

…."a broad set of processes covering the flows of know-how, experience & equipment for mitigating & adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, non-governmental organization (NGOs) & research/education institutions…".

It is a broad and inclusive term whereby "transfer" encompasses both technology "diffusion" and technology "cooperation" across and within countries[2].

[1] This section draws upon various UNFCCC documents. The focus is on the UNFCCC framework. The provisions of the Kyoto Protocol are not further elaborated.

[2] "Summary for Policymakers," Methodological and Technological Issues in Technology Transfer: A Special Report of IPCC Working Group III, IPCC (2000).

Evolution and current status

Subsequent to the UNFCCC coming into force in 1994, several decisions to promote the development and transfer of environmentally sound technologies (ESTs) at each session of the COP to the UNFCCC (Table 1). It was decided at the COP 1 itself to review, at each session of COP, the implementation of Articles 4 and 5 of the Convention. Therefore, the development and transfer of technologies is a standing agenda item for COP meetings as well as for the meetings of the Subsidiary Bodies to the UNFCCC.

The progress and evolution in the discussions on technologies in this regard is usually described in four main phases:

1. Phase 1 (COP 1-4): Berlin Mandate and work on various issues
2. Phase 2 (COP 4-7): Buenos Aires Plan of Action and Consultative Process on Technology Transfer
3. Phase 3 (COP 7-12): Marrakesh Accords & implementation of the Technology Transfer Framework for meaningful and effective actions to enhance implementation of Article 4.5 of the UNFCCC
4. Phase 4 (COP 12-16): Bali Road Map process, and Poznan strategic programme on technology transfer and technology mechanism established at Cancun

Efforts are underway to now move to the next phase, that is, towards an operational Technology Mechanism – hopefully at the COP 17 in Durban.

Table 1:
Key outcomes related to technology development and transfer

Decision 1/CP.1	Decided to review at each COP the implementation of Article 4, paragraphs 1(c) and 5, of the Convention as a separate agenda item under "Matters relating to commitments"
Decision 4/CP.4	Established a consultative process to achieve agreement on a technology transfer framework
Decision 4/CP.7	Adopted the technology transfer framework
Decision 3/CP.13	Reconstituted the Expert Group on Technology Transfer and adopted the set of actions as set out in the recommendation for enhancing the implementation of the technology transfer framework
Decision 4/CP.13	Decision on the development and transfer of technologies under the Subsidiary Body for Implementation
Decision 2/CP.14	Poznan strategic programme on technology transfer adopted
Decision 1/CP.16	Established the Technology Mechanism

Consultative process on Technology Transfer

At COP 4, as part of the Buenos Aires Plan of Action, it was decided to provide impetus to the technology issue by establishing a "consultative process on technology transfer" with the objective of making recommendations on a "framework for meaningful and effective actions" to enhance the implementation of Article 4.5 of the Convention.

As part of the consultative process, regional workshops and informal consultations were organised which generating several technical background papers, country papers and useful information. In addition, the process was able to draw on information and analysis contained in the submissions from Parties and, in particular, the IPCC Special Report on Methodological and Technological Issues in Technology Transfer.

This process culminated in the adoption of a Technology Transfer Framework for meaningful and effective actions to enhance the implementation of Article 4.5 at COP 7 in 2001, as part of the Marrakesh Accords (decision 4/CP.7).

Technology Transfer Framework

The purpose of the Technology Transfer Framework was to develop meaningful and effective actions to enhance implementation of Article 4.5 by increasing and improving transfer of and access to ESTs. Encompassing a country driven, integrated, participatory approach, the key framework covers five key themes with specific definition, purpose and implementation. These include:

(a) Technology needs and needs assessments,

(b) Technology information,

(c) Enabling environments,

(d) Capacity building,

(e) Mechanisms for technology transfer.

The Marrakesh Accords provided for the establishment of an Expert Group on Technology Transfer (EGTT) as part of Technology Transfer Framework to contribute towards its implementation by considering technology needs, and analysing and recommending ways to facilitate and advance technology transfer activities.

Implementation of the Technology Transfer Framework

A renewed impetus was provided to technology issues at COP 13 under the Bali Action Plan. The Bali Action Plan (decision 1/CP.13), established the Ad Hoc Working Group on Long-term Cooperative Action (AWG-LCA) with a mandate to focus on key elements of long-term cooperation, including technology transfer. A set of actions for enhancing the implementation of the technology transfer framework were decided upon and it was agreed that these activities would complement the actions in the Technology Transfer Framework. In addition, four sub-themes were added to the technology transfer framework as part of the mechanism theme: (a) innovative financing, (b) international cooperation, (c) endogenous development of technologies and (d) collaborative research and development (R&D).

At COP 13, the EGTT was reconstituted for another five years, and took on a more prominent role. EGTT provided significant recommendations for enhanced action on technology development and transfer, including effective mechanisms and ways to accelerate deployment, diffusion and transfer of affordable ESTs, innovative financing and enhanced cooperation on R&D of current, new and innovative technology, including beneficial solutions for all.

Under the work on mechanisms, the COP 13 also requested the Global Environmental Facility (GEF) to develop a strategic programme to scale up the level of investment for technology transfer for developing countries. The GEF's Strategic Programme on Technology Transfer was welcomed at COP 14 at Poznan and renamed the "Poznan Strategic Programme on Technology Transfer" (decision 2/CP.14). It was considered a step forward in scaling up investment and enhancing technology transfer activities under the Convention. The Programme contains three funding windows with a US$50 million: (a) Technology Needs Assessments (TNAs), (b) pilot priority technology projects linked to TNAs, and (c) dissemination of GEF experience and successfully demonstrated ESTs.

Subsequent to this, another major milestone was the COP 15 under the Copenhagen Accords deciding to extend the mandate of AWG-LCA to enable it to continue its work with a view to presenting the outcome at COP 16. The Copenhagen Accords also provided that Parties under Kyoto Protocol may deliver results of their work pursuant to decision 1/CMP.1 for adoption by the COP serving as the meeting of the Parties to the Kyoto Protocol at its sixth session.

Technology Mechanism

Perhaps the most significant milestone related to technology cooperation was in COP 16 at Cancun where the Technology Mechanism was established to facilitate the implementation of enhanced action on technology development and transfer to support mitigation and adaptation to climate change. The Mechanism, among other issues, is expected to help facilitate action to enhance access to technology and know-how, share between developers and end users at competitive costs, and ensure that technologies available in the public domain are shared between the end-users with minimum transaction cost.

The Technology Mechanism consists of the following two components:

(a) A Technology Executive Committee (TEC),

(b) A Climate Technology Centre and Network (CTCN).

The COP 16 also decided to terminate the mandate of the EGTT, and mandated the TEC of the new Technology Mechanism to further implement the Technology Transfer Framework. The TEC is envisaged with equitable representation from developed and developing countries and the CTCN to comprise national, regional, sectoral and international networks and organisations.

Towards an operational Technology Mechanism

During the course of negotiation of the AWG-LCA, the Parties have been debating on relevant issues, with a view to the COP 17 taking a decision in order to make the Technology Mechanism fully operational in 2012. Some of the key issues that are still under discussion include the governance structure (including reporting lines), operational modalities and procedures, resources and sustainability, links between the Technology Mechanism and other mechanisms under the UNFCCC, and any additional functions for TEC and CTCN. Unless these key issues are resolved, it may be difficult to make the Technology Mechanism operational.

Photo © Shashank Jayaprasad/UNDP India

Technology Cooperation: Issues

The evolution of the technology issue over the years clearly showcases that while progress has been made, there is still a long way to go for effective technology cooperation. To address these challenges, the establishment of the Technology Mechanism is a positive and welcome step. In this regard, however, it is also important to examine the implications of such a mechanism for developing countries such as India.

Firstly, with respect to the global negotiations, the countries have to decide upon positions in order to take proactive stances. It is imperative to deliberate on the prioritised climate technology needs, especially for developing countries, and examine the existing models and institutional arrangements for technology cooperation to draw lessons and inputs to contribute to national and global discussions on the Technology Mechanism.

Secondly, there may be implications for South-South and regional cooperation. There is an increasing emphasis on technology cooperation between developing countries as well as within the South Asian region. The issue is how the Technology Mechanism may impact technology cooperation for addressing climate change between the developing countries.

Thirdly, there is the implication at the national level. How will the objectives of such a mechanism translate into actions and incentives within countries? For instance, what are the likely implications for institutions for technology development and cooperation within India with decentralised nodes at sub-national levels?

Climate technologies

The foremost issue is the technologies that may be covered under the Technology Mechanism. Basically, what are the climate technologies that may be addressed through the mechanism?

The Convention refers to ESTs, defined by the IPCC as "technologies which protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, handle residual wastes in a more acceptable manner than the technologies for which they were substitutes, and are compatible with nationally determined socio-economic, cultural and environmental priorities. The term encompasses hard and soft technologies (United Nations, 1993)." However, it may be noted that climate technologies or technologies that address climate change, that is, which are climate friendly and climate responsive, are not necessarily always environmentally sound. For instance, technologies for large hydroelectric plants are climate friendly but could affect the environment of the locations where they are deployed[3]. However, it is assumed that climate technologies will be applied in such a way that they are environmentally sound. Also, climate technologies imply both technologies for mitigation and adaptation to climate change. Mitigation focuses on slowing climate change, whereas adaptation deals with the effects of climate change. Technology cooperation thus needs to encourage development that is climate friendly (mitigation) and climate responsive (adaptation), taking into account the need to adjust to the effects of climate change.

Another important point to note is that suitability of climate technologies may differ in different contexts. It is therefore important to ascertain which technologies will be most relevant in addressing climate change, especially since there is a range of such technologies that may be considered "priority climate technologies". Based on this, the "climate technology needs" require to be assessed not only globally but also within the specific context of developing countries and at national levels. It would also be useful if technology cooperation is demand driven, that is, the countries need to come together to understand the needs rather than respond to offers of technical support/cooperation.

The question is how can the climate technologies be identified and assessed. There are methodologies and tools that exists (for example, TNA), which may be useful in adapting to the national context. The issue will also be the ability to adopt and scale up to more efficient and effective technologies that are suitable to the nations' conditions and development objectives. The next set of issues would be to analyse which technology needs can be met with existing technologies and which require technology development. Of available technologies, which are public or proprietary, and how have they been developed and made available and affordable? Some of these issues in the special context of India are discussed further in Chapter 2. Broadly, the technology for both mitigation and adaptation needs have to be assessed on a continuous basis. In fact, a process is needed for constantly identifying technology needs on an ongoing basis both for mitigation and adaptation.

[3] IBID

Institutional structure of the Technology Mechanism

Another key issue is related to the institutional structure, governance and mandate of the Technology Mechanism. What will be the role of the Technology Mechanism with respect to the objectives of the Convention in the development and deployment of climate technologies? What will be the relationship between the TEC and the CTC?

There are several institutional models that may have lessons for the Technology Mechanism including both push and pull mechanisms. Lessons learnt from similar institutions and mechanisms that are currently used for proprietary technologies at affordable prices or diffusion of public technologies will be useful in this regard. In particular, what can be learnt from case studies of critical technologies (such as those related to food, medicine, internet, chlorofluorocarbons) for providing credible incentives for innovation, including jointly developed technology and intellectual property rights (IPR) sharing, enhancement of enabling environments, and leveraging additional financial resources for climate technologies?

IPR has become a key, and often contested, issue in the discussion on technology cooperation. Limited information and IPRs may constitute a barrier depending on several factors, such as whether or not the particular technology is patented, whether there are viable and cost-effective substitutes or alternatives, the degree of competition, the prices at which it is sold, and the degree of reasonableness of terms for licensing, etc[4]. In some cases, they may not pose a barrier for accessing technologies as alternative mechanism may be agreed upon. The issue is: what are the opportunities and challenges posed by IPRs? How does global technology transfer across countries with different national IPR frameworks work? How are 'reasonable returns' to the developer and 'affordability' reconciled? And, what is the role of the national government in such a transfer, negotiating with technology providers on behalf of multiple national users?

In this regard, Chapters 3, 4 and 5 deal with institutional structures and IPR issues with reference to technology cooperation for addressing climate change, and drawing lessons from existing models and examples. Chapter 3 provides a detailed assessment of the Consultative Group on International Agricultural Research (CGIAR) model which is considered a good example for both positives in terms of

[4] Various including Khor 2011 (chapter 4); Sustainability, Action Aid India and WWF-India 2010. Climate change and challenges of clean technology deployment in Indian power sector. New Delhi.

enabling food security and challenges related to ensuring long-term productivity and sustainability in terms of a continuous stream of relevant technology innovations (also see annex 2). Chapter 4 and 5 deal with issue of patents and their treatment under different regimes; they provide options for consideration under the negotiations for a more equitable and effective outcome.

Financing climate technologies

Financing for climate technologies remains a significant issue for technology cooperation. There are mechanisms and instruments under as well as outside the UNFCCC for financing climate actions and technology cooperation. According to the EGTT Report, however, the financing resources for technologies for mitigation and adaptation make up only a small share (probably less than 3.5 percent) of resources devoted globally to technology development and transfer and must be increased significantly[5]. The question is firstly, how will be Technology Mechanism be financed and how will the finances be sustained? There may be short-term requirements to quick start the functioning of the mechanism as well as longer term needs for its future development. What could be the relationship between the Technology Mechanism and the Financial Mechanism or the Green Climate Fund (GCF), which are currently being discussed at the international level? This is also relevant for the other financing mechanisms under the UNFCCC as well as other forums such as the G20 where there is increased talk about climate financing and cooperation.

Financing issues are pertinent for the Technology Mechanism. For instance, what will be the services provided and what will be financed by the technology mechanism (development/early adoption or enhanced diffusion of technologies, technologies as per needs or those listed in climate plans), and how (full costs/technical assistance/development process)? How will these translate to and complement national efforts considering that these issues are also relevant at national levels for technology diffusion to a more effective low carbon climate resilient path.

[5] Correa 2011 (chapter 3).

Technology Cooperation: Some Perspectives

In order to discuss the key issues listed above, a **Consultation on "Technology Cooperation for Addressing Climate Change"** was jointly organised by the Ministry of Environment and Forests (MOEF) and the United Nations Development Programme (UNDP) on 23-24 October 2011 in New Delhi. Some of the key takeaways from the Consultation are listed below. These issues are discussed in further detail in the subsequent chapters. The idea is to raise issues and offer perspectives so as to provide inputs for a more informed discussion at COP 17 in Durban and beyond.

On climate technologies

- Technology for both mitigation and adaptation needs has to be assessed on a continuous basis. We need a process that can do so in a systematic, robust and ongoing manner giving importance to both mitigation and adaptation technologies.
- In the climate change context for developing countries, issues of scale, compatibility and strategy are important along with affordability and accessibility. There is no 'one-shoe fits all' approach since different technologies have different innovation gaps from technical adaptation to make the technologies suitable to developing new ones to overcome deployment barriers. However, a common framework will be helpful.
- Technology cooperation activities should leverage and strengthen existing capacities including information, technical, financial, business and policy.

On institutional structures and IPRs

- There are several institutional models that may have lessons for the Technology Mechanism (probably the most useful is the CGIAR model). The importance of a good design and management of the cooperative agreement is clear.
- Domestic R&D capacity is not only necessary to develop new technologies but also to securitise scientific and technological developments that take place elsewhere and to generate capacity to adopt and adapt it.

- There is a need for developing nations to "leap frog" to highly efficient technologies rather than travel along a slow "market driven" curve towards the desired technologies which will be important for addressing climate change issues. This makes the IPR issues even more relevant to speed up and enhance actions that can be taken by nations.
- The IPR issue needs to be included in the discussions on the Technology Mechanism. Since climate change is a global issue, the best situation would be to adopt a principle wherein the countries exempt priority climate change technologies from patents, supplemented with global measures to enable sharing of trade information. As alternatives, other measures such as automatic granting of voluntary licence use of existing trade-related aspects of intellectual property rights (TRIPS) flexibilities, and patent pools or technology pools may be considered.

On financing climate technologies

- Key principles in the UNFCCC stipulating new and additional financial resources including those for transfer of technology needed by the developing country Parties must be respected and carried forward. The governance structures of the Technology Mechanism and the Financial Mechanism must be balanced through clear lines of accountabilities to the COP.
- Technology transfer may be facilitated by mandatory licensing of IPRs by developing countries with regulation of license fees. A financial mechanism may be developed and agreed upon to pay the license fees for technologies required by developing countries. The scope does not include strictly commercial technology licensing and/or imports of equipment embodying technology.
- There is a need to "mainstreaming" climate change actions in development programmes. There is also a need to combine budgetary and regulatory approaches and consider generating finance through existing and "innovative sources".
- Technology and financing need to be viewed in the context of policies, skills and capacities, awareness, information and institutions.

In Conclusion

Efforts to move towards a low carbon climate resilience future path are critically dependent, for their success, on the availability and use of the climate technologies across all countries and sectors. There is an urgent need for concerted and collaborative efforts to develop and provide increased access to technology for mitigation and adaptation at all levels – global, regional and national – enabled by capacity-building and provision of new and additional funding to meet the costs of integration of climate change considerations into the development process and stand-alone activities. While the Technology Mechanism envisages enhanced actions for cooperation in this regard, there exist several issues and questions. Implications of technology cooperation need to be examined at the international, regional and national levels.

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Chapter 2

Climate Technology Needs for India

Ambuj Sagar

Introduction

It has become clear that meeting the primary objective of the UNFCCC, that is, avoiding dangerous climate change, will require major reductions in GHG emissions. While often the need for GHG mitigation is seen as a potential impediment to economic and social aspirations in both rich and poor countries[1], there also is increasing consensus that action on this front really needs to begin sooner rather than later. At the same time, given that some level of climate change is unavoidable (and, in fact, already occurring), there is a need to ensure that the human, social and economic impacts of this changed climate are managed through adaptation programmes. There also is wide-ranging agreement that technology will play a central role in both mitigation and adaptation programmes. As the IPCC Special Report on Technology Transfer (SRTT) states, "[a]chieving the ultimate objective of the UNFCCC, as formulated in Article 2, will require technological innovation and the rapid and widespread transfer and implementation of technologies, including

[1] Of course, there is a large difference among countries in the financial and technical resources at their disposal to take such action ("capability") and their contribution to the climate problem ("responsibility").

Photo © Benoit Marquet/UNDP India

know-how for mitigation of greenhouse gas emissions. Transfer of technology for adaptation to climate change is also an important element of reducing vulnerability to climate change. This technological innovation must occur fast enough and continue over a period of time to allow greenhouse gas concentrations to stabilise and reduce vulnerability to climate change."[2]

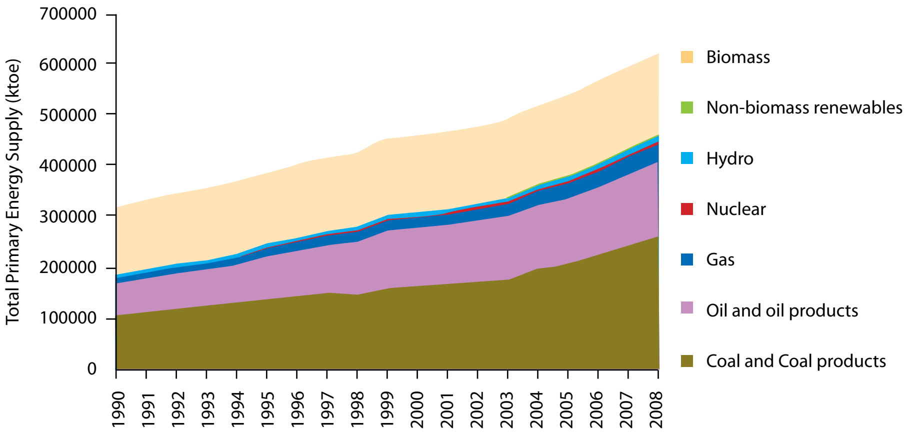
Given that starting point, some questions arise naturally for a developing country such as India: What technologies are likely to be useful to meet its climate challenges, while obviously paying heed to its developmental needs? How does one identify and prioritise among these technologies? And how can the potential of these technologies be realised most effectively? That is to say, what are the needs for appropriately leveraging climate technologies in India? This paper will attempt to shed some light on these questions by taking the energy sector – the largest contributor to the country's GHG emissions – as a case study.

[2] "Summary for Policymakers," Methodological and Technological Issues in Technology Transfer: A Special Report of IPCC Working Group III, IPCC (2000).

Setting the Context – India's Energy Sector

Figure 1 shows the total primary energy supply (TPES) for India since 1990. Even though it has almost doubled its TPES during this period, India accounted for just over 5 percent of the world's (with about one-sixth of the world's population) in 2008;[3] thus on a per-capita basis, Indians used about one-10th the energy compared to Annex-I countries (and less than half that of even non-Annex-I countries).[4]

Figure 1:
Total primary energy supply for India, 1990-2008[5]



The following points are notable:

- India (like most non-Annex-I and Annex-I countries) relies heavily on fossil fuels (especially coal and petroleum) and this dependence is increasing. In 1990, fossil fuels contributed about 55 percent to the country's TPES; by 2008, this number had risen to 71 percent. While the TPES in the country has increased by about 3.8 percent per year, the supply of coal has grown annually by about 5.1 percent per year (over 70 percent of this being used for power generation), and that of petroleum and related products by about 4.9 percent annually.

  But it should be noted that despite this growth, even in 2008, on a per-capita basis, India still used only one-fourth the coal and only one-13th the

[3] Author's calculations from IEA data.
[4] Climate Analysis Indicators Tool (CAIT) Version 8.0. Washington, DC: World Resources Institute (2010).
[5] IEA, "World energy balances", IEA World Energy Statistics and Balances (database).

oil compared to Organisation for Economic Co-operation and Development (OECD) countries. As India rises up the economic ladder, its energy use is likely to increase. In fact, the energy demand projections from the Indian Planning Commission's Integrated Energy Policy Report (see Table 2) indicates that the primary energy requirements in the country will rise rapidly if the trend of high economic growth that has been experienced in recent years continues in the coming years.

Table 2:
Projected energy requirements for India

Total Primary Energy Requirement (Mtoe)

Year	TPCES		TPNCES		TPES	
2006-07	389	397	153	153	542	550
2011-12	496	546	169	169	665	715
2016-17	663	739	177	177	842	916
2021-22	907	1011	182	181	1089	1192
2026-27	1222	1378	184	183	1406	1561
2031-32	1651	1858	185	185	1836	2043

Source: Integrated Energy Policy, Table 2.14

At the same time, there is a large spread of energy use among countries with similar levels of gross domestic product (GDP), indicating that increase in prosperity need not lead to a proportional increase in energy use.

- India still obtains almost a quarter of its energy supply from combustible renewables and biomass; the corresponding number for Annex-I countries is about 3 percent.[6] This number has come down significantly in the past two decades: in 1990, these resources accounted for over 40 percent of India's TPES. This share reduction in the use of this energy (as fraction of TPES, at least; in absolute terms, biomass use has grown by about 1.1 percent per year). This presumably is, in part, responsible for the increase in the carbon factor of the energy use, although this is more than offset by the reduction in the energy intensity of the country's economy, leading to a reduction in the overall carbon intensity. An estimated 160 million households (<770 million people) rely on biomass for cooking energy; the inefficient combustion of the traditional biomass cook stoves used by these households has significant health and other social impacts.

[6] IBID.

- About one-third of the population in India – almost 400 million people – still lack access to electricity. This is a major concern since electricity is a clean and versatile energy carrier, and therefore underpins a range of activities and services that are vital to human, economic and social development.
- Nuclear, non-hydro and non-biomass renewables (geothermal, solar, wind, etc.) remain responsible for a relatively small portion of the overall energy supply in India – as of 2008, these sources accounted for less than 1 percent of India's TPES. But the contribution of non-hydro, non-biomass renewable has grown rapidly (<30% per annum in the last two decades).

Figure 2:
Estimated primary energy consumption and losses in India[7]

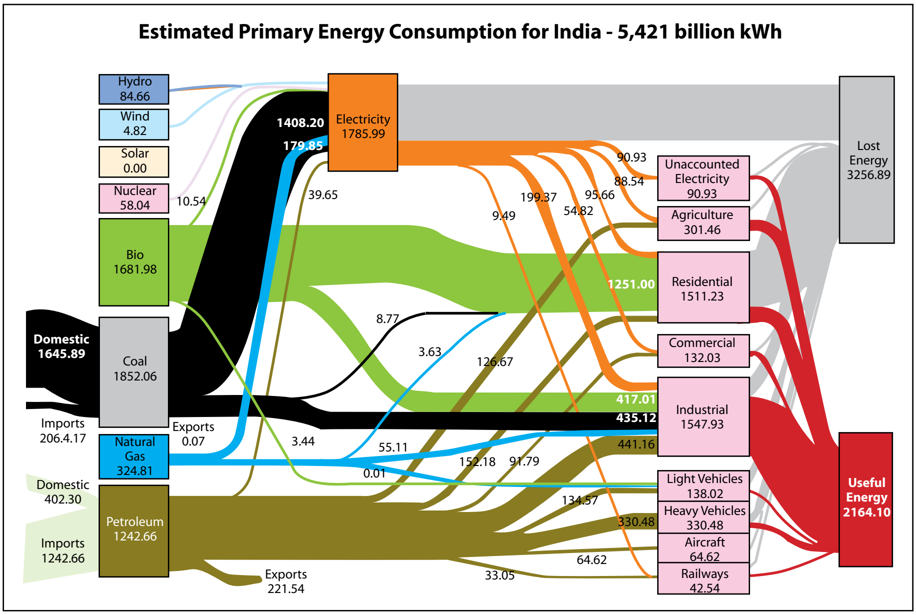


Figure 2 shows energy consumption and loss estimates for India. This indicates that there are a number of energy-consuming groups in India, of which the two largest groupings are (residential and commercial) buildings and industry. These also represent the greatest lost energy, along with the electricity generation sector.

This context, in terms of current state and future expectations, sets the stage for thinking about what India's energy technology needs might be with reference to GHG mitigation.

[7] "Technology: Enabling the Transformation of Power Distribution," CSTEP and Infosys, 2008.

Identifying Energy Technologies

In terms of identifying the major areas of focus, we luckily can draw upon a recent exercise undertaken by the Planning Commission to identify key opportunities for mitigation within the major energy sectors (see Table 3).[8] This exercise estimated that the total Indian GHG emissions in 2020, if the energy intensity was to stay at 2007 levels, would be 4,270 metric tonnes (MT) CO_2-eq, but that these could be brought down to 3,537 and 3,071 MT under the 'determined' and 'aggressive' scenarios, respectively. A few sectors – buildings, power generation and industry – together account for well over half of the total identified mitigation potential in the country for the 2020 time period. The key areas of technology focus for mitigation are power generation and consumption, transport (especially freight), residential, and selected major industrial sectors. This would require enhancing efficiency in the generation of

Table 3:
Projected green house gas emissions for India in 2020 (MT CO_2-eq.)

Sl.	Growth Scenarios	2007 Emissions	2020 with 8% GDP Growth	
	Higher & Lower Ends of the Range		Determined Effort	Aggressive Effort
1	GDP (1990-00 prices) Rs. Billion	30.619	83,273	83,273
2	CHG Emissions (MT CO_2-eq)#	1,570	3,537	3,071
	a. Power Plus Building Code	598	1,428 1,368	1,263 1,141
	b. Transport	142	435	413
	c. Industry i. Iron and Steel ii. Cement iii. Oil and Gas iv. Other Industries	478 117 130 55 176	1,167 406 336 125 300	1,009 360 294 115 240
	d. Other Household Energy	173	261	235
	e. Waste Management	58	163	146
	f. Miscellaneous	121	143	126
3	Emission at 2007 levels	1,570	4,270	4,270
4	Emission Intensity (grams CO_2-eq/Rs. GDP)	51.28	42.47	36.87
5	Emissions per capita (TCO_2-eq/person)	1.43	2.67	2.32

(Source: Planning Commission 2010)

[8] "Interim Report of the Expert Group on Low-Carbon Strategies for Inclusive Growth," Planning Commission, New Delhi (2011).

power and improving its end-use efficiency, especially in major power-using sectors (industry, residential and commercial buildings). It would also require the deployment of renewables to help decarbonise the power sector, where non-biomass-based renewable (especially wind and solar) have particular promise. In terms of rural energy, the deployment of biomass-based or other decentralised renewable technologies potentially can help provide low-carbon energy services in rural areas.

One of the key lessons of the study is that, given the high expected growth rate of the Indian economy, much of the base (whether it be industry, buildings or power generation) is yet to be installed and therefore greenfield developments offers a significant potential for deploying low-carbon technologies. At the same time, the existing base/stock also has a large scope for improvement. Box 1 lists some of these key technologies, with further details in Annexure 2.

Box 1:
Lists some of these key technologies, with further details in Annexure 2

Power (generation):
- More efficient coal generation
  - Retrofitting existing sub-critical coal power plants
    - Economizers
    - Air pre-heaters
    - Cogeneration
  - Greenfield
    - Supercritical/ultra-supercritical coal power Integrated gasification combined cycle
- Renewables
  - Wind
    - Advanced wind turbines/components
    - Grid-control systems
    - Simulation tools for optimized wind farm planning
    - Wind power density assessment

Buildings:
- More efficient appliances
  - Household
    - Fans (motors, blade design)
    - Lighting (LED-based lighting systems)
    - Refrigerators (compressors, insulation, design)
    - Air-conditioners (compressors, design)
  - Commercial
    - Innovative air-conditioning (hydrate slurry ac)
    - Lighting systems
- Building Integrated Management Systems
- High-reflectivity paints and windows

Industry (steel):
- Raw material processing
  - Pulverized coal injection
  - Coal-beneficiation technologies
  - Next-generation coke-making technologies
  - Sintering machine cooler waste heat recovery
- Improved core technologies
  - Smelt-reduction technologies (COREX. FINEX)
  - Continuous casting; integrated casting & rolling; cold-rolling..
  - DC arc technology (EAFs)
- Energy recovery and conservation
  - Top-pressure turbine
  - Coke dry quenching
  - Waste-heat recovery
  - Automated monitoring and process optimization

Industry (cement):
- Waste heat recovery
  - Co-generation
  - Low-pressure waster heat recovery
- Cement formulation
  - Low-carbon cement
  - Pre-blending processing technologies (increased blending percentage)

Beyond Technology Identification

Successful deployment of the kinds of technologies identified above requires a more sophisticated understanding of the nature of these technologies and what might be needed to facilitate their uptake. In terms of better characterising technologies and their characteristics, we suggest the following taxonomy could be useful by providing some guidance for the kinds of technology development/modification activities that might be needed:

Directly-deployable technologies and products

In many cases, technologies/products do not need to be significantly modified or redesigned and, therefore, their deployment is relatively simple, in technical terms at least. In some cases, the deployment of this technology may involve transport of assembled goods or local assembly of imported parts, although in countries with relatively large markets, firms may often even engage in local sourcing of parts (but implementing original design specifications) as a way to reduce costs. Examples include automobiles, high-efficiency turbines and motors as well as household electronics.

Existing technologies and products needing adaptation

In most cases, some (or significant) product modification or redesign is needed for the technology/product to be usable in the local context or markets. Such modifications may be carried out locally or with the help of the original equipment manufacturer. Examples of this include boilers that may need to be tailored to local coal characteristics and/or ambient conditions, 'green' or 'climate-proofed' building designs that need to take into account local climatic conditions as well as use patterns by occupants, or appliances such as air-conditioners or refrigerators, where the compressor and other components may need some changes in order to perform suitably in local conditions.

"Undeveloped/under-developed" technologies for local needs

In many developing countries, there are a range of technologies and product needs that are "local", that is, they meet needs that are particular to these countries and/or are locally developed. Often, global technology markets do not develop products for such consumers, even though cumulatively this group's needs may presents a significant opportunity[9]. Thus technologies are generally outside the mainstream

[9] This is what C.K. Prahlad has referred to as the "fortune at the bottom of the pyramid." (Prahalad 2005).

global energy innovation system and, in many cases, even outside the established commercial markets in developing countries. Examples include cookstoves and other biomass-burning devices (such as ovens), small-scale biomass conversion technologies (such as biomass gasifiers for power and thermal applications and biogas digesters), and kerosene and solar lanterns. Technology development as well as deployment activities in this area remain small and fragmented.

Deployment issues and approaches

Even when a technology potentially offers improved performance in terms of efficiency, reduced GHG emissions, or quality of service delivered, its deployment in developing countries may remain limited because of a number of factors, which include economic and financial aspects of new technologies, information and risk-perception about new technologies, market organisation, infrastructure, policies, and human and institutional capabilities.

Overall, the gaps/barriers that need to be overcome for successful leveraging of the potential of GHG-mitigating technologies include[10]:

- Technology-related:
  - Low investments by firms and many governments in R&D activities and capability-building,
  - Limited focus on, and capacity for, early-stage innovation
  - Dearth of technically-skilled human resources, and lack of critical mass within organisations (especially smaller firms),
  - Lack of understanding among firms regarding scale and scope of climate challenges, user needs, climate technologies, climate technology-markets, as well as availability of technological options that could help meet climate challenges.
- Financing:
  - Paucity of available climate innovation financing, including, at the early stage, for demonstrating technologies to build user confidence, for developing products, and for scaling-up production
  - Lack of exploration of innovative financing options,
  - Inadequate financial architecture,
  - Lack of awareness amongst financial actors about climate technology options and risks.

[10] Drawn from A.D. Sagar, "Climate Innovation Centres: Advancing Innovation to meet Climate and Development Challenges, Climate Strategies, Cambridge UK (2011).

- Firm:
  - Little technical, business-operation, strategic, or analytical support for smaller firms.
- Ecosystem:
  - Limited interactions and collaborations amongst various domestic organisations (academic and government laboratories/researchers, various firms (especially small)); even more limited interactions with industrialised-country actors,
  - Little coordination among financial actors
  - Little interactions between firms (technical and financial) and policy-makers
- Market:
  - Poorly-organised and sparse markets for climate technologies,
  - Lack of understanding about potential size and nature of climate-technology markets,
  - Few systematic efforts to overcome adoption risk by early adopters or overcome other barriers for large-scale adoption.
- Policy:
  - Lack of systematic policies to develop specific climate technologies or create and sustain markets for them[11],
  - Regulations (such as lowest-cost generation option for utilities) may hinder climate technologies,
  - Financial regulations may limit investment strategies and exit strategies for investors,
  - Regulations may impede fledgling technology businesses.

Importantly, while some of these gaps and barriers are systemic, many are specific to technologies. Therefore, it should be highlighted that any programme or activity that aims to realise the potential of a new or improved climate technology must be based on an understanding of the gaps/barriers specific to each technology and set in place policies and mechanisms that eliminate or overcome these gaps/barriers. It is only through such a process that needs for climate technologies will be better understood and fulfilled. This, in fact, is the rationale underlying the concept of the Climate Innovation Centres as an institutional mechanism to identify and fill the gaps that impede the successful deployment of technologies to meet climate challenges[12].

[11] Policies such as renewable portfolio obligations and feed-in tariffs that create markets for renewable technologies help overcome this gap

[12] See A.D. Sagar, "Climate Innovation Centres: Advancing Innovation to meet Climate and Development Challenges, Climate Strategies, Cambridge UK (2011), A. D. Sagar and Bloomberg New Energy Finance, "Climate Innovation Centres: A new way to foster climate technologies in the developing world?, infoDev/World Bank: Washington, DC (2010), A. D. Sagar, C. Bremner and M. Grubb, "Climate Innovation Centres: A partnership approach to meeting energy and climate challenges," Natural Resources Forum 33: 274–284 (2009); and M. Grubb, C. Bremner, and S. Omassoli, "Low Carbon Technology Innovation and Diffusion Centres," The Carbon Trust: London (2008).

Conclusion

While it is clear that technologies will play an important role in meeting the climate challenge, the process of identifying which technologies are relevant and how might their potential be realised is complex, given the large range of technological possibilities and the difficulty of successfully deploying them at the needed scale. To our mind, this will require systematic:

- Identification of technology needs by sector and by actor (for example, size of operations). The latter is important since actors, for example, firms of different sizes may have very different technology needs. We should also recognise that we need to pay special attention to adaptation technologies since much of the conversation in the climate arena continues to be dominated by mitigation.
- Prioritisation of technologies since the opportunities exceed resources and capacity. Here we also need to incorporate broader developmental considerations (energy access, employment, food security, etc.) into the calculus.
- Understanding of gaps to be overcome for successful deployment/scale-up and then ensuring that the climate technology programs appropriately identify ways to overcome these gaps.
- Developing systems of information collection and dissemination. Given the dynamic nature of technology, constant attention needs to be paid to technological development and advances so that there is a continuous improvement of technological systems. Meeting the climate challenge will be a long-term effort and understanding technology needs is not a one-time event but an ongoing process.

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Chapter 3

Mechanisms for International Cooperation in Research and Development in the Area of Climate Change

Carlos M. Correa

Introduction

Technology is central to addressing climate change; the development, transfer and timely diffusion of the technologies required for adaptation and mitigation constitute one of the major challenges faced by the international community. As noted by the UNFCCC Executive Secretary at the first meeting of the TEC under the UNFCCC (Bonn, 1 September 2011), there is a need for 'the development, diffusion and transfer of climate technologies on a massive scale'[1]. Technology is so essential to a global response to climate change that other efforts would be fruitless in the absence of a comprehensive and large-scale action to make technologies available and effectively deployed globally.

[1] TWN, Technology committee tussles over issue of chair, TWN Info Service on Climate Change (September11/01), Third World Network, www.twnside.org.sg, 2 September 2011.

COP 16 of the UNFCCC created a 'Technology Mechanism' and defined a number of priority areas for enhanced action on technology development and transfer[2]. Paragraph 10 of the decisions adopted on the outcome of the work of the AWG-LCA defined as one of such actions:

(a) [the] [D]evelopment and enhancement of endogenous capacities and technologies of developing country Parties, *including cooperative research, development and demonstration programmes;* (emphasis added).

In addition, one of the functions of the established 'Climate Technology Network' is to:

(b) Stimulate and encourage, through collaboration with the private sector, public institutions, academia and research institutions, the development and transfer of existing and emerging environmentally sound technologies, as well as opportunities for North/South, South/South and triangular technology cooperation;

These elements in the Cancun negotiated text reflect the importance attributed by the Parties to the UNFCCC, particularly by developing countries, to the implementation of effective cooperative mechanisms to develop and transfer ESTs.

In fact, Article 4.1(c) of the UNFCCC stipulated the Parties' commitment to:

"[P]romote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes… in all relevant sectors, including the energy, transport, industry, agriculture, forestry and waste management sectors".

Although the issue of technological cooperation in the area of ESTs was raised on several occasions by developing countries[3], little has been achieved so far. A report by EGTT, established in the context of the UNFCC in 2001[4], observed in this regard:

"While there are a large number of climate-related international collaborative activities, a preliminary survey of the landscape indicates a number of large gaps. First, most existing initiatives are focused on enabling frameworks and facilitating deployment. Second, mitigation technologies (and within that, energy

[2] Decisions adopted by the Conference of the Parties on the Outcome of the work of the Ad Hoc Working Group on long-term Cooperative Action, FCCC/CP/2010/7/Add.1, .available at http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=2.
[3] See, for example Decision 4/CP.7, 2001, paragraph 14(c), which urged all the Parties 'to promote joint research and development programmes, as appropriate, both bilaterally and multilaterally".
[4] The COP decided to terminate the mandate of the EGTT at the conclusion of its 16th session.

technologies) dominate; there is relatively limited focus on adaptation. Third, most of the collaborations between developed and developing countries are targeted at or take place with the major developing economies….

"One particular observation relating to technologies for both mitigation and adaptation is that, while there are many international collaborative initiatives around technologies to address climate change, many of these involve processes for identifying needs and facilitating the sharing of knowledge and experiences rather than actually undertaking collaborative R&D"[5].

Other relevant finding of the EGTT is the limited number of collaborative R&D initiatives in which least developed countries participate; not surprisingly, they are concentrated in the most advanced developing countries (notably India and China)[6].

This paper examines possible modalities of collaboration for R&D, understood as a comprehensive set of scientific studies and of activities for the generation of new processes and products and the improvement of existing ones[7]. It briefly discusses, first, the various sources of technology for adaptation to and mitigation of climate change. Second, the paper examines different elements relevant for fostering cooperation in R&D and the modalities that such cooperation may adopt, having in view experiences made in other areas of science and technology. Finally, an analysis of the cooperative model used to promote the development and diffusion of seeds in the 'green revolution' is presented, with the aim of exploring its possible applicability to the case of ESTs.

[5] Report on Options to Facilitate Collaborative Technology Research and Development. Note by the Chair of the Expert Group on Technology Transfer. United Nations Framework Convention on Climate Change (FCCC/SBSTA/2010/INF.11). Available online at: http://unfccc.int/resource/docs/2010/sbsta/eng/inf11.pdf, p. 4-5 and 26.

[6] Id., p. 27.

[7] This definition encompasses adaptive and incremental innovation as well as original developments.

Sources of Technology for Adaptation to and Mitigation of Climate Change

Countries may ensure the diffusion of technologies needed for adaptation to and mitigation of climate change through a combination of various sources: the application of technologies in the public domain (including by reverse engineering[8]), access – under licensing or other agreements – to foreign-owned technologies, and R&D leading to the implementation of new technologies. Differences in technological capacities and the range of technologies needed in different sectors are so wide that the utilisation of multiple sources of technologies seems unavoidable. Indeed, no individual country is likely to be self-sufficient in the generation of the technologies needed to address the effects of climate change.

Developing countries, in particular, may face three types of barriers in their efforts to incorporate technologies for the production and goods and services[9] suitable for adaptation to and mitigation of climate change:

Lack of skills and/or financial resources to utilise freely available technologies

Significant reductions in GHG emissions may be obtained without major technological breakthroughs, by diffusing technologies in the public domain, for instance, known techniques to improve carbon efficiency.

The public domain comprises technologies that have not been subject to IPRs, and those for which protection has expired; their use does not require any permission or compensation[10].

However, the effective use of production technologies, even if freely available, requires technical capabilities (which may often be supplied by consultancy and engineering firms) and investment. The fact that a technology is in the 'public domain' does not mean that it will be applied widely or without difficulty. Technological learning is neither automatic nor free of cost. In many cases, incorporating new technologies requires plant layout changes, purchase of equipment, adaptation to local raw materials and conditions, and training of personnel. Many developing

[8] 'Reverse engineering' consists of the evaluation of the technological features, function and operation of a device, object, or system in order to replicate it. Often the outcome of this process entails improvements on the evaluated matter.
[9] The adoption/consumption by final users of such products and services also faces a series of problems (for example, higher cost vis-à-vis conventional solutions, reliability, etc.) that may be addressed with various policies (for example, tax exemptions, subsidies). This paper does not address this set of issues.
[10] Secret know-how is not part of the public domain, since it is protected as 'undisclosed information', one of the categories of IPRs in accordance with Articles 2 and 39 of the TRIPS Agreement.

countries lack a broad pool of skilled personnel or the financial resources necessary to ensure the utilisation of ESTs even if in the public domain. This problem may be addressed through national measures and through international cooperation.

Reluctance to or onerous conditions for the transfer of technologies

Despite the role played by the public sector in the development of technologies relevant to address climate change, a large portion of ESTs is covered by IPRs[11]. Patenting has significantly grown in the last decade, particularly in solar photovoltaic (PV) and wind technologies; six countries – Japan, the USA, Germany, Korea, France and the UK – are the source of almost 80 percent of all patented innovations in the field of 'clean energy technologies' (CETs), including solar PV, geothermal, wind, and carbon capture[12]. In accordance with a recent survey, large conglomerates are starting to play an increasing role in the clean technology landscape, including smart grid/energy efficiency, lighting, electric transport, solar, energy storage, wind and water[13].

In some cases, technology owners exploit their technologies by licensing them to third parties, against payment of royalties or other forms of remuneration; in other cases, however, technology owners are reluctant to part with their technologies, particularly if potential recipients may become competitors in the local or global markets. As shown by the experience of some developing countries that were successful in catching-up processes (such as South-East Asian countries), recipients may not only absorb received technologies but improve on them and eventually enter the innovation race in competition with the original transferers of technology. This risk, which has become higher for technology owners with growing market globalisation, may lead to the outright refusal to transfer, or to transfer of only outdated or less efficient technologies, or to the demand of high prices that is a barrier for potential acquirers. Restrictive conditions (such as tying clauses, grant-back provisions, export and field of use prohibitions) may also hamper technology transfer.

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[11] This reflects both the importance of the private sector in the development of such technologies and the growing trend by public institutions to claim IPRs on their research outputs.

[12] European Patent Office, the United Nations Environment Programme and the International Centre for Trade and Sustainable Development (2010), Patents and Clean Energy: Bridging the Gap Between Evidence and Policy-making, available at http://www.unep.ch/etb/events/pdf/UNEP%20ICTSD%20EPO%20Geneva%20Trade%20&%20Development%20Symposium%201st%20December%202009.pdf.China also ranks high by the number of patent applications filed in a several fields of CETs (except carbon capture) but many patent filings are possibly made by the Chinese subsidiaries of multinational enterprises (Lee, B, Iliev, I. and Preston, F. (2009) Who Owns Our Low-Carbon Future? Intellectual Property and Energy Technologies, Chatham House, London, p. 14-15).

[13] Jefferies Group, Jefferies Survey Finds Investor Focus on Clean Technology is Becoming More Diversified, 20.4.11, available at http://www.4-traders.com/JEFFERIES-GRP-COM-13161/news/JEFFERIES-GRP-COM-Jefferies-Survey-Finds-Investor-Focus-on-Clean-Technology-is-Becoming-More-Diversi-13606192/.

Thus, in a case where an Indian company demanded the transfer of technology from a transnational corporation producer of HFC 134A, an ozone-depleting substance (ODS) substitute, the required price was more than 10 times what was deemed reasonable by the Indian company. Other options suggested by the supplier were a joint venture with a majority stake or export restrictions on HFC 134a produced in India[14]. Similarly, Indian firms found difficulties in their attempts to acquire fire-extinguishing technology: the owners of the patent did not accept licensing of the technology to wholly domestically owned companies, but only to joint ventures with a majority shareholding[15]. In China, it was found that, on average, Chinese companies pay high licensing fees for the use of the technology for the domestic market and even higher royalty rates often apply on exports. Local innovation is discouraged by contractual provisions limiting the freedom to undertake and exploit the results of licensees' R&D activities[16].

Other studies reported similar situations:

In a study of wind power industry development strategies in India, China and Spain, Lewis (2006) found that developing country manufacturers often have to obtain technology from second- or third-tier wind power companies. This is because leading manufacturers are less inclined to license to would-be competitors. Lewis notes that the technologies obtained from the smaller companies may not necessarily be inferior to those provided by the larger manufacturers, but such smaller companies have substantially less operational experience. The Energy and Resources Institute (2009) cites examples [in India, China, Indonesia, Malaysia and Thailand] in which local companies have terminated negotiations with licensors due to high royalty fees for licences or have incurred additional costs buying non-related equipment before accessing the desired technology[17].

The need for developing countries to get access to foreign-owned technologies (overwhelmingly held by private and public entities in developed countries) was already recognised by the UNFCCC, which in Article 4.5 included, among the commitments of the developed country Parties and other developed Parties listed in Annex II, the obligation to 'take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound

[14] Jayashree Watal (1998), "The issue of technology transfer in the context of the Montreal Protocol: case study of India", in Veena Jha and Ulrich Hoffmann (Eds.), Achieving Objectives of Multilateral Environmental Agreements: a Package of Trade Measures and Positive Measures. Elucidated by Results of Developing Country Case Studies, UNCTAD/ITCD/TED/6, Geneva, p. 50.

[15] Id., p. 51.

[16] Zhuang Wei, 'Intellectual Property Rights and Transfer of Clean Energy Technologies', in Kierkegaard Sylvia, Law Across Nations: Governance, Policy & Statutes, International Association of IT Lawyers, 2011.

[17] UNEP, EPO, ICTSD (2010), Patents and clean energy: bridging the gap between evidence and policy. Final report, available at http://ictsd.org/downloads/2010/09/study-patents-and-clean-energy_159101.pdf, p. 21.

technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention'. Little has actually been done so far to effectively implement this provision.

Asymmetries in R&D capabilities

Domestic R&D capacity is not only necessary to develop new technologies and provide local solutions to local problems, but also to scrutinise scientific and technological developments that take place elsewhere and to generate capacity to absorb and adapt foreign technologies. This dual role is critical for technologies relevant to climate change, largely held by entities from developed countries. An R&D capacity permits institutions and companies to screen how the scientific and technological frontier evolves. They may, through 'gate keeping' activities, benefit from technology spill-overs and choose possible partners for cooperation. "Gate keeping" refers to a permanent search for new sources of innovation, either within or outside the firm. It requires special skills in order to identify new sources of core information, and interpret and assimilate it[18].

Developing countries account for a growing but still minor proportion of global R&D[19]. North America accounts for more than one-third (35 percent), Europe for more than one-fourth (27.2 percent) and Japan for 13.2 percent (total 75.4 percent) of global R&D expenditures[20]. The OECD countries account for 78 percent[21]. Asia (without Japan) accounted for 19 percent[22], and Latin America (2.4 percent)[23], the Near and Middle East (1.2 percent) and Africa (0.7 percent).[24]

Thus, developing countries, excluding China, only account for around 10 percent of global R&D expenditures[25]. Although this share is much higher than the estimated share (4 percent) for such countries 20 years ago[26]; the world distribution of R&D is indicative of one the most dramatic North-South asymmetries[27].

[18] Faulkner, W., (1992), Understanding industry-academic research linkages: towards an appropriate conceptualisation and methodology, University of Edinburgh, Edinburgh.
[19] Defined in accordance with the OECD's Frascati Manual (OECD, The Measurement of Scientific and Technological Activities. Frascati Manual. Proposed Standard Practice for Surveys on Research and Experimental Development, 2002, Paris).
[20] Jacques Gaillard, 'Measuring Research and Development in Developing Countries: Main Characteristics and Implications for the Frascati Manual', Science, Technology & Society 15:1 (2010): 77–111, p. 95
[21] Id. p. 96.
[22] 11.8 percent corresponds to China alone.
[23] 1.3 percent corresponds to Brazil alone.
[24] 0.5 percent corresponds to South Africa alone.
[25] While R&D investments in the USA, Europe and Japan are generally between 1.5 percent and 3 percent of GDP, most developing countries invest much less than 1 percent of GDP in R&D. See Gaillard, op. cit. p. 96.
[26] Jean-Jacques Salomon, Francisco R. Sagasti and C. Sachs-Jeantet (editors), The Uncertain Quest: Science, Technology, and Development, United Nations University Press, The United Nations University, 1994,
available at http://archive.unu.edu/unupress/unupbooks/uu09ue/uu09ue0d.htm.
[27] In comparison, developing countries account for around 45 percent of world exports.

This is despite the fact that developing countries as a whole have performed well in the last decade in terms of consolidation of an R&D basis (see Box 2).

Box 2:
Expansion of R&D capacities in developing countries

The number of researchers in developing countries jumped from 1.8 million to 2.7 million over 2000-2007. The surge in researcher numbers means that the developing world employed 30 percent of researchers in 2002 but 38 percent by 2007. However, China accounts for over half (53 percent) of researchers in developing countries. In the 50 least developed countries (defined according to the standard UN classification), there was an average 20 percent increase in researchers.

While spending on R&D by developed countries grew by about one-third (32 percent) during 2000-2007, developing countries more than doubled their expenditures (103 percent), from US$ 135 to US$ 274 billion. This figure falls, however, to a less than three-quarters increase (73 percent) if China and India are removed from the calculation.

Total spending on R&D by developing countries accounted for 1 percent of their GDP in 2007, up from 0.8 percent in 2002. This compares with 2.3 percent for the developed world.

Source: Ochieng' Ogodo, 'Poor countries spending more on science', Scidev Net, available at http://www.scidev.net/en/news/poor-countries-spending-more-on-science-.html.

A number of features characterise R&D in developing countries:

- Governments have traditionally provided the principal funding for R&D; however, new sources of funds are emerging such as foundations, NGOs and foreign organisations[28],
- The business sector performs much less R&D than the government and higher education (public) sectors, particularly in the agricultural sector[29],
- In most developing countries, R&D is focused on basic and applied research, and much less in 'development': this likely means that more 'R' than 'D' occurs'[30],

[28] UNESCO, Measuring R&D: Challenges Faced by Developing Countries, Paris, 2010, available at http://www.uis.unesco.org/Library/Documents/tech%205-eng.pdf, p. 7.
[29] Id. p.12.
[30] Id.

- Minor or incremental changes, including adaptations and improvements on existing technologies, constitute the main source of innovation in developing countries[31],
- Although the number of R&D institutions has increased rapidly during the last decades, in the majority of the developing countries the research is largely concentrated in one or very few institutions[32],
- The scientific agenda in many developing countries concentrates around the issues of interest for developed countries[33].

However, there are growing differences among the developing countries in terms of R&D capacity. Some (notably China, Brazil and India), that are more scientifically advanced than others, are starting to reap benefits from decades of investments in education, research infrastructure and manufacturing capacity. These countries – which have been called in recent literature as 'innovative developing countries' (IDCs) – invest in R&D relatively more than other developing countries, there is a greater involvement of the private sector, and the interactions between public institutions and private companies and with innovation agents in developed countries are more frequent.

These differences are evident in the area of ESTs. As noted by a recent report:

"[I]n actual fact, developing countries themselves now constitute quite a diverse group, embracing a wide range of technological capabilities. Countries such as China, India and Brazil are already playing a leading role in developing, manufacturing, deploying and exporting (including to developed countries) various green technologies (such as solar panels, wind turbines and biofuel technologies). Moreover, global value chains, which extend across developed and developing countries and represent a new global division of labour, cannot be subsumed under the traditional technology transfer paradigm based on the "provider-receiver" relationship. Instead, many developing countries are already partners in the innovation, production and deployment of green technologies. This role will likely become increasingly important and its impact more widespread in the future"[34].

[31] Expenditures on this type of innovations, as well as on reverse engineering, are not captured by the data on R&D, as defined by the Frascati Manual.
[32] Gaillard, op. cit., p. 89.
[33] Foreign support to local research, collaboration with foreign institutions and the possibility of publishing in international journals are often crucial in determining the areas of research.
[34] United Nations (2011), op. cit., p. 24.

The range of technologies suitable for being applied for adaptation to or mitigation of climate change is so vast (including in the fields of transportation, mining, agriculture, building, energy and manufacturing) and the potential for 'migration' from conventional technologies so wide, that calculating the investment in relevant R&D is a difficult task. The EGTT under the Convention estimated (as of 2009) that the global resources available for R&D, deployment, diffusion and transfer for *mitigation technologies*[35] were between US$ 77.3 and 164 billion per year[36]. The largest part of this investment, however, is accounted for by deployment and diffusion, while the private sector is the main source of financing for R&D[37].

Partial estimates for financial resources available within developing countries are shown in Table 4.

Table 4:
Estimates of current financing for development and diffusion of climate mitigation technologies, by stage of technological maturity and source (billions of US dollars per year)

	R&D (total spending	Demonstration (total spending)	Deployment (additional cost of climate technologies)		Deployment (additional cost of climate technologies)		Total
	Global	Global	Global	Developing countries	Global	Developing countries	Global
Public	6 10	Included with R&D	33 45 30	NA	19.5-27.0	8.0-15.5	55.5-82.0
Private	9.8-60	Included with R&D	NA	NA	12-22	3.3	21.8-82.0
Total	15.8-70		30-45	NA	31-.5-49	11.3-18.8	77.3-164.0

NA = not available,
Source: UNFCCC, 2009a

In accordance with the EGTT report, despite the uncertain figures, the following broad patterns of financing are clear:

(a) The financing resources for technologies for mitigation and adaptation make up only a small share (probably less than 3.5 percent) of the resources devoted globally to all technology development and transfer,

(b) Most of the financing resources (probably over 60 percent) for the development and transfer of climate technologies are provided by businesses,

[35] It was not possible to make similar estimates on technologies for adaptation, due to the absence of reliable data.
[36] UNFCCC (2009), Recommendations on future financing options for enhancing the development, deployment, diffusion and transfer of technologies under the Convention. Report by the Chair of the Expert Group on Technology Transfer, Document FCCC/SB/2009/2, UNFCCC, Bonn (summary available at http://unfccc.int/resource/docs/2009/sb/eng/02sum.pdf), p. 2.
[37] Id. p. 3.

(c) Most of the remaining resources (about 35 percent of the total) are provided by national governments,

(d) Technology development is concentrated in a few countries/regions (about 90 percent): the USA, the European Union, Japan and China,

(e) Although R&D is becoming more international, there is no international funding mechanism and there is limited coordination for such activities,

(f) Only about 10-20 percent of financing resources are used for the development and transfer of technologies to developing countries,

(g) Current financing resources need to be increased significantly[38].

Other imbalances in R&D portfolios have been observed. For instance, a study found that current investments in energy R&D by the public sector, in all industrialised countries, are heavily biased in favour of nuclear energy, to the detriment of energy efficiency research[39]. Investment in this latter area has typically been less than 10 percent of the overall public sector R&D budget in the countries of the International Energy Agency (IEA), despite the fact that energy efficiency is deemed to be the most important option for achieving significant and long-term reductions in GHG emissions (up to 50 percent of the potential reduction under different scenarios)[40].

There is a wide range of policy measures that developing countries may adopt to promote domestic R&D relating to climate change. In fact, a large variety of such measures, including subsidies, are used in developed countries. It has been noted in this regard that:

"research and development subsidies (some of which take the form of investment incentives) seem to be increasing. In the European Union, it was the third largest horizontal aid in 2005 at 5.7 billion. Many Canadian provincial officials have come to favour it as a relatively non-specific subsidy that is less likely than other types of support to attract countervailing duty complaints from the United States.... Numerous US states have tax incentives for R&D. Its popularity notwithstanding, it is likely that R&D aid exacerbates regional inequality…if we compare industrialised and developing countries, the disparity is undoubtedly wider"[41].

[38] UNFCCC, 2009, p. 4-5.
[39] Grubler A. and Riahi K., 'Do Governments have the right mix in their energy R&D portfolios?', *Carbon Management* 2010 1(1):79-87.
[40] Id.
[41] Kenneth Thomas (2007), Investment Incentives. Growing Use, Uncertain Benefits, Uneven Controls. An Exploration of Government Measures to Attract Investment, The Global Subsidies Initiative (GSI) of the International Institute for Sustainable Development (IISD) Geneva, Switzerland, available at http://www.globalsubsidies.org/files/assets/GSI_Investment_Incentives.pdf, p. 28.

In addition to the observed inequality, developing countries may face legal challenges when the progress they achieve in certain areas may alter the competitive landscape. Thus, the USA challenged the World Trade Organisation (WTO) compatibility of China's Special Fund for Wind Power Equipment Manufacturing in 2010, on the argument that subsidies were granted conditional on the use of local inputs in violation of Article 3.1(b) of the Subsidies and Countervailing Measures (SCM) Agreement and that China had failed to notify the WTO of these measures[42]. Accordingly to the United States Trade Representative, Trade Representative (USTR), the fund provided grants to those Chinese wind turbine manufacturers that used locally-produced input rather than foreign imports... Individual grants had ranged from US$ 6 to 22 million, with several hundred million dollars being spent since the inception of the programme in 2008[43]. In June 2011, China notified that it had decided to formally revoke the legal measure that had created that programme[44].

[42] See US Proclaims Victory in Wind Power Case; China Ends Challenged Subsidies, *Bridges Weekly Trade News Digest,* 15: 21, (8 June 2011).
[43] Id.
[44] Id.

Cooperation in R&D

As noted above, despite the commitment originally contained in Article 4.1(c) of the UNFCCC and the perceived need of massive investments in R&D, deployment and diffusion of technologies[45], little has been achieved in the area of technological cooperation, particularly in relation to the development of adaptation technologies. As noted in a recent report: "[A] sustained scaling up and reform in international cooperation and finance are required to achieve the global technological revolution"[46]. Given the limitations of technology transfer from developed countries, and the need for a global effort to generate new technologies, developing countries must participate in the creation, transfer and diffusion of new technologies suitable to their conditions and development objectives. The UN report quoted above has noted that:

"The required greater international cooperation… must encompass greater cooperation between developed and developing countries. During previous technological revolutions, beginning with the first industrial revolution, the role of developing countries was a limited one. Mainly, they were relegated to the status of colonies supplying material resources and providing captive markets. Based on their historical role, these countries continue, generally, to be viewed primarily as receivers of the technologies produced in developed countries. However, if the technology revolution for a green economy is to be successful, developing countries will need to be true partners in developing, utilising and generally sharing the new technologies."

Despite the weaknesses and asymmetries in R&D capabilities in developing countries mentioned above, there is great potential for cooperation among developing countries and between them and developed countries. Several possible models for such cooperation exist. They can be categorised in accordance with a number of features, such as:

- Whether they are 'pull' or 'push' mechanisms, based on incentives that operate on demand (for example, advance purchase contracts) or on supply (for example, subsidies for research),
- The type of R&D to be conducted (such as basic or applied research, development of pre-competitive or competitive technologies),

[45] The EGTT report estimated that 'current financing for mitigation technologies needs to increase by US$ 262.670 billion annually until 2030 (to a total of US$ 332.835 billion annually)' (UNFCCC, 20009, p. 3).
[46] United Nations (2011), World Economic and Social Survey 2011, The Great Green Technological Transformation, E/2011/50/Rev. 1-ST/ESA/333, New York, 2011, p. xix.

- The thematic fields selected for R&D,
- The type of cooperating parties (public, private, mixed),
- The policies regarding the generation and availability of R&D results for utilisation or further research (intellectual property issues),
- The organisational structure of the R&D activities.

These aspects are briefly explored in more detail below.

Push-pull mechanisms

The use of push and pull mechanisms to promote technological development critically depends on the kind of outputs sought (scientific knowledge, prototypes, etc.) and on the prospective market for new products. Pull mechanisms are particularly suited to overcome insufficient markets, which they may help to create or secure. Push mechanisms, such as subsidies, essentially aim at reducing the cost or risk of R&D[47].

An example of a 'pull' mechanism is the offer of a prize that may be awarded for reaching specified results (for example, a product with certain characteristics) or some defined milestones in the R&D process. One advantage of this mechanism vis-à-vis the conventional 'push' incentives, is that the prize is only paid when success has been achieved. So far, prizes have been successful in encouraging mechanical inventions, electronic systems, and engineering; they have also been proposed to encourage the development of health products needed to address diseases prevailing in developing countries. This is the case, for instance, of the Health Impact Fund (HIF)[48]. Some non-profit and for-profit organisations have experimented in recent years with this approach.[49]

Another 'pull' mechanism is the 'advance market commitment', which has also been broadly discussed to overcome market failures in health. For instance, in 2009, a pilot project was launched:

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[47] It is worth noting that there has been considerable scholarly debate on whether innovation is primary driven by market demand (that is market needs) or by technological shifts (for example, changes in technology). See, for example, Chidamber, Shyam R.1; Kon, Henry (1994) ,'A research retrospective of innovation inception and success: the technology-push, demand-pull question', *International Journal of Technology Management*, 9:1, p. 94-112.

[48] See Aidan Hollis and Thomas (lead authors) (2008), The Health Impact Fund: Making New Medicines Accessible to All, available at,http://www.yale.edu/macmillan/igh/hif_book.pdf.

[49] For instance, the X PRIZE Foundation is an educational nonprofit organisation 'whose mission is to bring about radical breakthroughs for the benefit of humanity, thereby inspiring the formation of new industries and there vitalisation of markets that are currently stuck due to existing failures or a commonly held belief that a solution is not possible' (see http://www.xprize.org/about/who-we-are); Innocentive is a private company that organises prize competition for clients to find technological solutions; currently, for instance, a prize of US$ 100,000 is offered to find 'solutions for a transformative and sophisticated insulin drug for patients with diabetes, to improve glucose control, decrease or eliminate the need to test or monitor blood glucose levels, and reduce their chances of short- and long-term diabetic complications' (https://www.innocentive.com/ar/challenge/9932818).

"to supply 2 billion doses of pneumococcal vaccine by 2030, potentially averting 7 million childhood deaths. The pilot is useful for this vaccine in particular because versions of the vaccine effective against the virus form circulating in the developing world will soon be ready and may attract more than one supplier. The funding for this pilot project is a cooperative effort among many international stakeholders, including the governments of Canada, Italy, Norway, Russia, and the UK. Other parties are the Bill & Melinda Gates Foundation, the World Bank, the GAVI Alliance, and UNICEF"[50].

Type of R&D

Regarding the type of R&D, there is potential for cooperation in basic research and in different forms of applied research and technological development. The funding and organisational structure of such cooperation will significantly vary, however, depending on what their specific object is.

While there is a considerable tradition of scientific cooperation between North-North, North-South and South-South, there is much less in the technological arena. Unlike in the case of technologies, non-appropriable, public goods are typically created through scientific research, thus avoiding tensions and possible rivalry[51]. In addition, as noted, many developing countries have emphasised scientific rather than technological research, often under the assumption that there is a linearity between science and technology, that is, that investment in science will naturally lead to progress in the field of technology. This assumption has proven, however, to lead to an incorrect understanding of the dynamics of the innovation process[52].

Scientific cooperation in climate change-related areas is not only desirable but needed to avoid unnecessary duplication, and to share skills and resources to address difficult issues, especially those demanding an interdisciplinary approach.

Technological cooperation generally requires a more complex governance structure than that centred on science. Since the main locus of technological innovation is the firm, such cooperation is generally sought to enhance the competitive advantages of the cooperating parties. However, public sector entities also play an important role in the development of ESTs.

[50] See http://ghtcoalition.org/incentives-pull.php.

[51] This does not mean, however, that rivalry and conflicts do not exist; in many cases, there is tough competition among scientific research teams to be the first to arrive at a discovery leading to prestige and eventually more funding for further research. See, for example, Paula Stephan, (1996), "The Economics of Science", *Journal of Economic Literature*, vol. XXXIV.

[52] See, for example, Benoît Godin (2006), 'The Linear Model of Innovation. The Historical Construction of an Analytical Framework', *Science Technology Human Values*, 31:6, p. 639-667.

A key determinant of the modalities of cooperation is whether the technology to be developed is such that it would create a pre-competitive platform for the further development of more specific technologies, or whether the latter is the case. The way in which the relationship between the cooperating parties are organised is crucial for technological cooperation. Four aspects are crucial:

1. The orientation or common predisposition to work together, whether this may involve taking advantage of or sharing an asset (generating economies of scale) or taking advantage of complementarity,
2. Dependence, deriving from the fact of different organisations working together,
3. The link which, in some way, is a measure of connection (albeit unspecified) between the parties which interact,
4. The investments made by the parties, which will determine the future obligation of the relation, and which normally materialise in the form of people and time[53].

Such cooperation may be crucial for developing countries in the area of climate change-related technologies. Development is generally more costly than research, except when it focuses on incremental changes or adaptations; the pooling of funds and human resources may be the only option for developing countries to undertake large-scale or complex technological projects.

Typical objectives of technological collaborations are sharing limited resources, minimising costs, reducing risks and achieving economies of scale and/or rationalisation. However, they may be more strategic in nature and seek a number of indirect effects, such as strengthening the partners' capacity to undertake R&D as well as keeping open options that may have be foreclosed in the absence of the cooperation. For this reason, the mere cost-benefit analysis of a strategic alliance based on inputs-outputs may be inadequate[54].

Technological cooperation may, among other advantages, shorten research duration, reduce transaction costs, make it possible to reach the critical threshold necessary for undertaking large-scale projects, and spread a new technology more rapidly[55].

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[53] See Nieves Arranz and Juan C. Fdez. deArroyabe (2009), 'Technological Cooperation: a New Type of Relations in the Progress of National Innovation Systems', The Innovation Journal: *The Public Sector Innovation Journal,* 14:2, p. 5., who quote Johanson, J. and Mattson, L.G. (1987), "Interorganisational Relations in Industrial Systems: A Network Approach Compared with a Transaction Cost Approach". International Studies of Management Organisation, 17:1, 34-48.

[54] See, for example, Doz, Yves and Hamel, Gary (1998), Alliance Advantage. The art of creating value through partnering, Harvard Business School Press, Boston, p. 9-10 and 12.

[55] Arranz and Fdez. deArroyabe, op. cit., p. 8 (references omitted).

Finally, cooperation schemes between R&D entities may differ depending on the resources that each of the partners bring thereto. They may be classified as:

- 'Symmetrical' when partners bring together similar resources to generate economies of scale, rationalise capacity, transfer knowledge, or share risk,
- 'Complementary' where partners contribute different assets and build on their respective strengths and advantages.

Thematic fields

Establishing the themes for scientific and technological cooperation is one of the greatest challenges from a technical, economic and political point of view. R&D is subject to different levels of risks (the highest for basic science, the lowest for incremental technological developments) and, in view of limited resources, choosing the targets to be achieved is a challenging task. The rationale for such choices in the private and public sectors would normally differ substantially. As noted above, the private sector accounts for a great portion of investment in R&D; as a consequence, a large part of resources will be oriented by the expectation of profit gains. The extent to which the public sector may influence (through incentives of different type) the patterns of private R&D is an open question.

According to UNFCCC Secretariat:

"further research on carbon capture and storage, hydrogen and fuel cells, biofuels, power storage systems and micro-generation, clean energy technologies, early warning systems for extreme weather events and biotechnology will also be required – which will in turn require a range of government support packages"[56].

The UNFCCC Secretariat also noted that:

"Many developing countries have undertaken detailed assessments of their technology needs. A synthesis of technology needs in 69 developing countries was prepared in 2009….The most commonly identified technology needs for mitigation were renewable energy technologies, technologies for improved crop management, energy-efficient appliances, waste management technologies, forestry-related technologies and more clean and efficient vehicles. The most commonly identified technology needs for adaptation were related to crop management, efficient water

[56] UNFCCC (2009), Second synthesis report on technology needs identified by Parties not included in Annex I to the Convention. Note by the secretariat, Document FCCC/SBSTA/2009/INF.1, UNFCCC: Bonn, available at http://unfccc.int/resource/docs/2009/sbsta/eng/inf01.pdf (references omitted).

use, improving irrigation systems, technologies for afforestation and reforestation, and technologies to protect against and accommodate rises in sea level"[57].

On the other hand, the EGTT report mentioned above found a "'weak coverage on technologies for adaptation" and that:

"the portfolio of existing R&D programmes are strongly focused on energy technologies, in particular on renewable energy. There are far fewer collaborative R&D activities in industry, transport and energy efficiency in buildings, and forestry, agriculture and waste are covered only within more general programmes"[58].

Type of cooperating parties

Technological cooperation may involve different parties both from the public and private sectors. There are abundant examples of public-private cooperation in various fields for the development of technologies and in scientific research. Governments in developed and many developing countries have made significant efforts to promote such cooperation through direct incentives and by giving private partners the right to assert IPRs emerging from cooperative activities[59]. A large number of public-private partnerships (PPPs) have been established, for instance, with the objective of developing drugs and vaccines. One example is the TB Alliance financed by public agencies and private foundations which, in association with research institutes and private pharmaceutical companies, aims at developing novel treatments for tuberculosis that are affordable and accessible to the developing world[60]. PPPs commonly use some private sector approaches to address R&D challenges; their primary objective is public health rather than a commercial goal; and their principal funders are foundations rather than governments[61]. This latter feature raises concerns about the long-term viability of these initiatives.

The Asia-Pacific Partnership on Clean Development & Climate, established in 2005 by Australia, Canada, India, Japan, the People's Republic of China, South Korea and the United States, is an example of governmental cooperation to accelerate the development and deployment of CETs. The objectives of the Partnership are to:

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[57] Id. (references omitted).
[58] UNFCCC, 20009, p. 26.
[59] The model adopted by the US Bayh-Dole Act has influenced policy making in many developing countries, such as South Africa, Malaysia and India. See, for example, Anthony D. So, Bhaven N. Sampat, Arti K. Rai, Robert Cook-Deegan, Jerome H. Reichman, Robert Weissman and Amy Kapczynski, 'Is Bayh-Dole Good for Developing Countries? Lessons from the US Experience', *Plos Biology*, 6(10): e262, available at http://www.plosbiology.org/article/info:doi/10.1371/journal.pbio.0060262.
[60] See www.tballiance.org/.
[61] See Report of The Commission on Intellectual Property Rights, Innovation and Public Health (CIPIH) (2006), WHO, Geneva, p. 72.

- Create a voluntary, non-legally binding framework for international cooperation to facilitate the development, diffusion, deployment, and transfer of existing, emerging and longer-term cost-effective, cleaner, more efficient technologies and practices among the Partners through concrete and substantial cooperation so as to achieve practical results,
- Promote and create enabling environments to assist in such efforts,
- Facilitate attainment of our respective national pollution reduction, energy security and climate change objectives,
- Provide a forum for exploring the Partners' respective policy approaches relevant to addressing interlinked development, energy, environment, and climate change issues within the context of clean development goals, and for sharing experiences in developing and implementing respective national development and energy strategies[62].

The areas identified for cooperative work include cleaner fossil energy, renewable energy and distributed generation, power generation and transmission, steel, aluminium, cement, coalmining, buildings and appliances[63].

Policies regarding availability of R&D results and IPRs

R&D creates intangibles that, by their very nature, are public goods, that is, goods that are non-rival and non-excludable[64]. Non-rival goods have the property that they can be available for public use[65]. Knowledge may become excludable by action of its possessor (limitations to access, secrecy) or by legal means (for example, patent protection).

Technological cooperation may be based on different models regarding the appropriability of the results obtained. They may include the generation of results for which IPRs are not claimed or asserted, that is, they remain freely available without prior authorisation or compensation. Such results, however, may be protected by IPRs, such as patents, and their utilisation by third parties subject to different conditions such as:

- Licensing agreements with payment of a compensation,

[62] See http://www.asiapacificpartnership.org/english/about.aspx.
[63] Id.
[64] See, for example, Joseph Stiglitz (1999), "Knowledge as a global public good", Kaul, Inged; Grunberg, Isabelle and Stern, Marc, (Eds.), Global public Goods. International Cooperation in the 21st Century, New York, p. 309.
[65] Once knowledge has been created, its use by one agent does not reduce the amount or quality of the knowledge available for use by others.

- Licensing agreements without compensation or with special conditions for utilisation by certain categories of parties, in certain countries or for specific purposes.

An example of a cooperative R&D arrangement designed to produce freely available R&D results is the case of CGIAR which will be reviewed in more detail below.

The negotiation of licensing agreements with payment of a compensation could be necessary to recover R&D costs and to finance further R&D, and to avoid 'free riding' by others. Many public R&D institutions have adopted this approach in the last two decades. In the area of agricultural research, for instance, some institutions in developing countries started to request plant variety protection to be able to obtain compensation from private companies that utilised their improved varieties.

An example of the model based on licensing agreements without compensation or with special conditions for utilisation by certain categories of parties, in certain countries or for specific purposes, is provided by the 'humanitarian license reservation' (or equitable access license) proposed by a number of institutions and universities[66], whereby title-holders leave open the possibility of sharing their technology with third parties for the benefit of people in need. For instance, the policy statement of a US university, part of the 'Universities Allied for Essential Medicines' notes that:

"Equitable Access Licensing works by segmenting the world market – any drug developed using an upstream university innovation can remain under patent protection in countries where the pharmaceutical industry earns the vast majority of its revenue. Generic competition is allowed only in markets where there is little access – and therefore little revenue – in the first place. For any given product, then, a pharmaceutical company's bottom line remains relatively intact, and, by extension, any decrease in revenue from licensing at Penn [University of Pennsylvania) would be vanishingly small"[67].

[66] See, for example, Brewster, Amanda L., Chapman, Audrey R., Hansen Stephen (2005), 'Facilitating Humanitarian Access to Pharmaceutical and Agricultural Innovation', *Innovation Strategy Today*, 1:3 (2005), available at http://www.biodevelopments.org/innovation/ist3.pdf.

[67] Available at http://www.med.upenn.edu/uaem/issues.shtml.

Organisation of the R&D Activities

One of the most critical issues for cooperation in R&D is its organisation and governance, including funding, coordination, relationship between partners and third parties, sharing of costs and benefits, and the management[68] of the agreed upon activities.

There is a variety of models that may be applied, ranging from the conventional schemes of inter-institutional relations governed by agreements where the participants, objectives, fund allocation, tasks, etc. are defined, to the creation of a an institutionalised network of research institutions, resorting to a common pool of resources and services[69].

An interesting example of an innovative cooperative organisation for R&D is the Open Source Drug Discovery (OSDD) inspired in the Open Source model for software development and the Human Genome Project[70]. OSDD was launched by the Council of Scientific and Industrial Research (CSIR) of India:

"with a vision to provide affordable healthcare to the developing world by providing a global platform where the best minds can collaborate and collectively endeavour to solve the complex problems associated with discovering novel therapies for neglected tropical diseases like Malaria, Tuberculosis, Leshmaniasis, etc. It is a concept to collaboratively aggregate the biological and genetic information available to scientists in order to use it to hasten the discovery of drugs…The OSDD consortium launched in September 2008 has more than 4,500 registered users from more than 130 countries around the world has emerged as the largest collaborative effort in drug discovery. Launched on the three cardinal principals of Collaborate, Discover & Share, it is a community driven open innovation platform to address the unmet need research and development of drugs for diseases that affect the developing world. Its objective is affordable healthcare"[71].

[68] Although most literature on technological cooperation focuses on issues related to cooperation formation, adequate management is essential to achieve a satisfactory performance. See, for example, Chen, Hung-hsin (2003), Cooperative Performance: Factors Affecting the Performance of International Technological Cooperation, University of Manchester, Manchester.
[69] The example of the CGIAR is considered in a separate section below.
[70] See http://www.osdd.net/about-us.
[71] Id.

Photo © Shashank Jayaprasad/ UNDP India

OSDD aims at accelerating research and reducing its cost; all the projects and the research results are reported on the web-based platform http//sysborg2.osdd.net[72]. In addition, "to ensure affordability, the drugs that come out of the OSDD platform will be made available like a generic drug, without Intellectual Property encumbrances"[73].

OSDD is supported by direct funding from the Government of India of INR 46 crore (about US$ 12 million), with an overall project outlay of about US$ 46 million[74]. Although this scheme seems essentially suitable for the discovery phase of new products, the aim of the OSDD is to also undertake clinical trials if potential candidate molecules are identified, eventually in partnership with the private sector.

[72] Id.
[73] Id.
[74] Id.

The CGIAR Model[75]

Several proposals have been made to foster climate change R&D and ensure a broad availability of their results. They include the establishment of specialised international funds, such as a 'multilateral technology fund'[76], and the setting up of "regional R&D networks of existing indigenous research institutions in developing countries for climate change technology development and commercialisation that permit sharing of resources and cost for innovation infrastructure and expensive equipment"[77].

At the Delhi High Level Conference on 'Climate Change: Technology Development and Transfer', held on 23 October 2009, a proposal was made to create a network of international research institutes inspired by the CGIAR. *In accordance with* the Chair's summary of the Conference:

"The second lesson we will take away from here is what President Nasheed called a Green Power Revolution, learning from the lessons of the Green Revolution in which India led the way, with international cooperation, in the 1960s and 1970s, to address what was then the most formidable threat faced by developing countries, the threat of famine and food insecurity. Several speakers alluded to the CGIAR network as a model for addressing the challenge of climate change as well as energy poverty. As you are aware, the Green Revolution relied on an elaborate mosaic of interlocking institutions for research, education, credit, marketing, inputs provision and, most importantly, extension – getting the knowledge into the hands of those who needed it. Within 10 years we had transferred knowledge from a few hundred scientists to millions of farmers, the vast majority of whom were illiterate. The CGIAR network provided international support and cooperation in research and education (paragraph 9)"[78].

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[75] This section is partially based on Carlos Correa (2009), 'Fostering the Development and Diffusion of Technologies for Climate Change: Lessons from the CGIAR Model', ICTSD, Geneva, available at http://ictsd.org/downloads/2009/12/climate_change_technology_an_-the-_cgiar.pdf.

[76] World Economic and Social Survey 2009, p. 147, available at http://www.un.org/esa/policy/wess/wess2009files/wess09/chapter5.pdf. It has also been proposed to create an international fund to match developing country commitments to targeted climate change R&D undertaken at developing country universities and other research institutions. See Cynthia Cannady (2009), Access to Climate Change Technology by Developing Countries: A Practical Strategy, ICTSD, Issue Paper, Geneva, available at http://ictsd.org/i/publications/58385/. See also a proposal to negotiate a binding agreement to enhance access to basic science and technology by developing countries at reasonable cost, in John Barton and Keith E. Maskus (2006), 'Economic perspectives on a multilateral agreement on open access to basic science and technology', in Simon J. Evenett and Bernard M. Hoekman, eds, Economic Development and Multilateral Trade Cooperation, Basingstoke, World Bank and Palgrave MacMillan, United Kingdom.

[77] See also Cynthia Cannady (2009). Access to Climate Change Technology by Developing Countries: A Practical Strategy, ICTSD Programme on IPRs and Sustainable Development, Issue Paper 25, Geneva, available at http://ictsd.org/i/publications/58385/.

[78] Chair's Summary of the Delhi High Level Conference on 'Climate Change: Technology Development and Transfer', 23 October 2009, Available at http://moef.nic.in/downloads/public-information/Chair%27s%20summary-FINAL.pdf

A CGIAR type of global network could provide international support for research and cooperation and ensure that they become centres of excellence (paragraph 10).

The 2010 World Development Report – Development and Climate Change – has also raised the question about the CGIAR as a model for climate change[79], while a report by the Clean Energy Group and the Meridian Institute has suggested that the CGIAR's 'Challenge Programmes'[80] may provide a good model for technology sharing and cooperative research to foster open and distributed innovation[81]. Similarly, the already mentioned World Economic and Social Survey 2011 also suggested the CGIAR as an example of a successful mechanism to achieve the rapid worldwide diffusion of new technologies[82].

History

The CGIAR was born in 1971 as a result of the joint initiative of a number of international and bilateral agencies, supported by the Ford and Rockefeller Foundations. The CGIAR emerged as a loose network of international agricultural research centres that, although independently managed, worked together to create and disseminate improved plant varieties[83] in the context of what has been termed the 'Green Revolution', with the goal of alleviating hunger and poverty. Various factors decisively contributed to the establishment of the CGIAR:

a) During the 1960s, there was significant public and scientific concern about a 'Malthusian' threat of a world food crisis, that is, the risk 'that rapidly rising population in developing countries would soon outstrip the world's capacity to provide food'[84]. This was associated with a sense of urgency to address the widespread problem of hunger in developing countries.

b) Successful experiences with the development of and diffusion of high-yielding varieties, initially in Mexico, India and Pakistan, created the perception that, given the available scientific and technological tools, targeted research could be undertaken to significantly increase food production in developing countries. In particular, work by Norman Borlaug on semi-dwarf, high-yield, disease-

[79] The 2010 World Development Report- Development and Climate Change available at http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/EXTWDRS/EXTWDR2010/0,,menuPK:5287748~pagePK:64167702~piPK:64167676~theSitePK:5287741,00.html p.306

[80] See below.

[81] See Clean Energy Group and the Meridian Institute (2009), Accelerated Climate Technology Innovation Initiative (ACT II): A New Distributed Strategy to Reform the U.S. Energy Innovation System, available at http://www.cleanegroup.org/Reports/ACTII_Report_Final_November2009.pdf.

[82] United Nations (2011), p. xx.

[83] As mentioned below, the CGIAR later adopted a more holistic view of agriculture and expanded its activities to other areas of biodiversity.

[84] Warren Baum (1988), CGIAR - How it all began, A 1985 Report Reprint, available at www.worldbank.org/html/cgiar/publications/cgbaum.pdf.

resistant wheat varieties created the basis for a revolutionary transformation of agriculture, by putting improved varieties and other agricultural technologies within the reach of small farmers in those countries.

c) The constitution of the CGIAR built on the previous creation, with the support of the Ford and Rockefeller Foundations, of four international research centres specialised in particular crops: the International Rice Research Institute (IRRI) in the Philippines (rice), the Centro Internacional de Mejoramiento de Maiz y Trigo (CYMMIT) in Mexico (wheat and maize), the International Institute of Tropical Agriculture (IITA) (crops for low, humid tropics) and the Centro Internacional de Agricultura Tropical (CIAT) (tropical crops).

d) The heads of the Food and Agriculture Organization (FAO), UNDP, the World Bank, British, Canadian, Swedish and US aid organisations, were personally involved in the process leading to the creation of the CGIAR. The Asian Development Bank, the Inter-American Development Bank, and Japan's Ministry of Foreign Affairs also participated. The Ford and Rockefeller Foundations had a decisive role in this process. The World Bank offered technical advice and financial assistance and provided the secretariat to the new institution.

e) An independent Technical Advisory Committee (TAC), composed of scientists and research administrators, was created in order to define priorities and assess CGIAR's activities. TAC – replaced in 2004 by the 'Science Council' – was effective in defining the overall CGIAR research strategies. It subjected the centres to periodic and thorough evaluations, conducted by external teams of scientists and other experts. Despite the centres' independence, the extent to which they contributed to the CGIAR general mission was permanently scrutinised by a centralised unit.

f) While the main focus of the CGIAR centres has been biological research in various fields, social science played a significant role in determining their objectives and modes of operation. Gender, malnutrition, poverty, international norm setting[85], inter alia, became issues of system-wide relevance. In particular, the International Food Policy Research Institute (IFPRI), which was associated to the CGIAR in 1980, provided economic analysis for the system's operation[86].

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[85] The CGIAR has been actively involved, through the International Plant Genetic Resources Institute (IPGRI), recently renamed as Bioversity, in the design and implementation of international agreements and rules in the area of plants genetic resources for food and agriculture.

[86] Centres' staff included economists nearly since the beginning of the CGIAR. See Dana G. Dalrymple (2006), 'International Agricultural Research as a Global Public Good: Concepts, the CGIAR Experience, and Policy Issues', Journal of International Development, 20:3, pp. 347-379.

The CGIAR is a strategic partnership with 64 members that include 21 developing and 26 developed countries, four co-sponsors as well as 13 other international organisations. Most of the funding is provided by development assistance agencies of developed countries. The World Bank covers the Secretariat costs in Washington DC. The CGIAR operates a centre-driven coalition of 15 research centres[87]. The centres are international legal entities established on the basis of specific agreements with the host countries.

The CGIAR was conceived as 'a loose federation of independent centres' and not as "an organisation at all, but an arrangement for consultation"[88]. Each centre is managed by its own board, has an independent budget, and can seek funding for its own activities. While the core operations of the centres have been supported by 'unrestricted' funding (that is, not linked to specific tasks or projects), the relative weight of 'restricted' (that is, targeted) funding grew over time, possibly to the detriment of activities of global interest as opposed to those of national or regional relevance[89]. Since contributions to the CGIAR are entirely voluntary, the level of funding is one of the constant challenges faced by CGIAR's management and the centres themselves. The system, however, has been successful in securing funding for their activities, subject to the limitations found in all types of public research activities[90].

The existence of the CGIAR has permitted the centres to share resources and coordinate policies at the system level, and thereby generate economies of scale and of scope that enhance the centres' capacity to perform their missions. The centres rely on more than 8,000 scientists and staff, with activities in over 100 countries[91]. Although, at its inception, the CGIAR research focused on the diffusion of the Green Revolution (essentially through increases in the productivity of food grains), as economic and social changes took place in developing countries, its

[87] The number of centres reached 17 in the 1990s, later reduced to 15 as a result of mergers.

[88] Baum, op. cit. p. 10.

[89] In accordance with Dalrymple, this may have contributed to the CGIAR's shift from a 'science-driven' to a 'donors-driven' model leading to under-emphasis on global public goods. See Dana G. Dalrymple (2006), op. cit.

[90] The total CGIAR revenues in 2008 were US$ 553 million. They doubled the revenues obtained in 1994 (see http://www.cgiar.org/who/members/funding.html). However, in constant terms, total funding 'increased by only US$ 21million (in 2007 dollar terms) from 1995 to 2007, a rise of less than half a percent in 12 years. Furthermore, 36 percent of funding in 2007 was unrestricted as compared with 63 percent in 1995 and 100 percent in 1972. In addition, a lack of coordination among investors results in sub-optimal resource use' (CGIAR Change Steering Team, 2008,,A Revitalized CGIAR — A New Way Forward: The Integrated Reform Proposal, , Washington, DC, p. 2, available at http://www.cgiar.org/pdf/agm08/agm08_reform_proposal.pdf).

[91] See http://www.cgiar.org/who/index.html.

work expanded into areas of natural resources management, problems of the poor (including enhancing the micronutrient content of food staples) and analysis of policy and institutional issues[92]. Currently, the CGIAR mission is:

to achieve sustainable food security and reduce poverty in developing countries through scientific research and research-related activities in the fields of agriculture, forestry, fisheries, policy, and environment. The priorities of CGIAR research are defined as follows[93]:

- Reducing hunger and malnutrition by producing more and better food through genetic improvement,
- Sustaining agriculture biodiversity both in situ and ex situ,
- Promoting opportunities for economic development and through agricultural diversification and high-value commodities and products,
- Ensuring sustainable management and conservation of water, land and forests,
- Improving policies and facilitating institutional innovation[94].

The CGIAR system produces a number of global public goods[95], such as the maintenance of the world largest collection of germplasm of various crops. However, the extent to which the centres operate globally vary significantly. Although most of them function with a global reach, 'there is a tendency to emphasise one or two regions, particularly Africa'[96].

"In addition, the expansion of IPRs in different areas of biodiversity, and the growing role of the private sector in agricultural research, required the adaptation of the centres' modus operandi to a new reality. According to the Science Council:

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[92] See Science Council, An Assessment of the Impact of Agricultural Research in South Asia since the Green Revolution (2008), which reviews and assesses the large body of evidence on the impacts of agricultural research by the CGIAR and its partners in South Asia, p. xi, available at http://impact.cgiar.org/eims_search/1_dett.asp?pub_id=249792
[93] See http://www.cgiar.org/who/index.html.
[94] Idem.
[95] The concept of 'global public goods' was first used by TAC in 1997 and defined by the Science Council in 2005 as 'as data, information, and value-added information and services based on data and information that are :
- Searchable and located in repositories (electronic)
- Globally available
- Open and easily accessible to all
- Demonstrably sustainable'
- Contributing substantially to the CGIAR mission. See Science Council (2005), Consultative Group on International Agricultural Research, CGIAR Research Priorities 2005-2015. Draft, Science Council Secretariat, FAO, Rome). See also Katell Le Goulven and Selim Louafi (2008), 'Biens publics mondiaux: de la théorie à la pratique', Techniques financieres et development, No. 91, p. 20.
[96] Dana G. Dalrymple (2006), op. cit.

the centres have found, increasingly and particularly in the molecular biology area, that they need to be able to use proprietary technologies; the need for and the implementation of humanitarian licences have become much debated; biotech crops, with varying levels of statutory protection but still under the control of an increasingly consolidated international plant breeding industry, are now being grown widely in a number of developing countries; and, the System has had its first experiences of third party IP in its own biotech crops"[97].

Despite the proposal of a system wide IPRs policy elaborated in 2000[98] and the establishment of a Central Advisory Service for Intellectual Property, defining a common approach to IPRs has posed a complex challenge to the CGIAR Centres. The Genetics Resources Policy Committee (GRPC) elaborated a new proposal on the subject. In accordance with this proposal, the centres might only exceptionally seek or assert IPRs, such as when it is indispensable to ensure further development of a research result, or to get access to technologies under the control of private companies that are needed to fulfil the CGIAR mission[99].

A distinct feature of CGIAR's operation is the constant efforts made to identify and evaluate the impact of the centres' activities. According to an independent review conducted in 2008 of CGIAR's governance, scientific work and partnerships, "its research has produced high returns since its inception, with overall benefits far exceeding costs… Even under the most conservative assumptions, they far outweigh total research expenditures of US$ 7.1 billion since 1960 (expressed in 1990 dollars)"[100]. The impact of policy-oriented research has also been positively evaluated in 2007-2008 by the CGIAR's Standing Panel on Impact Assessment[101].

The CGIAR's Organization

The Chair of the CGIAR, usually a Vice President of the World Bank, is nominated by the World Bank's President and endorsed by CGIAR members. As mentioned earlier,

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[97] Science Council Secretariat (2006), CGIAR research strategies for IPG in a context of IPR. Report and Recommendations Based on Three Studies, p. 1, available at www.sciencecouncil.cgiar.org/fileadmin/.../Reports/IPR_Report_Web.pdf

[98] See GRPC (2002), Guiding Principles for the Consultative Group on International Agricultural Research Centers on Intellectual Property Relating to Genetic Resources, Report of the 11th Meeting of the GRPC for ICW2000, Appendix 3, available at http://www.cgiar.org/corecollection/docs/icw0009.pdf.

[99] See the proposal by the CGIAR Genetics Resources Policy Committee for a 'Policy of the Alliance of CGIAR Centres on Intellectual Assets', available at http://cgiar.org/pdf/grpc_25th_meeting_minutes.pdf.

[100] See http://www.cgiar.org/pdf/pub_cg_corp_folder_inserts_IMPACT_10_09.pdf. Based on the development of a counterfactual scenario of world food production without CGIAR contributions, it was found that 'world food production would be 4-5 percent lower, and developing countries would produce 7-8 percent less' and 'world grain prices would be 18-21 percent higher' (Idem).

[101] See http://impact.cgiar.org/eims_search/briefs.asp#Impact%20Assessment%20of%20Policy-Oriented%20 Research%20in%20the%20CGIAR:%20Evidence%20and%20Insights%20from%20Case%20Studies.

the World Bank facilitates the services of a professional secretariat to the CGIAR. The Director of the CGIAR acts as Chief Executive Officer and heads the CGIAR Secretariat[102]. In addition, a 'virtual' System Office was created to integrate services provided to the centres by the CGIAR Secretariat and other office units[103], including strategic planning and development, monitoring and evaluation, communication and resource mobilisation and management.

Annual General Meetings (AGMs) provided CGIAR members and stakeholders a forum for discussion about needs to be addressed, strategies and programmes. The GRPC and the Private Sector Committee were established to deal with particular issues and ensure the participation of civil society and other stakeholders in CGIAR debates and activities.

The CGIAR's organisation and programming approach has changed over time in order to adapt to changing realities and perceived needs. Two significant changes were undertaken in the last 10 years. In 2001, a 21-member Executive Council was established in order to act on behalf of the CGIAR on matters delegated to it by the Group, facilitate decision-making, provide oversight during the implementation of the Group's decisions, and ensure continuity between the AGMs. In addition, the Alliance Executive of the CGIAR centres provides support and perspective on system-wide issues and on technical and management concerns of the centres, while the Alliance Board AB makes recommendations to the individual Boards about policies, methodologies and practices. In addition, a set of 'Challenge Programmes' was established. A 'Challenge Programme' is "a time-bound, independently-governed programme of high-impact research, that targets the CGIAR goals in relation to complex issues of overwhelming global and/or regional significance, and requires partnerships among a wide range of institutions in order to deliver its products"[104]. While for some CGIAR members these programmes should have reinforced the CGIAR's role as producer of public goods (by allowing, inter alia, broader cooperation with different partners), the new CGIAR vision and strategy, as adopted in 2000, rather gave preference to a regional focus in research in order to complement and supplement the national approach[105].

[102] See http://www.cgiar.org/who/structure/executive/index.html.

[103] These units are: Central Advisory Service on Intellectual Property, Alliance Office, Gender & Diversity Programme, Media Unit, Science Council Secretariat, Internal Audit and Human Resources Unit.

[104] See http://www.cgiar.org/impact/challenge/index.html. The Programmes approved so far are: Water and Food, Harvest Plus (interdisciplinary, research to breed nutrient dense staple foods), Generation (use of molecular biology to create a new generation of plants), the Sub-Saharan Africa Challenge Program (SSA CP), Climate Change, Agriculture and Food Security" (CCAFS).

[105] See Technical Advisory Committee (2001), Regional Approach to Research for the CGIAR and its Partners. TAC Secretariat, SDR/TAC: IAR/01/09, FAO, Rome.

In December 2008, the CGIAR decided to significantly change its governance structure in order to establish a results-oriented research agenda, clarify accountability across the system, and streamline governance and programmes for greater efficiency[106]. The AGMs has been replaced by a biennial Global Conference on Agricultural Research for Development, which is intended to provide a consultation forum for stakeholders to provide input into the formulation of the CGIAR strategy. Under the new organisational model, a 'more programmatic approach than in the past' will be taken through "mega-programmes" that would 'bring CGIAR scientists and partners together to address critical issues and deliver international public goods that advance global development objectives[107]. A 'Consortium of the CGIAR Centres' and a 'CGIAR Fund' were established. The Consortium will provide a single entry point for the Fund to contract research products from the centres and partners.

The new governance structure entails significant changes for centres' operations. The new 'Consortium of the CGIAR Centres' is a new legal entity intended to unite the centres[108]. The CGIAR Fund is a new

"Multi-donor, multi-year funding mechanism set up to provide strategic financing to support priority agricultural research areas...[It] will finance Mega Programmes under the SRF [Strategy and Results Framework] for implementation by the centres and their partner institutions implementing the Programmes. It is intended to facilitate harmonisation of donor support by providing a single entry point for financing through three designated funding "windows[109]."

Can the CGIAR model be applied in the area of climate change?

The focus of the centres' research, the significant spillovers of their activities, their strong interaction with national agricultural research institutions, and their autonomy to pursue their specific missions, have been crucial for the centres' successful performance in the almost 40 years of the CGIAR's existence.

However, changing circumstances, including the broadening of the centres' mandates, the reduction in unrestricted funding, and the growing role of the private

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[106] See http://www.cgiar.org/changemanagement/index.html.
[107] Idem.
[108] Idem.
[109] See http://www.cgiar.org/exco/exco17/exco17_cgiar_fund_development.pdf.

sector in agricultural research, have required significant adjustments in the policies and organisation of the CGIAR[110].

While the CGIAR´s experience may provide useful lessons, the possibility of establishing a similar network of institutions for the coordinated development and broad diffusion, as public goods, of climate change adaptation and mitigation technologies, poses a large number of political, strategic and managerial challenges.

Science is normally more amenable to cooperative work and dissemination as a public good than technology, which generally requires adaptation to particular needs and circumstances. In an international scenario dominated by the private development and appropriation of technologies, a set of public institutions of excellence in research would be a useful mechanism to undertake a common programme of activities. Existing national institutions may welcome additional international funding, but governments may be reluctant to lose control over them[111]. Given the vast array of fields where research is needed to generate adaptation and mitigation technologies, defining a set of priorities would require scientific competence and political commitment. A mechanism of monitoring and evaluation should also be put in place. As the CGIAR experience shows, such a mechanism would be essential to define priorities, ensure an efficient utilisation of resources and to achieve the concrete results that are urgently needed.

In designing a possible international network of research institutions to work on climate change technologies, the following issues should be considered:

- Selection of participating institutions or establishment of new ones,
- Funding mechanism and plans,
- Governance of collaborating institutions and capacity to engage in joint research,
- Mechanisms to determine research priorities, distribute tasks, monitor progress and evaluate the achievement of the defined objectives,

[110] According to the CGIAR Change Steering Team, "[S]ince its inception in 1971, the CGIAR System has evolved into an increasingly complex entity, characterised by complicated governance structures. The result is a loss of efficiency due to overlaps in mandates, cumbersome monitoring and review procedures, an inability to harmonise funding and resource allocation and a lack of authority to enforce decisions. There is no mutually agreed "compact" outlining the obligations of donors and centres" (CGIAR Change Steering Team, op. cit., p.1).

[111] As noted above, the CGIAR centres are international entities that are not subject, hence, to the jurisdiction of the national government of the country where each centre was established.

- Conditions for cooperation with and use of technologies held by the private sector,
- Establishment of common policies on diffusion of research outputs and use of the IPRs system,
- Participation of developing countries´ institutions in research and means for facilitating access by developing countries to all relevant research results.

Conclusion

Technology is crucial to face the effects of climate change. The diffusion of existing technologies and the development and transfer of new ones need to be undertaken on a large scale and in the short term. The unprecedented challenge posed by climate change finds the developing countries in a phase of expansion of their R&D capacity, but with growing differences among them. While national efforts may be feasible and show positive results in the some cases, they are likely to be insufficient to provide the necessary tools that those countries need.

Since the adoption of the UNFCCC, technological cooperation has been on the agenda, but little action has been taken. There seems to be, however, an increasing recognition, at least by developing countries, that such cooperation must be effectively implemented. There are different models to do so and, understandably, delicate decisions to be made. But there are useful experiences and many options open for policy makers to put in practice what has so far remained a mere aspiration.

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Chapter 4

Climate Change, Technology and IPR

Martin Khor

Technology Transfer, Sustainable Development and Climate Change

Developing countries, to meet their objectives of mitigation of and adaptation to climate change, and move along the sustainable development pathway, need access to ESTs at affordable prices.

The central role of technology transfer to developing countries as well as the development of endogenous technology in these countries was recognised in the 1992 Rio Summit as well as in its related conventions including the UNFCCC. It was recognised that technology transfer had to be undertaken beyond the commercial arena, and that the proactive role of public policy at the national and international levels was required to enable developing countries' access to technology.

Thus, technology transfer was one of the two key "means of implementation" in Agenda 21, the other being financial resources. Chapter 34 of Agenda 21 defines ESTs comprehensively as not just individual technologies but total systems that include know-how, procedures, goods and services, equipment and organisational and managerial procedures. Thus technology transfer should also address human resource development and local capacity-building aspects of technology choices. It states the principle of the need for favourable access to and transfer of ESTs to developing countries through technology cooperation enabling transfer of technological know-how and building up of economic, technical and managerial capabilities for the efficient use and further development of transferred technology.

The UNFCCC also recognises technology development and transfer in several provisions, including Article 4.3 (developed countries shall provide financial resources including for technology transfer needed by developing countries to meet their agreed full incremental costs of implementing measures), Article 4.5 (developed countries shall take all practicable steps to facilitate and finance transfer of and access to ESTs and know-how particularly to developing countries; and shall support the development and enhancement of endogenous capacities and technologies of developing countries) and Article 4.7 (the extent to which developing countries will implement their commitments will depend on effective implementation of developed countries' commitments on financial resources and technology transfer).

Despite the recognition of the central role of technology transfer, there has been, in fact, little transfer of climate-friendly technology under the UNFCCC. This implementation gap is sought to be rectified. It was agreed under the Bali Action Plan (adopted in December 2007) that developed countries would provide technology support to developing countries in a measurable, reportable and verifiable manner. An executive committee on technology has been established under the UNFCCC to address technology transfer issues, and held its inaugural meeting in September 2011.

Technology transfer is not merely the import or purchase of machines and other hardware at commercial rates. A central aspect of technology development and transfer is the building of local capacity so that people and institutions in developing countries can design and make technologies which can be diffused into the domestic economy. As recognised in Agenda 21 (para. 34.12), a "critical mass of research and development capacity is crucial to the effective dissemination and use of environmentally sound technologies and their generation locally".

In the first phase of technological development, developing countries can go through three stages: (1) initiation stage, where technology as capital goods is imported, (2) internalisation stage, where local firms learn through imitation under a flexible IPRs regime, and (3) generation stage, where local firms and institutions innovate through their own R&D (UNCTAD, 2007).

In stage 1, the country is dependent on capital imports, some of which may be extra high in cost (those that are patented) because of the higher prices enabled by monopoly margins. In stage 2, costs may be lowered by versions produced locally. In stage 3, the local firms are able to design and make their own original products. Technology transfer may involve the purchase and acquisition of equipment; the know-how to use, maintain and repair it; the ability to make it through "emulation" or reverse engineering; to adapt it to local conditions; and eventually to design and manufacture original products. The process of technology transfer involves progressively climbing through all these aspects.

Several conditions have to be present for technology transfer and development to take place. The absence of such conditions can form barriers to technology transfer. Among the barriers that are normally listed are poor infrastructure, inadequate laws and regulations, shortage of skilled personnel, lack of finance, ignorance of technology issues, high cost of certain technology agreements, problems created by equipment suppliers, and IPRs.

IPR has become an important, and often contested, issue in the discussion on technology transfer and development. Whether IPRs constitute a barrier depends on several factors, such as whether or not the particular technology is patented, whether there are viable and cost-effective substitutes or alternatives, the degree of competition, the prices at which it is sold, and the degree of reasonableness of terms for licensing, etc.

Categories of Technologies and Their Treatment

In terms of proprietary rights, technologies and related products can be usefully placed under three categories: those that are not patented and are thus in the public domain; those that are patented; and future technologies (which are likely to come under patents unless there are new mechanisms or initiatives).

Technologies in the public domain

Some technologies are in the public domain; they are not patented or their patents have expired. According to Agenda 21 (para. 34.9), a large body of technological knowledge lies in the public domain (is not covered by patents) and there is a need for developing countries to access such technologies as well as the know-how and expertise required to use them. In this case, the main barrier to technology transfer may be lack of financial resources, and international funds should be established to enable developing countries to purchase and manufacture such technologies.

An important measure to promote sustainable development is to expand the space for technologies in the public domain, and accelerate transfer of publicly-funded technologies to developing countries. Governments in the developed countries play an important role in funding R&D programmes, many of which are implemented by the private sector. In addition, governments sponsor a range of R&D that underpins private sector investments in developing ESTs (IPCC, 2000, Chapter 3, page 95).

A UNFCCC paper surveyed government R&D funding of ESTs in the US, Canada, the UK and Korea. It found that, in most countries, governments allocated their rights (patents, copyrights, trademarks, etc.) to the recipient research institutions to a significant degree. As a result, the diffusion of climate-friendly technology would "typically be along a pathway of licensing or royalty payments rather than use without restriction in the public domain" (Sathaye, et al., 2005).

The IPCC study (2000) calls on OECD countries to direct the flow of such technology directly through their influence on the private sector or public institutes that receive funding from government for their R&D to be more active in transferring technologies to developing countries. It cites Agenda 21 (chapter 34, paragraph 34.18a) that "governments and international organisations should promote the formulation of policies and programmes for the effective transfer of environmentally sound technologies that are publicly owned or in the public domain." Products that emerge from publicly funded R&D should be placed in the public domain. Those that are partially funded should be in the public domain to the extent to which they are publicly funded.

At the international level, there can also be public funding and joint planning of R&D programmes. Products and technologies emerging from such publicly funded programmes should be placed in the public domain.

Patented technologies

For technologies that are patented, there should be an understanding that patents should not be an obstacle for developing countries to have access to them at affordable prices. Agenda 21 (para. 34.10) states that: "Consideration must be given to the role of patent protection and intellectual property rights along with an examination of their impact on the access to and transfer of environmentally sound technology, in particular to developing countries, as well as to further exploring efficiently the concept of assured access for developing countries to environmentally sound technology in its relation to proprietary rights with a view to developing effective responses to the needs of developing countries in this area." Agenda 21 (para. 34.18e) also agreed that, in the case of privately owned technologies, measures would be adopted particularly for developing countries, including developed countries providing incentives to their companies to transfer technology; purchase of patents and licenses for their transfer to developing countries; prevention of the abuse of IPRs including through compulsory licensing with compensation; providing funds for technology transfer; and developing mechanisms for technology access and transfer.

While the patent system provides incentives for innovation, it can also be a barrier to the transfer of technology to developing countries at affordable prices. There are examples of developing countries and their firms being hampered from adopting climate-friendly technologies or products due to patents on these products, and due to the unreasonable demands made by the patent holders on companies in developing countries that requested a voluntary license from the patent holder.

There are also various ways in which the barriers posed by IPRs can be addressed within the framework of the international patent system itself (as characterised by WTO's TRIPS Agreement) and also outside of it. Under the TRIPS Agreement, there is considerable flexibility provided to WTO Member States on grounds for issuing compulsory licenses. These grounds are not restricted, as confirmed by the WTO Ministerial Declaration on TRIPS and Public Health (WTO, 2001b). In developed countries, there have been many compulsory licenses granted by the government to facilitate cheaper products and technology in the industrial sector. In many developing countries, compulsory licenses have been issued for the import or local production of generic drugs. Thus, compulsory licensing is an option particularly when the patent-holder is unwilling to provide a voluntary license with reasonable conditions.

Some developing countries have previously proposed at the WTO that countries be allowed not to patent ESTs so that its transfer and use can be facilitated. The relaxation of the TRIPS rules in the case of climate-related technologies has also been proposed by developing countries in the UNFCCC; however, this was opposed by major developed countries. Governments can also facilitate easier access to voluntary licenses. Measures can also be taken to ensure that royalty and other conditions in voluntary licenses are fair and reasonable.

These two aspects (patents as a barrier, and methods to address this) are discussed in more detail later in this paper.

Future technologies

For technologies to be developed for future use, the nature of the funding of research and development will exert influence on the proprietary nature of the products and technologies.

In line with the goal of having as many technologies in the public domain as possible, a technology fund (or technology window in the GCF to be set up under the UNFCCC could allocate a part of its resources to R&D for new technologies. The fund can establish priority areas for research, based on the decision of UNFCCC members, and research grants can be provided to successful applicants in line with the priority areas. Since the funding is made available by the fund, the patents for the inventions are to be owned by the fund, and this principle should be one of the conditions for the grants. It can be part of the understanding in this scheme that the fund would make the inventions available to firms in developing countries with licenses at no cost or nominal cost, also on the condition that the users cannot apply to patent the technologies.

The up-front funding of innovation, linked to making the ensuing technologies available at the most affordable prices to developing countries since the latter will obtain the technologies without paying for patent royalties and since there will be free competition in the production, would be more cost-effective than the fund having to purchase the technologies (with patents attached to them) at full cost and distributing them to developing countries.

This scheme would not, of course, prevent privately funded innovation activities from taking place, and the two could co-exist. However, the larger the resources available for global publicly funded R&D activities, the larger will be the share of future technologies that will be in the public domain.

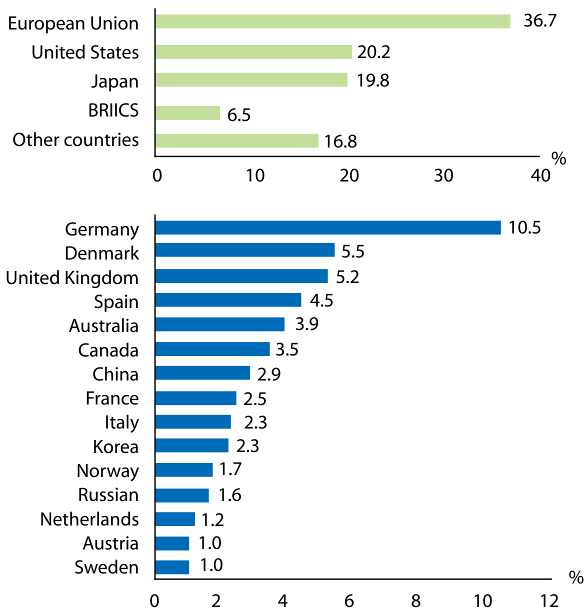
Agenda 21 also has many useful proposals and decisions, including establishment of a collaborative network of research centres, support for cooperation and assistance programmes, and building capacity for technology assessment, and collaborative arrangements. These should be revisited as part of the Rio Plus 20 process.

International collaboration for R&D (including arrangements for its financing) is an important possibility that should be explored fully. This can be within the UNFCCC context, where two important mechanisms (Finance and Technology) are now being established and operationalised. Models of collaboration (such as existed or exist in agriculture, health, etc.) should be examined to see if the lessons learnt can be adopted and adapted for the climate area.

Effects of Patents on Access to Climate-related Technologies

In relation to ESTs, there is a strong case that IPRs hinder the ability of developing countries to attain ESTs as well as new technologies in general. The great majority of patents worldwide are held by companies based in North America, Western Europe or Japan. In climate-related technologies, the developed countries also have an overwhelming share of patents worldwide. In 2005, the EU countries held 36.7 percent of patents linked to renewable energy, with the US holding 20.2 percent and Japan 19.8 percent, while China held 2.9 percent and Korea 2.3 percent (OECD 2008) (see Figure 3).

Figure 3:
Share of countries in renewable energy patents, 2005



Source: OECD (2008) as reproduced in Shashikant (2009).

A study by Lee, et. al. (2009) examined patent ownership of six energy technologies (wind, solar, photovoltaic, concentrated solar power, biomass-to-electricity, cleaner coal and carbon capture) and found that the US, Japan and Germany are clear leaders in energy innovations. The leading emerging countries such as China, Brazil and India have no companies or organisations in the top 10 position in these sectors. The study concluded that companies and institutions in the OECD countries will determine the speed of diffusion of the most advanced energy technologies in the next decade.

Another sector dominated by major developed countries is automobile pollution control technologies, which comprise technologies used to reduce pollutants produced and released into the atmosphere by automobiles (OECD, 2008) In 2005, EU (49 percent with Germany having 33 percent), Japan (31 percent) and the US (14 percent) held the highest share in patents for these technologies. Brazil, China, India, Indonesia, Russian Federation and South Africa (BRIICS) held only 0.7 percent of the patents.

In agriculture, one particular concern over IPRs is the filing of patent applications by large agrochemical and seed companies to pursue exclusive monopoly over plant gene sequences. Hundreds of patents have been applied for in relation to genes of what is termed "climate-friendly" crops that are genetically engineered to withstand environmental stress such as drought, heat, cold and floods.[1] For example, at least 261 families of patents (subsuming 1,663 patent documents) published between June 2008 to June 2010 make specific claims to confer "abiotic stress tolerance" (from drought, heat, flood, cold, salt) in plants. This patent application rush could lead to a few mega corporations monopolising genes, seeds and crops that contain them. Just six gene-related companies and their two biotech partners control 201 or 77 percent of the 261 patent families referred to. The group ETC has raised concern that this would restrict the access to germ plasm and seeds, and has called for a review of the social and environmental implications of these new varieties, and a review also of IPR laws regarding approval of "climate-related genes" (ETC Group 2010).

There are several ways in which a strong IPRs regime can hinder access of developing countries to technology, and transfer to developing countries of technology (including EST):

- Firstly, a strict IPRs regime can discourage research and innovation by local researchers in a developing country. Where most patents in the country are held by foreign inventors or corporations, local R&D can be stifled since the monopoly rights conferred by patents could restrict the research by local researchers,
- Secondly, a strict IPRs regime makes it difficult for local firms or individual researchers to develop or make use of patented technology, as this could be prohibited or expensive,
- Thirdly, should a local firm wish to make use of patented technology, it would usually have to pay significant amounts in royalty or licence fees. TRIPS increases the leverage of technology suppliers to charge a higher price for their technology.

[1] ETC Group (2010), Capturing climate genes.

Many firms in developing countries may not be able to afford the cost. Even if they could, the additional high cost could make their products unviable,

- Fourthly, even if a local firm is willing to pay the commercial rate for the use of patented technology, the patent holder can withhold permission to the firm (refusal to deal) or impose onerous conditions, thus making it impossible or extremely difficult for the technology to be used by the firm,
- Fifthly, the royalties to be paid by developing countries can be a drain on national resources and foreign exchange. For countries facing balance-of-payments constraints, this may be an acute problem. For India, net royalties and license fees paid in 2010 totalled US$ 2,309 million compared to US$ 325 million in 2002 and US$ 997 million in 2007, according to International Monetary Fund (IMF) balance-of-payments data. For developing countries as a whole (including South Korea), the payments have increased from US$ 6.8 billion in 1995 to US$ 50.6 billion in 2009.

South Centre (2009) has pointed out that since most of the IPRs on ESTs are held by firms in developed countries, this can impede the ability of developing countries to have meaningful and affordable access to these technologies. The barriers examined by this study include: (a) high royalty fees, (b) refusal to license by the patent holder, (c) "ever-greening of patents", (d) increasing patent litigation, and (e) impediments to innovation.

A well-documented case of IPRs being a barrier to transfer of climate technology is the difficulties of firms in India and Korea in obtaining the rights to producing substitutes for chlorofluorocarbons (CFCs), chemicals used in industrial processes as a coolant, which damage the atmosphere's ozone layer. This hinders their ability to meet commitments under the Montreal Protocol which tackles ozone-layer loss by phasing out the use of CFCs and other ozone-damaging substances by certain target dates.

In a study of the effect of IPRs on technology transfer in the case of India in the context of the Montreal Protocol, Watal (1998) pointed out that technology-transfer provisions in the Montreal Protocol are particularly relevant for developing countries which are producers of ODS, such as India, Brazil, China, South Korea and Mexico. In India, Korea and China, such production is dominated by local-owned firms, for which the access to ozone-friendly technology on affordable terms has become a central issue of concern. The study concludes that: "Efforts at acquiring substitute technology have not been successful as the technologies are covered by IPRs and are inaccessible either on account of the high price quoted by the technology suppliers and/or due to the conditions laid down by the suppliers. This would require domestically owned firms to give up their majority equity holding through joint ventures or to agree to export restrictions in order to gain access to the alternative technology."

Another study that also reviewed transfer of technologies for substitutes for ozone-damaging chemicals under the Montreal Protocol has provided details for some cases in which technology transfer to developing countries' firms was hindered by either high prices or other unacceptable conditions imposed by companies holding patents on the chemical substitutes onto companies in developing countries that wanted a license to manufacture the substitutes[2]. Examples include:

(a) The case of HFC-134a, a chemical used in to replace harmful CFC in refrigeration. When Indian companies requested a license from a US company owning the patent for HFC-134a, in order to manufacture the chemical, they were asked to pay a very high sum (US$ 25 million) which was far above the normal level, or to allow the US company to own a majority equity stake in a joint venture and with export restrictions on the chemical produced in India; both options were unacceptable to the Indian producers.

(b) Korean firms also faced difficulties when they wanted to replace CFCs with acceptable substitutes HFC-134a and HCFC-141b, which had been patented by foreign companies in Korea. "South Korean firms are of the opinion that the concession fees demanded by technology owners represent a lack of intention to transfer the alternative technology" (Anderson, *et. al.,* 2007 p. 262-265).

(c) The case of HFC-227ea: This chemical (known also as FM-200) is a substitute for halon-1301 for fire protection applications. The US owner of FM-200 patent requires that licensed fire protection systems satisfy certain design and inspection requirements and only three enterprises (in the US, UK, Australia) have satisfied the approvals. The patent owner offered joint ventures with majority shareholding but does not want to license the technology to wholly locally owned firms, and thus Indian firms are unable to avail themselves to this product (Anderson 2007 p. 265).

(d) Many of the technology agreements between Korean firms and their partners in Japan and the US contain restrictions such as they are not allowed to consign to a third party, to export, and that the improved technologies should be shared (Anderson 2007).

[2] Reference to these cases are in Martin Khor (2008), Note on access to technology, IPR and climate change.

Some recent studies that analysed specific sectors of climate-related technologies have also pointed out the potential for IPR protection for becoming a barrier to technology transfer. The IP holder can prevent access to the protected technology and know-how and thus prevent other firms from imitating the technology or innovating on the basis of new technologies (Ockwell, *et. al.,* 2007, pg 40)[3].

Ockwell, *et. al.* (2007) looked at Light Emitting Diode (LED) lighting[4] technology and the main barriers that India faced in the transfer of such technology. On IPRs, the study concludes: "Another barrier relates to the IPR issue associated with LED manufacturing. It is a highly protected technology. As there are various processes involved in manufacturing LED chips, each process is patented and requires huge investment. At present, the cost of investing in both chip manufacturing and resolving IPR issues is substantially high compared to importing the chips."

The study also indicates significant IPR issues faced by Indian manufacturers in biomass technology and in manufacturing hybrid vehicles since there are many patents associated with the equipment and technologies. On "biomass technology" the study found that IPR, though it is "not a very important issue" in this sector in the context of India, has created "some friction between the European and Indian manufacturers of briquetting machines" as "small-scale industries such as briquetting machine manufacturers are typically 'copycat' businesses based on reverse engineering…" The study also recognises that Europe is dominant in biomass fuel of pellets and not briquettes, thus it concludes that, "the growth of the pellet market in Europe has some implications for technology transfer to developing countries like India"[5].

On hybrid vehicles[6], Ockwell, *et. al.* (2007), found that commercially viable technologies for hybrid vehicles are held by companies in developed countries[7]. The study also found that "there may be IPR issues associated with imitating patented hybrid drive-trains" since companies such as Toyota, GM and BAE have strict patents relating to their hybrid drive-trains". Ockwell (2008) also reviewed three studies on the issue of IPRs in the context of low carbon technology transfer and concluded:

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[3] This and the following survey of recent literature on climate technology and IPRs are largely based on Shashikant 2009a (p29-31).
[4] LED is a semiconductor diode that emits light when an electric current is applied in the forward direction of the device. LEDs are widely used as indicator lights on electronic devices and increasingly in higher power applications such as flashlights and area lighting
[5] Ockwell, *et. al.* (2007), pp. 82.
[6] Hybrid vehicles are viewed by many as having a significant role to play in reduction of carbon emissions related to transport, for example, buses and private vehicles. These vehicles combine a conventional internal combustion engine with battery-driven electric motors to achieve a significant reduction in fuel consumption and thus carbon emissions.
[7] Ockwell, *et. al.* (2007), pp. 90.

"Developing country firms were generally not observed to have access to the most cutting edge technologies within the sectors examined".

A study by Barton (2007) on three sectors (solar PV, biofuels and wind technology) found that despite patents being prevalent in these sectors, competition between the various types of energy kept prices and costs relatively low. However, his study did not rule out IPRs being a possible barrier, and he warns of "serious plausible patent issues likely to arise from the new technologies" and the risk of broad patents which may complicate the development of new, more efficient or less expensive technologies, as well as anti-competitive practices if the small number of suppliers cooperate to violate competition-law principles. On Barton's study, Ockwell (2008) states: "It is notable that for all of the case studies he examines, uncertainty is expressed as to the likelihood of developing country firms gaining access to the most advanced technologies in these industries".

In the case of PV[8] technology, Barton suggests that access to the newer thin-film technologies (which is subject to much more extensive patenting than the older silicon-slice technology) is likely to be difficult. Similarly, patent holders of new methods, enzymes or micro-organisms important in the case of biofuels may be hesitant to make these technologies available to developing country firms[9]. Barton also identifies wind technologies as an area where existing industrial leaders are hesitant to share their leading technology for fear of creating competitors.

On wind technologies, Ockwell (2008) argues that only smaller companies in developed countries which are likely to gain more from licensing and lose less from competition are willing to sell licenses for use of their technologies[10]. In support, Ockwell refers to a study by Lewis on how leading wind technology manufacturers in developing countries like Suzlon (India) and Goldwin (China) acquired access to wind technology by license purchases but from second-tier developed country firms which had less to lose in terms of competition and more to gain in license fees. Leading firms in developed countries have been reluctant to license their technologies to potential developing country competitors. Lewis argued that it was a disincentive for leading companies to license to potential developing country competitors that have cheaper labour and materials available[11].

[8] A panel that produces electricity when exposed to sunlight.
[9] Ockwell (2008).
[10] This case is cited by Shashikant (2010) and South Centre (2009).
[11] Lewis, J., (2007), quoted in Ockwell (2008).

The Indian institute TERI led a study on technology transfer and climate change issues in which research institutes from five Asian countries (China, India, Indonesia, Malaysia and Thailand) participated. The study concluded that where important patents are in the hands of a few dominant players, this creates a monopolistic situation where dissemination of knowledge is restricted on account of limited access and higher prices of climate friendly technologies (TERI, 2009). A case is cited of the Chinese Yantai Integrated Coal Gasification Combined Cycle (IGCC) demonstration power plants, in which Chinese companies failed to get technology from foreign companies "due to high cost and reluctances to transfer the key technologies on the part of patent holders". After prolonged negotiations, the project was stopped.

TERI (2009) also points out that the IPRs create a barrier not only in terms of direct costs (that is, royalties or license fees) but also increased spending by the recipient company, either due to refusal of technology transfer or unreasonable conditions put in the technology transfer agreements. For instance a Malaysian company Solartif managed to get access to foreign technology only on condition of buying machines from the technology holder. The costs of acquiring technology through imports as a result of conditions in technology transfer agreements "do not get reflected as a part of IPR costs, since these are not royalties or licence fees, but are nevertheless associated with them" (TERI 2009).

A recent study (Zhuang 2011) on whether patented wind technologies have been transferred to developing countries shows how wind companies in China have faced problems relating to IPRs[12]. Citing data from Lee (2009), the study points out that Germany, the US and Japan owned around 60 percent of wind technology patents approved in 1998-2007, while Denmark, Spain, UK, France and the Netherlands together accounted for another 23 percent. China may be the largest owner of patents in emerging economies for wind technology but its share of claimed priority patents was only 1.5 percent.

The study makes the following findings:

- There has been a major boom in China in companies that manufacture wind power equipment. However, to produce a piece of complete wind power equipment, China has to buy foreign design and technologies related to core components, such as gear boxes, which generally contribute to the largest part of the price,

[12] Zhuang, Wei (2011). "Intellectual Property Rights and Transfer of Clean Energy Technologies."

- The requirements for China to access patented wind-energy technologies are also very strict. Zhuang (2011) cites a survey by Zhou, *et. al.* (2010) that, on average, Chinese companies have to pay high licensing fees for the technology and 5 percent royalties per piece of equipment when the final product is sold domestically; however, higher royalty fees usually apply when the final product incorporating foreign patent(s) is exported. Most importantly, Chinese innovation is discouraged because R&D activities relating to the patent are commonly only possible after the agreement of the licensor[13],
- Technologies transferred are not the most advanced. Because the 'unlikeliness" of leading manufacturers in the industry to license to potential competitors, studies show that developing countries manufacturers in China and India often have to obtain technology from second- or third-tier wind power companies who had less to lose in terms of international competition, and more to gain with regard to license fees[14],
- China has not acquired the corresponding technological capacities. Much wind power equipment is produced by Chinese enterprises; however, the real owners of the technologies are foreign companies and China has not acquired corresponding technological capabilities[15]. Most applicants for renewable energy-related patents have been foreign enterprise subsidiaries in China; China's top three applicants for wind power patents are all developed country enterprises. During the past 20 years, the gap in wind turbine technology between China and developed countries has not been narrowed,
- To sum up, in the wind energy sector, the innovation is still concentrated in a few developed countries and the technologies have been generally transferred to other industrialised countries. Such technologies are rarely licensed to developing nations, and then mainly to emerging countries like China. The licensees do not have the freedom to use and improve the technologies acquired. Developed country companies often refuse to transfer the advanced or key technologies. The technologies from industrialised countries are strongly protected and it is difficult for developing countries to build their own technological base.

[13] Zhou Yuanchuan, Zou Ji et Wang Ke (2010). How to conquer the IPR barriers in the low carbon technologies?, in Chinese, *Environmental Protection,* Vol 2. 2010.
[14] Lewis J. (2008). Leapfrogging in China and India, China Dialogue, http://www.chinadialogue.net/article/show/single/en/1784, visited on 27 May 2011.
[15] UNDP China 2010. China Human Development Report: 2009/10: China and a Sustainable Future: Towards a Low Carbon Economy and Society, p.41.

Shahsikant (2010)[16] also points out that opportunistic and anti-competitive lawsuits by patent owners can hamper access to climate technologies. IPR holders are known to use legal suits to preserve their market monopoly, or to place themselves in a position to be able to extract significant royalties from the opposing entity that has used or intends to use the protected technology. Syam (2010) also mentions cases where a large company that hold patents in wind energy technology prevented a European firm from entering the US market through patent litigation, until finally the European firm was acquired by the US firm. Similarly, a US firm filed a patent infringement lawsuit against a UK firm claiming infringement of five patents over seminal quantum dot technology, used in the solar power sector.

In the context of developing countries that are likely to be a focus of such litigation in the future, patent litigation or the threat of litigation may result in deterring developing country firms from investing in mitigation and adaptation technologies. Protracted lawsuits would also slow the diffusion of technologies.

Ockwell, *et., al.,* (2007) refers to a discussion with Prof. N Narendran, Director of Research, Lighting Research Center in New York, which highlighted that, "As there are a number of patents associated with each process and almost all manufacturers sue each other over patents it is really difficult to resolve IPR issues"[17]. Thus, an outcome of extensive litigation could be a disincentive to invest in innovation.

Proponents of a strong IPR regime have argued that patents boost technology transfer because the patent applicants have to disclose information on their claimed invention when submitting their application. However, in reality, there are many problems with this such as that the patent agents usually avoid including information that enables competitors to exploit the invention on patent expiry; the applicant also often omits information that allows reproduction of all embodiments; and technicians in developing countries are often without the experience needed to work the disclosed patent specifications. Moreover, during the term of the patent, the patented invention cannot be exploited by others (unless permission is obtained from the patent holder) even if the information is available (Shashikant, 2009a, p. 33).

[16] Shashikant, S. (2010). IPRs and technology transfer issues in the context of climate change.
[17] See Ockwell *et. al.* (2007), p. 69.

Possible Treatment of Patented Technologies

There are a number of measures that can be taken to address problems arising from patents becoming a barrier to the transfer of climate-related technologies.

Regulation of Voluntary Licenses

One option for facilitating the lowering of barriers posed by IPRs is to have better regulation over voluntary licenses and the terms attached to them. This could be part of national legislation. It should also be facilitated by international standards. The issues to be addressed could include a limit to the patent holders' refusal to grant a license, a reasonable rate of royalty payment (or possible exemption for developing country firms), conditions on other costs imposed on the licensee, and regulation on other conditions to be imposed on the licensee (such as limitations on the licensee's market including exports, and the ownership or rights over the innovations or modifications made by the licensee on the licensed technology). Regulation of the conditions for voluntary licenses is necessary to remedy the kinds of problems which companies in developing countries faced when trying to get a license from patent holders to produce substitutes to ozone-harmful chemicals.

Compulsory Licenses

An important measure is the exercise by governments of their right to provide compulsory licenses. Under the TRIPS Agreement, there is considerable flexibility provided to WTO Member States on the grounds for issuing compulsory licenses. These grounds are not restricted, as confirmed by the WTO Ministerial Declaration on TRIPS and Public Health (Doha, 2001). For example, and contrary to a quite widespread notion, it is not necessary for a government to declare its country is in a state of health emergency in order for it to issue a compulsory license for a pharmaceutical drug. Certainly the fact that a country requires a product or technology in order to meet its objectives or responsibilities to mitigate climate change or to adapt to climate change is a valid ground for compulsory licensing.

Compulsory licensing is not a unique or exceptional policy. In developed countries like the US and the UK, there have been many compulsory licenses granted by the government to facilitate cheaper products and technology in the industrial sector. According to Reichman (2003), "the United States government has broad powers to seize and use any invention protected by privately owned patents, subject to the payment of reasonable and entire compensation, and it makes extensive use of this power". In fact, in the US, compulsory license provisions are incorporated into specific legislation[18]. For example, the US Clean Air Act provides for compulsory licensing of patented technologies needed to meet agreed standards[19].

In many developing countries, compulsory licenses have been issued for the import or local production of generic drugs. A particular type of compulsory license, "government use", has been utilised by an increasing number of developing countries in the area of pharmaceutical drugs. In such cases, prior negotiation with the patent holder is not necessary although remuneration or royalty to the patent holder is required.

Compulsory licensing is thus an option that developing countries can consider using for those patented climate-friendly technologies for which they have need, which are expensive, and when negotiations with the patent holder are unable to result in a sufficiently affordable price either for the original product or for a license for an intended generic product.

Use of other TRIPS Flexibilities

Besides compulsory licensing, the TRIPS Agreement has several other flexibilities which can be used to promote transfer of climate-related technologies. These include parallel importation, exemptions to patentability, exceptions to patent rights, and measures to address anti-competitive behaviour. The possible use of these flexibilities is detailed in a South Centre report (2009).

WTO Declaration on Patents and Climate Technology

The Brazilian Foreign Minister, Mr. Celso Amorim, in his speech at the plenary session of the UNFCCC Bali climate conference in December 2007, stated that inspiration should be drawn from the case of TRIPS and access to medicines (which resulted in a WTO Ministerial Declaration on TRIPS and Public Health), and that a move should be considered to have a similar Declaration on TRIPS and climate-friendly technologies. Strictly speaking, it is not necessary for such a statement to be made by ministers before a country exercises rights that are already provided for in the

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[18] *The Atomic Energy Act (42 USC Sec 2183)* allows for such licensing when the patented innovation is "[u]seful in the production or utilisation of special nuclear material or atomic energy." The Atomic Energy Commission can determine whether a compulsory patent license should be granted and the reasonable royalty owed by the licensee. *The Bayh-Dole Act (42 U.S.C. Sec 7608)* permits compulsory patent licensing when a recipient of federal grants and contracts "has not taken, or is not expected to take within a reasonable time, effective steps to achieve practical application of the subject invention." The federal government can also exercise its "march-in rights" by showing that a compulsory patent license is necessary "to alleviate health or safety needs," or "to meet requirements for public use specified by Federal regulations".

[19] *The Clean Air Act (35 USC 203)* provides for compulsory patent licenses when the patented innovation is necessary to comply with the emission requirements, no reasonable alternative is available, and where non-use of the patented innovation would lead to a "lessening of competition or a tendency to create a monopoly". A district court can, with the Attorney General's assistance, determine whether a compulsory patent license should be granted and set the reasonable terms.

TRIPS Agreement to issue compulsory licenses for climate-related technologies. However, some developing countries may not be familiar enough with these rights, or they may fear that the exercise of such rights may lead to an outcry from the companies holding the patents or to penalties from the developed countries. Therefore, developing countries may find it useful that an international declaration is made, so that they would have greater confidence to issue compulsory licenses.

An important feature of the TRIPS and Public Health Declaration is that it created new rights for countries to waive a provision in the TRIPS Agreement that limits the supply of a generic product (under compulsory license) to "predominantly" in the domestic market. This restricts the volume of exports of a firm producing generics, and it also affects the adequacy of supply of generic products that a country with no or limited manufacturing capacity can import. A Declaration on TRIPS and Climate Change could establish a similar waiver to the restrictive TRIPS provision for climate-related technologies. This will enable an increase of supply of "generic" technologies and products to countries that lack capacity to produce their own products.

Details on elements of a possible Declaration are contained in a South Centre report (2009).

Legislation to facilitate easier compulsory licensing

To further facilitate compulsory licensing of climate technology, developing countries can be encouraged to introduce legislation that makes it easier to obtain compulsory licenses for certain purposes or category of products. For example, the Clean Air Act of the United States provides for compulsory licenses to be given when the patented innovation is necessary to comply with the emission requirements, when no reasonable alternative is available, and where non-use of the patented invention would lead to a "lessening of competition or a tendency to create a monopoly". Under the Act, a district court, with the Attorney General's assistance, can determine whether a compulsory license should be granted and set reasonable terms.

Shashikant (2010) also points out two other US laws that mention compulsory licensing. *The Atomic Energy Act (42 USC Sec 2183)* allows for compulsory licensing when the patented innovation is "[u]seful in the production or utilisation of special nuclear material or atomic energy." The Atomic Energy Commission can determine whether a compulsory patent license should be granted and the reasonable royalty owed by the licensee. *The Bayh-Dole Act (42 U.S.C. Sec 7608)* permits compulsory patent licensing when a recipient of federal grants and contracts "has not taken, or is not expected to take within a reasonable time, effective steps to achieve practical application of the subject invention". The federal government can also exercise its "march-in rights" by showing that a compulsory patent license is necessary "to alleviate health or safety needs," or "to meet requirements for public use specified by Federal regulations".

Exemption from patentability

Another set of proposals that is more fundamental has to do with exemptions or partial exemptions for climate-friendly technologies from patentability. Proposals along this line have already been made at the WTO for many years.

An exemption from patentability for ESTs was proposed by India at the WTO's Committee on Trade and Environment in 1996.

More recently, the Indian delegation at a climate change meeting as part of the G8-plus-5 Summit in Gleneagles, proposed as an option the redefinition of the extent of patent protection for climate-friendly technologies, so that the protection "could exclude the use of such technologies in developing countries"[20].

The above provides two options in exclusion of patents: the first is a blanket exclusion of patentability for *environmentally sound technologies,* and the second is an exclusion applied only to developing countries. In the second option, patent holders that funded their own *research and development* could recoup their innovation costs through a monopoly (for the specified period in the TRIPS Agreement) of their products in the developed countries while, in the developing countries, competition to such technologies is allowed through an exemption from patentability. An appropriate amendment of the TRIPS Agreement would be required in either case, to the effect that WTO Members (or WTO developing country members) can exempt such technologies from patentability.

Such a proposal should not be considered unrealistic. Before the adoption of the TRIPS Agreement, many countries exempted food and pharmaceutical drugs from patentability. Although the TRIPS Agreement does not allow patent exclusion on a sectoral basis, it recognises circumstances in which IPRs can be suspended. For example, Article 73 states that in situations of war or other emergency in international relations, nothing in TRIPS will be construed as preventing a Member from taking any action which it considers necessary for the protection of its essential security interests. There is a strong case for equating the climate crisis with a global emergency situation. Since climate change is an extremely serious crisis threatening human survival, and there are only a few years left for strong action to be effective in preventing catastrophic effects on human life and the environment,

[20] India paper at Gleneagles Summit, "Dealing with the threat of climate change".

the situation is similar to a global emergency with war-like conditions. In such conditions, individual commercial interests such as patents can be suspended so that there can be concerted global and national actions in the most effective way, to face the common threat. Developing countries require technologies at the cheapest possible prices. If they obtain the needed technology at one-third the price, they can increase the rate of change to put into effect mitigation and adaptation measures many times more rapidly and effectively.

This can be considered a justifiable demand if climate change is considered a serious challenge. Developed countries cannot justify business as usual in the old system while also demanding a radical departure by developing countries from business as usual in their emissions pathways[21]. Least Developed Countries (LDCs) already have some flexibility in this regard. LDCs that are members of WTO have a special transitional period for the implementation of the TRIPS Agreement.

Technology pooling through a collective global approach

A "Global Technology Pool for Climate Change" could be developed in which owners of ESTs are required to place their IPRs in a pool, and make them available to developing country firms on payment of a low compensation (in some circumstance royalty free) and on standard terms (that are to be negotiated)[22]. This approach has the potential (if fair and reasonable terms that take into account development needs are negotiated) to manage the patent system, prevent abusive practices by the IPR holder and makes it administratively and financially easier for access to take place. Similar approaches have also been advocated by various experts[23].

The nature of the pool should be mandatory in that either through law or policy (for example, a condition for receiving public funding for R&D), the protected subject matter is given to the pool for licensing to developing country firms. Patent holders would still be able to extract high commercial royalties from the far richer developed markets.

Global system to share know-how and trade secrets

Another measure requiring international cooperation is the establishment of a global system for sharing know-how and trade secrets linked to climate-friendly technologies. The withholding of "trade secrets", or the knowledge on how to make the technology, can be a major barrier to technology transfer, even for technologies that are not patented, as it can prevent the development of technology in developing

[21] TWN (2008a).
[22] TWN, (2008a)
[23] See European Patent Office, (2007), p. 95; See also Reichman (2005).

countries. Thus, there is a case for an international cooperation mechanism to make trade secrets and know-how that are linked to climate-related technologies more accessible to developing countries.

Understanding or initiatives on publicly-funded technologies

OECD countries, which hold ownership of most of the ESTs for mitigation and abatement, are in a strategic position to direct technology flows directly through their influence on the private sector or on public institutes which receive funding for R&D. That would require them to be more active in transferring technologies to developing countries[24].

Fully-owned government technologies and related know-how can be transferred at no cost and on favourable terms. Where governments partially fund R&D, they should have partial ownership of any resulting patent[25]. When a license is issued to a developing country firm, a corresponding proportion of the cost of the license should be waived, thus reducing the overall cost to the country. Incentives can also be given to entities (that are publicly funded) to make the patented technology, with its know-how, available to developing countries. It has also been proposed that to support no and low cost transfer, developed country governments should compile a "Publicly-owned Technology Inventory"[26]. As noted above, governments can also use their leverage as funders of R&D to place conditions on recipients to ensure licensing to firms in developing countries on fair terms that take into account their development priorities and needs.

One example of publicly-funded research being made available to the public is the mandatory Public Access Policy of the US National Institutes of Health (NIH)[27] which requires all investigators funded by the NIH to make their publications publicly available through the National Library of Medicines's PubMed Central, no later than 12 months after the official date of publication, thus improving the sharing of scientific findings, the pace of medical advances, and the rate of return on benefits to the taxpayer. A similar concept could also be envisaged to address prompt availability of publicly-funded technologies to developing countries.

At the UNFCCC meeting in Accra, G77 and China put forward a proposal for the establishment of a Multilateral Climate Technology Fund[28]. The expectation is for the fund to finance enhanced action on technology development and transfer.

[24] IPCC (2000).
[25] TWN, (2008a)
[26] TWN, (2008a).
[27] See Consolidated Appropriations Act of 2007 (H.R. 2764), see also http://publicaccess.nih.gov/policy.htm
[28] Stillwell (2008a).

More specifically, it is proposed that the fund will finance *inter alia* support for research, development, manufacture, commercialisation, deployment and diffusion of technologies for adaptation and mitigation and the creation of manufacturing facilities for ESTs.

Financing of R&D of new technologies by any future fund should be subject to conditions concerning IPRs. IPRs of any technology resulting from R&D financed from the fund should belong to the fund under the UNFCCC. The technology with its know-how should be made available royalty free to firms in developing countries that would like to produce or do further R&D (for example, to adapt the technology to local conditions). Where countries are more interested in purchasing the technology (that has been developed through financing under the Technology Fund, rather than manufacturing or conducting R&D), the technology should be made available at prices affordable to the population of the said developing country. In short, provision of financing for R&D of new technologies should be subject to certain conditions that ensure that there is no impediment to equitable and affordable access to the products of the research or follow-on research by others.

Conclusion

Any WTO Member State is already allowed by the TRIPS Agreement to make use of "flexibilities" and take measures such as compulsory licenses and parallel importation to obtain technologies or products (that are patented) at more affordable prices. But the processes of negotiating with the patent holder and of issuing compulsory licenses, etc., can be quite cumbersome to countries not familiar with the procedures. Consideration should thus be given to facilitating the easier use of compulsory licensing and other TRIPS flexibilities, and also the possible exemption by developing countries of at least the critical technologies required for climate adaptation and mitigation. Innovating firms could recover their research costs through patenting in developed countries. Intellectual property should not be treated as something sacred that has to be upheld at all costs. That would send a signal that climate change is not a serious threat, as commercial profits from monopoly would be seen as being on a higher scale of values and priorities than are the human lives that are at stake due to global warming. Technology transfer to developing countries to enable them to combat climate change should be the far higher priority. The UNFCCC process should therefore adopt the principle that developing countries can exempt climate-friendly technologies from patents. This should be supplemented with global measures to enable the sharing of trade secrets. As second-best alternatives, other measures can be considered, such as automatic granting of voluntary licenses and regulation of such licenses, and patent pools.


Photo © UNDP India

Chapter 5

Enabling Policies for Technology Transfer in the Context of Climate Change

Biplove Choudhary and K.M. Gopakumar

Introduction: Role of Technology Transfer in Dealing with Climate Change

Issues of facilitating technology transfer, innovation and adaptation in assisting developing countries to pursue self-reliant development strategies have been debated over the last several decades. However, technology generation, transfer and diffusion have, in recent years, acquired a new salience in the context of dealing with the unprecedented challenges of climate change impacts. It is clear that current growth models predicated on existing choice of technologies would create unacceptable trade-offs between growth and environment protection. It is widely believed that an effective international response to the adverse fallouts of climate change hinges significantly around ensuring access and utilisation of ESTs, by both the developed and developing countries.

A shift towards a green growth path in a 'compressed' timeframe of around four decades through what has been termed as the 'great green technological

revolution'[1] is critical in the light of wide ranging climate change impacts and wide asymmetries, generally speaking, between the developed and developing countries for effective adaptation and mitigation strategies. Previous technological revolutions needed more than seven decades to be completed. The scale of the current task of moving to a green growth path and the relative short span of time in which this has to be accomplished demand that a comprehensive approach to both understanding and addressing technology transfer needs of the developing countries is undertaken while ensuring that, besides market forces, government retains an important role. Technology development is a path dependent process and, therefore, the public sector has an important role in enabling such technological shifts[2].

It is now well understood that the current channels of technology transfer as well of its pace are inadequate to deal effectively with climate change[3]. The EGTT under the UNFCCC highlighted the problem as follows: "The implementation challenge is to stimulate the development of a continuously changing set of technologies (currently consisting of approximately 147 mitigation technologies and 165 technologies for adaptation) that are at different stages of technological maturity and have different requirements for further development. Those technologies need to be adapted for, and transferred to, about 150 developing countries, each with its own needs for specific technologies and enabling environments to support them"[4]. Earlier, the United Nations Conference on Environment and Development and the adoption of Agenda 21 clearly identified the need for *favourable* access to and transfer of ESTs through transfer of technological know-how and all-round capacities (economic, technical and managerial) for the efficient use and further development of transferred technology[5] (italics added).

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[1] UN (2011). World Economic and Social Survey, The Great Green Technological Revolution, New York.
[2] IBID.
[3] WMO, UNEP (2000) Intergovernmental Panel on Climate Change, IPCC, Special Report, Methodological and Technological Issues in Technology Transfer.
[4] IBID, page 162.
[5] IBID.

Putting Technology Transfer in Perspective

Technology transfer is recognised as an important tool for attaining national development goals. Efforts for establishing an international regime to ensure acquisition of technology on equitable terms date back to the 1950s. During the 1960s and 1970s, it became an important theme of deliberations in various international organisations including at the UN General Assembly. At the UN General Assembly, the issue was seen as central for envisaging a new international economic order and in drawing up of the Charter of Economic rights and duties of states).

UNCTAD launched negotiations to develop an International Code of Conduct on transfer of technology in 1978[6]. These deliberations resulted in the incorporation of technology transfer provisions in several international treaties including the UN Convention on the Law of the Seas, Convention of Biodiversity, UNFCCC, etc[7]. Often, the legal provisions on technology transfer were incorporated as endeavour clauses which tend to be interpreted in an open-ended subjective manner rather than as specific legal obligations to undertake transfers in a time bound manner. The current international discussions on technology transfer, with reference to both climate change adaptation and mitigation technologies, should be seen as a continuum of the efforts of developing countries to ensure affordable and equitable access to technology as a critical driver of development.

The term technology transfer includes both 'hard' and 'soft' components of technology and "is understood now not only as the purchase and acquisition of equipment but the transfer of skills and know-how to use operate, maintain as well as to understand the technology hardware so that further independent innovation is possible by the recipient firm"[8]. The end result of the process of technology transfer should be to strengthen the capacity and expand the technological base of developing countries to contextually respond to climate changes. This should extend to the possibility of developing countries replicating the technology through reverse engineering or adapting it to suit local contexts and integrating it with indigenous technologies.

This broad approach to technology transfer has also been embedded in the deliberations of the IPCC. IPCC defines technology transfer as a "broad set of processes covering the flows of know-how, experience and equipment for

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[6] UNCTAD, Compendium of International Arrangements on Transfer of Technology: Selected Instruments, p. 261 available at http://www.unctad.org/en/docs//psiteipcm5.en.pdf.

[7] IBID.

[8] Sangeeta Shahikant and Martin Khor. Intellectual Property and Technology Transfer Issues in the Context of Climate Change, p. 2 available at http://www.twnside.org.sg/title2/IPR/pdf/ipr14.pdf.

mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, NGOs and research/ education institutions"[9].

UNFCCC clearly recognises the importance of technology transfer from developed countries to developing countries (North to South). Article 4.5 of UNFCCC there is an obligation on developed countries "to 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" and to "support the development and enhancement of endogenous capacities and technologies of developing country Parties". Article 4.7 goes further and states, "The extent to which developing country Parties will effectively implement their commitments under the Convention will depend on the effective implementation by developed country Parties of their commitments under the Convention related to financial resources and transfer of technology". Hence, any obligation on the part of developing countries needs to be based on concurrent obligations of developed countries under Article 4.5 to both availability of financial resources and transfer of technology.

At the COP 6 at Bonn in 2001, a framework for meaningful and effective actions to enhance the implementation of Article 4.5 of the Convention was set forth. The Framework encompasses five key areas for action:

1. Technology needs and needs assessments,
2. Technology information,
3. Enabling environment,
4. Capacity building,
5. Mechanisms for technology transfer.

Technology transfer is also one of the four pillars of the ongoing climate change negotiation. Bali Action Plan at the COP 13 to UNFCC in 2007 refers to technology transfer. Bali Action Plan provides the mandate to develop "effective mechanisms and enhanced means for the removal of obstacles to, and provision of financial and other incentives for scaling up of the development and transfer of technology to developing country Parties in order to promote access to affordable environmentally sound technologies". Hence the negotiating mandate is to develop an effective mechanism and enhanced means to promote access to affordable environment technologies. Further, the negotiation mandate includes not only the institutional mechanism for technology transfer but also barriers to technology transfer.

[9] WMO, UNEP (2000). Intergovernmental Panel on Climate Change, IPCC, Special Report, Methodological and Technological Issues in Technology Transfer.

Determinants of Technology Transfer and Select Issues of Policy Relevance

Technology transfer processes are recognised as complex and intertwined between identification of needs, choice of technology, assessment of conditions of transfer, agreement and implementation together with adjustment to local conditions and replication. A number of social, economic, political, legal and technological factors influence the flow and quality of technology transfer and vary from sector to sector. Successful cases involve availability of financing, consumer and business awareness, availability of information, technical, business, management, regulatory skills together with economic policy and regulatory skills.

Many factors, viz., human resources, science and technology infrastructure, policy tool, macro economic policy, etc., determine the environment for technology transfer. These factors do not necessarily lie within the control of a country. Academicians and policy makers have identified several channels of technology transfer consisting of market and non-market channels. Market channels consist of foreign direct investment, licensing and joint ventures and cross border movement of professionals. Non-market channels include imitation, employees setting up new ventures, patent landscaping and temporary migration[10]. Similarly, various barriers to technology transfer have been identified, which include absorption capacity, anticompetitive licensing practices, intellectual property, etc. While policy space on most of these barriers still remains with countries, there is limited or little policy space on certain barriers like IPR.[11] Similarly, countries in the past used many policy measures through various policy instruments such as industrial policy, trade policy, investment policy, science and technology policy, etc., to ensure transfer of technology. However, the feasibility of these measures in the present times depends on many factors including the international legal obligations on trade and investment undertaken by a country at multilateral, plurilateral and bilateral levels. Therefore, it is important to identify the right law and policy tools and their feasibility under the existing trade and investment framework for enabling transfer of technology. Such an exercise would help developing countries to incorporate such policy tools in their policy framework, viz., industrial policy, trade policy, investment policy, science and technology policies and agricultural policy settings.

Experience of implementing technology transfer provisions says that efforts are mainly directed at ensuring an attractive climate to ensure foreign investment flows

[10] Thee Kian Wie. The Major Channels of International Technology Transfer to Indonesia: An Assessment, *Journal of the Asia Pacific Economy*, 10:2, 214–236, May 2005 available at http://www.devone.biz/technologyxfer.pdf

[11] Keith Maskus. Encouraging International Technology Transfer, ICTSD 2004 http://www.iprsonline.org/resources/docs/Maskus%20-%20Encouraging%20International%20ToT-%20Blue%207.pdf

and capacity building to absorb and utilise imported technologies. An important issue to recognise is that quantification attempts of the annual transfer of climate relevant technologies especially when combined with capacity building efforts are hard to come by. Financial flows embodying technology transfer do not permit meaningful comparisons[12]. With diverse policy contexts around the interplay of each of the above factors and prevalence of varied initial conditions, it is difficult to generalise on how technology transfer can be accelerated to meet the challenges of climate change. However, the link to private transfers as a major channel of technology flows, an enabling IPR regime has been seen as a 'potentially decisive determinant of technological upgrading in developing countries'[13].

It has been seen that technology transfer can be made more effective through concerted efforts at capacity building, creation of an enabling environment and mechanisms for technology transfer[14]. Capacity building is a prerequisite at all the different stages of technology transfer for both adaptation and mitigation technologies. People and organisations need to adapt while acquiring new skills to enable moving on to a new technological trajectory. All stakeholders need to be engaged including local governments, institutions, businesses and consumer groups.

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[12] WMO, UNEP (2000). Intergovernmental Panel on Climate Change, IPCC, Special Report, Methodological and Technological Issues in Technology Transfer.

[13] UN (2011). World Economic and Social Survey, The Great Green Technological Revolution, New York.

[14] WMO, UNEP (2000). IBID.

Intellectual Property Rights and Technology Transfer

Current trends show that ownership of intellectual property in ESTs is concentrated mostly in the developed countries and adds to the overall costs of the shift to green technologies. Flexibilities in the TRIPS Agreement of the WTO, on issuance of 'compulsory licenses' and 'parallel importation' with payment of due compensation, have been difficult to implement and are countered by strong lobbies and all forms of indirect pressures.

Efforts to introduce a stronger IPR regime (both in terms of scope and coverage and period of effect) pursued by the developed countries vis-à-vis the developed countries through bilateral and/or regional free trade agreements may result in further barriers to access of appropriate technologies. It is important, therefore, to strike an effective balance. International cooperation is needed to ensure that protection of IPRs must be balanced with measures to 'prevent abuses' of such rights including through compulsory licenses with provision of equitable remuneration to the right holder. Such an approach has been followed in Article 16 of the Convention on Biological Diversity relating to access to and transfer of technology and is worthy of emulation in the current context of creating an enabling IPR regime. Article 16.5 of the Convention on Biological Diversity states that, *"The Contracting Parties, recognising that patents and other intellectual property rights may have an influence on the implementation of this Convention, shall cooperate in this regard subject to national legislation and international law in order to ensure that such rights are supportive of and do not run counter to its objectives"* [15].

It needs to be noted though that more evidence-based studies would be useful to ascertain the IPR related barriers including lack of legal expertise or infrastructure, pressures of foreign investors which may influence the ability of developing countries to utilise TRIPS related flexibilities.

[15] Convention on Biological Diversity (CBD) texts available at http://www.cbd.int/convention/articles/?a=cbd-16.

Proposals for an Enabling Environment to Technology Transfer: Potential Good Practices

The Proposal of the Working Group on Trade and Transfer of Technology (WGTTT) of the WTO on steps that might be taken to increase the flow of technology to developing countries is relevant to be reiterated here as well. It was suggested that since most of the technology transfer related provisions in WTO agreements are only voluntary, a possible recommendation is to *encourage the formal adoption of voluntary guidelines, such as those of the OECD to Multinational Firms. Governments could incentivise their multinational firms to "perform science and technology development work in host countries", grant licenses "on reasonable terms and conditions", and adopt "practices that permit the transfer and rapid diffusion of technology and know-how" to developing countries*[16].

Another recommendation has been for the WTO Members to *seek ways of expanding or encouraging the mobility of scientists, technologists and technicians under General Agreement on Trade in Services (GATS), develop science and technology agreements to promote international scientific and industrial R&D collaboration, and encourage their firms and public institutions to employ, at least temporally, fresh graduates and offer consultancy services or contracts and attachment to experts from developing countries to facilitate transfer of knowledge*[17].

The WGTTT also recommended that more information sharing on the diverse incentives provided to firms to facilitate investment in R&D , technology acquisition or generation would help in making it more targeted and reciprocal to encourage R&D investment, or expenditure, facilitate technology transfer and investment in R&D, technology acquisition or generation[18].

A listing of positive measures which can facilitate technology transfer has been proposed by UNCTAD (Table 5). Again, since these positive measures lack any legal backing this may require generation of consensus in order for it to be effective.

Recently, the World Health Organisation's 64th World Health Assembly proposed a new mechanism based on international cooperation and transfer of technology on equitable terms for pandemic influenza preparedness, sharing of influenza viruses and access to vaccines and other benefits. This development demonstrates the potential and possibility of cooperative action internationally on health challenges but can easily be extended to other areas including ESTs. There was a consensus around building of new production facilities in developing and/or industrialised countries through transfer of technologies, skills and know-how. The Framework specifically proposed that *Member States should urge influenza vaccine, diagnostic and pharmaceutical manufacturers to make specific efforts to transfer these technologies to*

[16] WTO, WT/WGTTT/W/10, 13 October 2005 (submission by India, Pakistan and Philippines).
[17] IBID.
[18] IBID.

other countries, particularly developing countries, as appropriate. Also, the Framework urged that *influenza vaccine manufacturers who receive Pandemic Influenza Preparedness biological materials may grant, subject to any existing licensing restrictions, on mutually agreed terms, a non-exclusive, royalty-free licence to any influenza vaccine manufacturer from a developing country, to use its intellectual property and other protected substances, products, technology, know-how, information and knowledge used in the process of influenza vaccine development and production, in particular for pre-pandemic and pandemic vaccines for use in agreed developing countries.*

Table 5:
The interaction of trade and positive measures: an indicative typology (adapted from Osikawa, 1998)

	Trade Measures	Positive Measures
Coercive	Bans/prohibitions Quotas Taxes/charges Mandatory labelling schemes	
Cooperative	Import/export permits Prior informed consent procedures Waivers Tradable emission permits	Transfer of environmentally friendly technologies Joint implementation of projects Project financing Funding incremental costs "Green loans" Credit guarantees Elimination of environmentally harmful subsidies "Green non-actionable subsidies" Grace periods within which to satisfy MEA commitments Market access and "green market access" Technical assistance for capacity-building

Source: IPCC, available at http://www.ipcc.ch/ipccreports/sres/tectran/index.php?idp=38

This brief overview brings out a number of interesting dimensions to technology transfer which needs to be kept in view. First of all, the extent of technology transfer is not amenable to quantification now and does not permit an assessment of global efforts in this direction. This highlights the need to come up with some specific sets of targets, measureable indicators which can help in establishing some baselines/benchmarks for progress. Technology transfer needs to be aggressively pursued in a South-South cooperation framework including through potential establishment of cooperative research consortia and patent pool systems.

National efforts are barely likely to succeed unless there are synergistic inter-linkages created at the national, regional and global levels in an international cooperation framework. Moreover, the evolving inter-linked patterns of income, production and consumption between one part of the world to another operates through a complex web of international trade and investment routes, and international cooperation would need to address this dimension. Any cooperative framework also needs to consider putting in place innovative financing facilities and a predictable flow of development assistance for scaling up efforts on adapting to and mitigating climate change impacts. Countries that provide technologies could implement measures and mechanisms for the private sector to enhance technological cooperation and the transfer of pertinent proprietary technology.

Photo © Benoit Marquet/UNDP India

Chapter 6

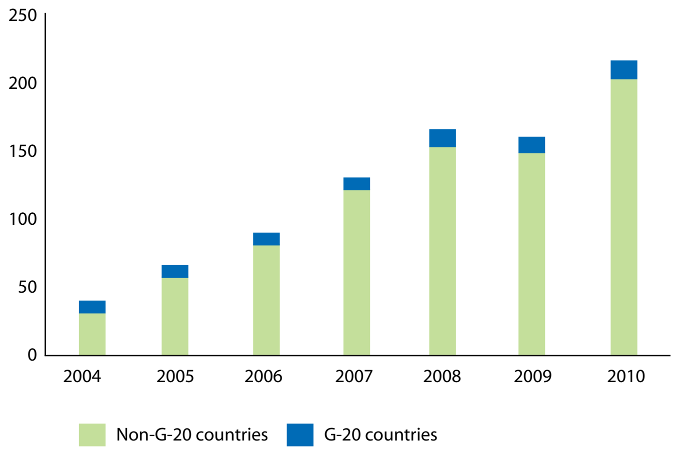
International Financing Instruments for Meeting Technology Needs

Martin Krause

Climate change does not belong any more in the category of an "environmental problem". To slow down the pace of climate change – so that it becomes manageable – fundamental shifts in the economic fabric (particularly related to energy generation and consumption) are necessary. In the absence of a significant reduction in global emissions from current levels, between now and 2050, world temperatures could rise by 4°C, and possibly 6°C, by 2100. The world only has 100-150 months to dramatically change the world's energy supply trajectory and limit temperature rise to the 2°C threshold stipulated in the Copenhagen Accord.

According to the Stern Report 2008, mitigation activities will demand at least US$ 500-600 billion per annum while adaptation measures will entail the investment of another US$ 400-500 billion per annum. The sums involved in a shift to a low-carbon economy are daunting but not impossible to achieve. Governments and the international community have developed a number of public policies, public finance mechanisms and market-based instruments to shift investments from fossil fuels to more climate-friendly alternatives over the past few years. As a result, investments in the sustainable energy market have grown from US$ 22 billion in 2002 to over US$ 200 billion in 2010 and could reach US$ 400-500 billion by 2020 (Figure 4).

Figure 4:
Growth of private investment in clean energy



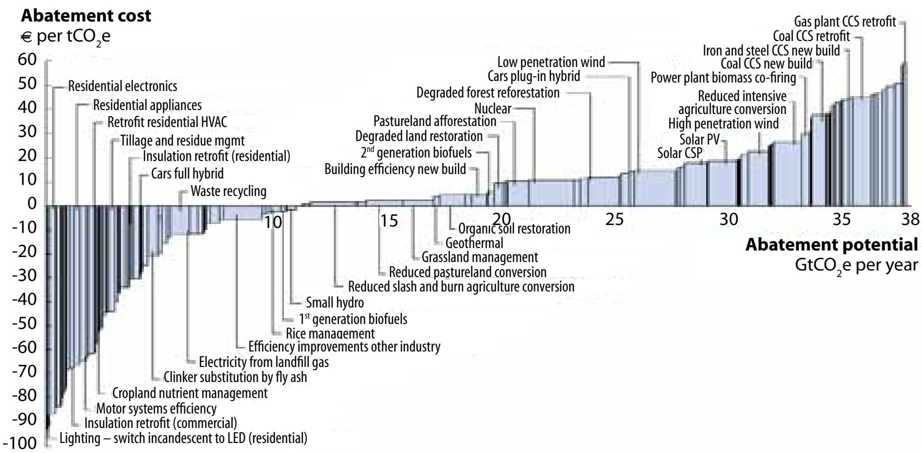
Source: The Pew Charitable Trust (2011).

While the international dialogue on technology cooperation and financing continues within the context of the UNFCCC negotiations, many countries have already taken actions to facilitate cooperation on low carbon and climate resilient technologies. Furthermore, there are some lessons and experiences with technology financing that can inform the next stage of expanding and accelerating technology cooperation using tailor-made blends of international, national, private and public financing instruments. Some developing countries have already taken concrete steps towards transforming their economies and societies; numerous pilot projects and programmes have been implemented to promote renewable energy, energy efficiency and, in more recent years, also certain climate adaptation technologies.

Many of these programmes have shown the need to address technology cooperation and finance within the broader context of aligning policies and regulations, strengthening relevant skills and capacities, paying proper attention to the institutional context and stimulating the demand side at the same time. Experiences have shown that providing financing alone does not lead to the successful dissemination and market penetration of low carbon, climate resilient technologies. Widespread adoption of climate relevant technologies, without having addressed all relevant market barriers, rarely happens. Therefore, the first challenge is to address technology cooperation and financing as a subset of a broader range of issues related to policies, markets, institutions and skills, and promote interventions that address all in a comprehensive manner.

Secondly, technology cooperation and financing needs to be discussed in the context of specific technologies considering their respective stage of market maturity. Technologies at the R&D stage need a different combination of financing instruments as compared to technologies that are commercially available. The identification of specific technologies that are needed and relevant in a specific local, national or sector context is a prerequisite for meaningful dialogue and action. Methodologies and guidance on assessing technology needs are available and helpful.

Figure 5:
Abatement cost curve for selected technologies

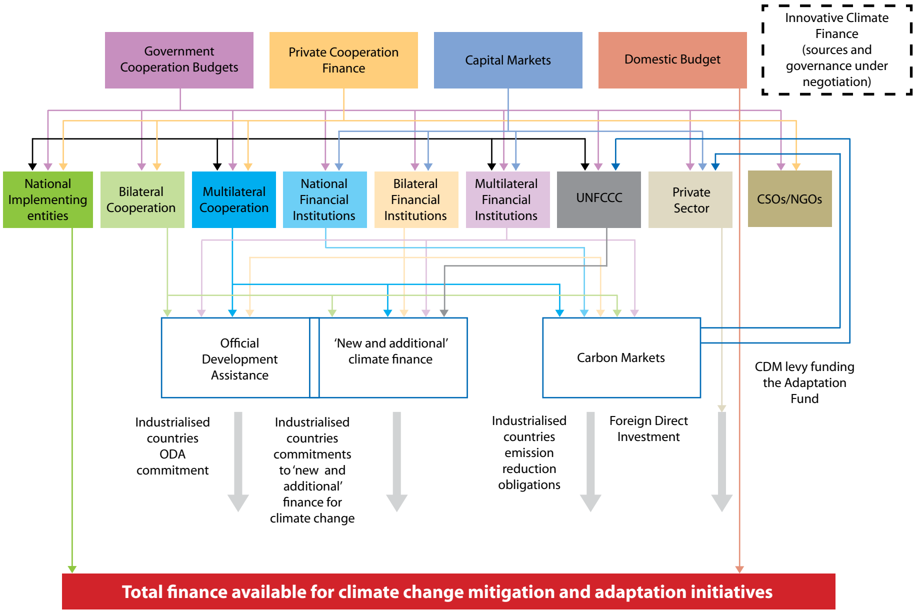


Source: McKinsey & Company (2009)

After identifying suitable technologies, the full range of barriers that prevent their widespread adoption needs to be assessed. Lack of international technology cooperation and financing might be one of the obstacles, amongst others, such as low institutional capacities, policies favouring fossil fuels, limited awareness and knowledge, and lack of technical skills. UNDP's work over the past 18 years at the interface of climate mitigation, energy and classical development work has shown that each of these barriers requires specific measures and actions. Therefore, designing and implementing an appropriate mix of policies, instruments and programmes that comprehensively address relevant market barriers is needed.

In terms of financing such comprehensive interventions, it is paramount to combine and sequence public, private, domestic and international sources of financing. Unfortunately, only a limited number of developing countries are so far benefitting from new climate financing opportunities. The global climate change financial architecture is quite complex as illustrated in Figure 6 and, often, it is not easy for countries to navigate through this.

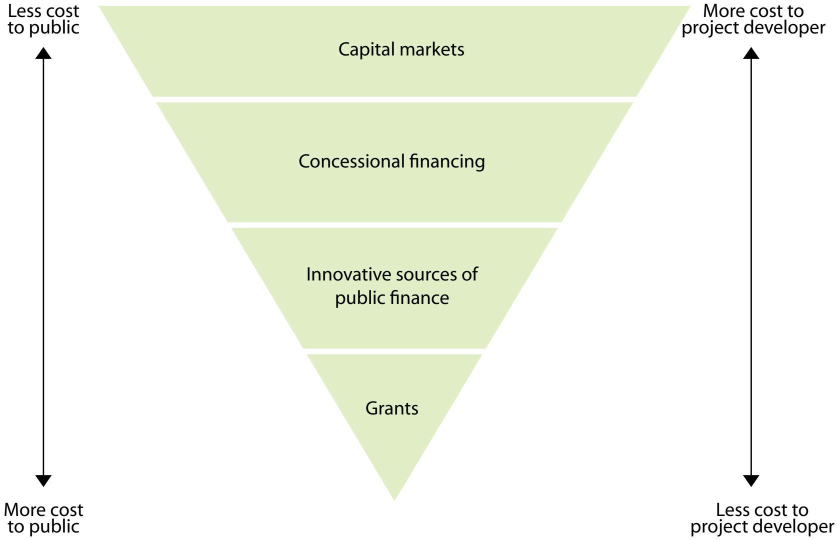
Figure 6:
Abatement cost curve for selected technologies



Source: McKinsey & Company (2009)

Existing markets in developing countries often fail to attract investments in low carbon projects. For the private sector to invest in developing countries would require a supportive policy structure with feed-in tariffs, developed financial markets and active private investors. Therefore, it is important that climate financing is accompanied by an enabling policy environment, capacity building, awareness building and technology innovation. There are many examples worldwide wherein climate change financing has been used to help bring down policy barriers and create capacity which has led to successful projects. Many countries lack the capacities for combining and sequencing different sources of funding, including carbon finance. Transition towards low carbon economies and societies needs to be initiated with the right mix of policies, capacities and access to finance.

Figure 7:
Comparative scarcity of funding sources



Source: Glemarec, Yannick (2011). Catalyzing Climate Finance

International agencies such as UNDP, International Bank for Reconstruction and Development (IBRD), Asian Development Bank and others are providing access to climate finance, assisting countries to combine and sequence private, public, grant and loan financing. For example, over the past four years Asia/Pacific countries could access over US$ 250 million in grant financing through UNDP. Enhancing the capacity of developing countries to leverage new public policy and financial tools to address climate change is a key priority for many development partners. Current finance sources under the Convention and Kyoto Protocol include the GEF Trust Fund, the Special Climate Change Fund (SCCF), Least Developed Countries Fund (LDCF), Adaptation Fund and Clean Development Mechanism and, hopefully in the near future, the GCF. Combining and sequencing the various instruments available is as important as choosing the right instrument which, in turn, depends on market conditions and the stage of commercialisation of the various technologies.

Apart from private investments, technology cooperation and diffusion needs to rely on various types of environmental finance such as official development assistance (ODA) , debt/equity finance, fiscal instruments, etc., which will continue to play a major role. Project developers will need to identify the best sources of funds to finance project activities (ODA, quasi-ODA, carbon trading, etc.). Even though the funds available from various sources such as the GEF may seem extremely small for

Table 6:
Selected International sources of financing

CIF	Mitigation, Adaptation	US$ 6 bil
GEF Trust Fund	Mitigation	US$ 1.4 bil (2010-2014)
Bi/Multilateral donors	Mitigation, Adaptation	US$???
Special Climate Change Fund (SCCF)	Adaptation, Technology Transfer	US$ 134 mil
Least Developed Countries Fund (LDCF)	Adaptation	US$ 320 mil
Adaptation Fund	Adaptation	US$ 240 mil
Clean Development Mech.	Mitigation	US$ 7-9 bil/a
Green Climate Fund (GCF)	Mitigation, Adaptation	US$???

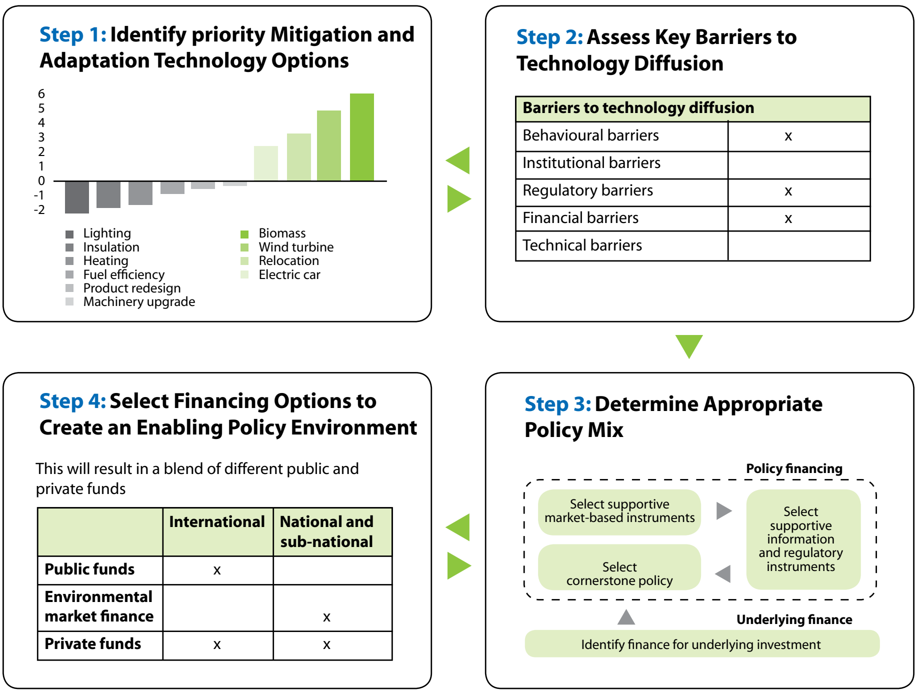
Table 7:
Climate finance instruments and schemes

	International Schemes	National/Subnational Schemes
Public Funds	– ODA (multilateral, bilateral and decentralised cooperation) – CC Multilateral Funds	– Export Credits – Green economic stimulus – Rebates & Subsidies (phase-out of subsidies on fossil fuels and re-investing in CETs) – Tax credits & Tax Free Bonds – Low interest loans – Credit lines
Private Funds	– Green Equity Finance – Private Investment funds Foundation – NGOs – Global Philanthropic Foundations – Corporate Social Responsibility	– Utility DSM – Green mortgages – Tax free climate change bonds
Market-based Instrumentws	– Carbon Cap and Trade Mechanisms (CDM, JI, voluntary) – Tradable Renewable Energy Certificates – Green insurance contracts – Cat Bonds – Weather Derivatives	– Domestic carbon projects – Tradable Renewable Energy Certificates – Green insurance contracts – Cat Bonds – Weather Derivatives – Insurance Pools
Innovative Sources of Finance	– Transaction Taxes (Tobin) – World CC Fund – Air Travel Levy – Global Carbon Tax – Debt-for-Efficiency Swaps – Int. Auction Funds – Int. non-compliance fees	– Carbon Taxes – Energy Taxes – Auction of Emission Allowances – National Non-compliance fees – GIS of Carbon Credits (AAUs, etc)

the challenge at hand, it is possible to use finances strategically to remove market barriers and enable a policy environment in which an unviable low carbon project can become an attractive low carbon project.

The overall goal for accelerating technology cooperation is to align human development and climate change management efforts by promoting mitigation and adaptation activities that do not slow down but rather accelerate socio-economic progress. Successful efforts in managing climate change will require a dramatic increase in support to developing countries for capacity development, technology cooperation and investment. Addressing climate change and achieving the Millennium Development Goals requires a new development paradigm that puts climate change into national strategies and plans, and links technologies with policy-setting and the financing of solutions both in terms of mitigation as well as adaptation.

Figure 8:
Four-step process for selecting the appropriate combination of policy and financial instruments for technology diffusion



Source: Glemarec, Yannick (2011). Catalyzing Climate Finance

Photo © Tom Pietrasik/ UNDP India

Annexures

Annexure 1: Relevant Articles of the Convention

Article 4.1 (c)	**Article 4.3**	**Article 4.5**	**Article 4.7**
All Parties, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, shall: (c) Promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol in all relevant sectors, including the energy, transport, industry, forestry, agriculture, and waste management sectors.	The developed country Parties and other developed Parties included in Annex II shall provide new and additional financial resources to meet the agreed full costs incurred by developing country Parties in complying with their obligations under Article 12, paragraph 1. They shall also provide such financial resources, including for the transfer of technology, needed by the developing country Parties to meet the agreed full incremental costs of implementing measures that are covered by paragraph 1 of this Article and that are agreed between a developing country Party and the international entity or entities referred to in Article 11, in accordance with that Article. The implementation of these commitments shall take into account the need for adequacy and predictability in the flow of funds and the importance of appropriate burden sharing among the developed country Parties.	The developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention. In this process, the developed country Parties shall support the development and enhancement of endogenous capacities and technologies of developing country Parties. Other Parties and organizations in a position to do so may also assist in facilitating the transfer of such technologies.	The extent to which developing country Parties will effectively implement their commitments under the Convention will depend on the effective implementation by developed country Parties of their commitments under the Convention related to financial resources and transfer of technology and will take fully into account that economic and social development and poverty eradication are the first and overriding priorities of the developing country Parties.

Annexure 2: Illustrative Technology Needs

Buildings

Building energy (and GHG) efficiency can be improved through retrofitting buildings, adopting new designs, and integration of renewables into building energy systems, each of which has different technical needs. As we look into the future, given the high projected growth in the addition of new built-up area, the greatest emphasis should be on improving the energy performance of new buildings – once these have been built, it is difficult to change some fundamental features (such as orientation, location of opening, etc.) that have a significant influence on their energy performance. But even with mandatory energy-efficient building codes, compliance is likely to be 60-70 percent (given previous experiences), which means that retrofitting will be an ongoing activity (in addition to focusing on currently-existing stock). Though the design modification possibilities for the existing building stock might be limited, they can achieve higher energy efficiency through appliance and control systems retrofitting. To move towards net zero energy usage, buildings and beyond would require an integration of renewable sources of energy in the building design. While it may be technologically and economically infeasible to move the existing building stock towards zero energy usage, the new constructions could incorporate these interventions at the design stage itself.

The present design processes (not just in India but worldwide) often employ a linear approach, with little integration of energy saving features/systems at the various stages of design. An introduction of design solutions like the Buildings Integrated Management (BIM) could alleviate this situation thus ensuring better compliance with the energy saving norms. Software tools for design and integration are available but are expensive. Reducing the costs of these tools would increase their use, as would greater availability of trained manpower. Interventions like use of high light reflection and high heat radiation type energy saving paints, innovative air-conditioning systems (for example, hydrate slurry air-conditioning system), use of high reflection glass, and rooftop greening possess the potential to reduce net energy usage in buildings.

Certain specific technologies for lighting and air-conditioning purposes that promise higher energy savings are yet to be introduced in the Indian market. For example, air conditioning systems that use the outside air for cooling or use of high efficiency turbo refrigerators have been employed at limited places if any. The adaptation and subsequent adoption of these systems in India is expected to result in considerable energy savings in the Indian buildings sector.

An important consideration while using imported technologies in India is their adaptation to the climatic conditions as well as physiological preferences of the local populace. Integration of these inputs into the standards as well as design solutions would ensure an optimal energy saving for the Indian buildings. But developing such an understanding of the local needs and integrating into appropriate standards and norms that are relevant to the Indian context will require some research.

Similarly, buildings can use systems like the Building and Energy Management System (BEMS) to automatically monitor and control the energy savings through an optimisation of indoor condition and energy performance. Given the small market for energy efficient buildings, the materials and systems required to achieve the above interventions could prove to be costly, unless demand emanating from statutory regulations creates a sizeable market in India and cheaper technologies become available.

The control systems for verification, monitoring and implementation of modern energy saving technologies constitute an important area where imported systems need to be replaced with cheaper indigenous ones. Further, there exists a lack of standards and testing equipment for the energy saving features of building materials and equipment. The current state of renewable technologies does not permit an easy integration with the building's design primarily due to physical dimension barriers as well as lack of appropriate control systems for integration with the building's power supply.

Expanding the scope of interventions beyond buildings to district-level opens up the potential for even larger energy savings. District-level heating and cooling systems can save up to half the energy that would be required if each building had separate systems. This approach, though, not only requires more careful and integrative planning but also more sophisticated technologies, especially control systems.

Along with the availability of technologies, there is a need to facilitate the development of an indigenous material/appliance manufacturer and, thus, lower the costs of adoption. At the same time, the human resource base also needs to be expanded – international collaboration to strengthen existing educational and training programmes and to create new ones will be very helpful.

Cement

The growing emphasis on infrastructure development in the recent five year plans coupled with strong demand from a booming Indian economy is set to ensure a firm growth for the Indian cement industry. Future projections put the cement production above 400 MT in 2020 with a further rise in the share of blended cement in the production mix. The energy intensive nature of cement production necessitates technology improvements to ensure that the energy and carbon footprint of the increased production are mitigated to the extent possible.

The Indian cement industry has managed to adopt the five to six stage preheated dry kiln process in a majority of the plants thereby improving the energy efficiency of cement production. However, there is a scope to further the penetration of the Best Available Techniques (BATs) in the sector through a retrofitting of the existing plants (which is limited, to some extent, by the capital investment requirements). Generally, companies operating a small number of cement plants (one or two) have not been able to adopt the BATs in a comprehensive manner due to limited financial incentive for such investments. Increasing energy costs and incentives for improving energy efficiencies (for example, Perform, Achieve and Trade) are expected to further an encompassing adoption of BAT technologies by the Indian cement industry. Furthermore, smaller firms may require assistance with the tracking, adaptation and adoption of newer technologies for use in Indian conditions (raw material and coal quality milieu). An important emerging area that may require such intervention is that of low carbon cements. With active ongoing research in the area, the developments are expected to be protected by IPR and the related technologies may require policy efforts for transfer to the smaller firms.

A large amount of heat is wasted at various operational levels in cement production, this waste heat can be successfully recovered using the modern cogeneration technologies and converted to electric power. The high cost of the patented low pressure waste heat recovery technology through foreign companies had made this intervention quite costly in the past; however with domestic companies now offering co-generation solutions the cost of cogeneration in plants has come down slightly. Japanese plants have reported a potential emission saving of up to 0.06 MT CO_2/MT cement through cogeneration. However, Indian plants utilise part of the process waste heat in drying of the feedstock materials and coal (which have higher moisture content than the global average) thus resulting in a reduction in the cogeneration potential[1]. In spite of this characteristic, the absolute amount of waste heat generated in Indian plants is enough to provide for meaningful cogeneration, more so with the increasing captive power costs.

The use of blended cement, in which clinker is replaced by alternative materials such as blast furnace slag and fly ash from coal-fired power stations, results in lower CO_2 emissions and has been adopted for the production of over 65 percent of cement in India. Increase in the blending percentage for blended cement has a potential to mitigate the energy and emissions intensity of cement production by reducing direct fuel usage for clinker production as well as reducing material decarboxylation. This intervention would require the blending norms and standards for the cement varieties to be modified after requisite testing. The increasing prices of materials like fly-ash and slag used for blending in blended cement have put pressure on the competitiveness of plants manufacturing blended cement. Further, a major consideration for the Indian cement industry while increasing the blending percentage in blended cement would be the availability of high quality slag and fly-ash, requiring a stringent quality control regime enforced by the Bureau of Indian Standards (BIS). Furthermore, the provision of requisite pre-blending processing technologies is a must for adopting this intervention comprehensively.

Intervention in the form of the usage of waste materials for fuel substitution offers a scope for substantial efficiency improvements in the sector; however the non-availability of logistic support for the "doorstep" delivery of these waste materials has created adoption problems for the cement plants. The increasing prices of materials like fly-ash and slag used for blending in blended cement have also put pressure on the competitiveness of plants manufacturing blended cement. As with the capital intensive interventions in the other sectors, the "cogeneration" option for the cement industry is also plagued with financial unattractiveness. A clearing up of these bottlenecks would ensure a quicker and more complete adoption of efficiency improvement measures by the cement industry in India.

Other technology interventions such as vertical roller mill technology, fluidised bed cement fired kiln system and use of mineralisers in a more comprehensive manner by the Indian plants could further reduce the carbon intensity of Indian cement. However, a caveat goes with the emissions reduction potential of these interventions when seen together; these improvements are not additive with the interventions having impact on each other's reduction potential. For example, an increase in the use of alternative fuels (which could have higher moisture content) can increase the specific energy consumption in clinker production. The actual reduction achievable by a plant would depend on the feedstock quality and the 'mix' of technology and other interventions adopted.

[1] IBID.

Steel

To mitigate the GHG impact of this growth, the process of ensuring a lower energy and emissions intensity for the Indian steel plants would require adoption of appropriate technologies at the various stages of production. With several technology alternatives available for each step in the production chain, the following interventions are noteworthy: a) adopting more efficient technologies for the principal process systems or the "mother technologies", b) adopting technologies for energy recovery and conservation, and c) technologies for raw material enhancement. With each of these approaches having considerable potential to mitigate energy usage and emissions in steel production, it is imperative that a balanced mix of these interventions is adopted by the Indian steel industry.

Technology adoption for improvising upon the principal process systems would improve the efficiency of steel production to a considerable extent. The BF-BOF plants can reduce their emissions through an all-encompassing adoption of continuous casting and integrated casting and rolling operations. A shift towards DC arc technology for the electric furnace steel production is estimated to improve the process efficiency by over 5 percent with other advantages like improved melting efficiency and increased hearth life. Technologies like LD convertor, cold rolling and slab casting have been adopted by several plants in the Indian steel sector, with a more encompassing adoption of these technologies in existing plants providing a further scope for intensity reduction. Further, newer smelt reduction technologies like COREX and FINEX obviate the need for coking and sintering plants by using non-coking coal with lump ore and pellets as inputs. This is particularly attractive in India, where coking coal availability is a major issue for the steel industry.

Energy recovery and conservation represents an area that offers considerable opportunities for intensity reduction in steel production. An emerging technique in the steel industry that promises energy savings of over 1 gajoules of primary energy per tonne of crude steel (GJ/tcs) is the Coke Dry Quenching (CDQ) technique. CDQ is a process that quenches carbonised coke using an inert gas; the heated gas is then used to generate electricity, thus affording energy benefits over the conventional wet quenching. With about 90 percent Indian plants yet to adopt CDQ, a potential for energy savings is being underutilised. The adoption of Top Pressure Turbine (TPT), a power generation system for converting the physical energy of the high pressure blast furnace top gas, also promises an energy saving of up to 0.55 GJ/tcs. Further, several waste heat recovery technologies are available to tap into the process waste heat and convert it into useful energy. The adoption of an automated monitoring system for ensuring process optimisation in the plants would also reduce the energy and emissions intensity of steel production. This intervention would, however, require availability of modern control systems and trained personnel to operate them.

A major source of energy use and ensuing emissions in the steel industry is the process of raw material processing, with coke making and sintering processes representing over 15 percent of the total energy consumed in steel making (CSE, 2010). The use of Pulverised Coal Injection (PCI) over the conventional coke usage also results in energy and emissions saving by obviating the energy intensive coke making process and would be adopted more widely by the plants (NEDO, 2008). Further, waste heat recovery from the cooler used to cool heated sintered ore could provide medium heated steam that could be put to use for power generation. This technology in the form of a sintering machine cooler waste heat recovery device can lead to savings of about 0.25 GJ/t-SI (sintered steel). Next generation coke making technologies (SCOPE21) offer more flexibility in terms of coal resource quality and provide reductions in energy and emissions intensity of the coke making process (NEDO, 2008). The SCOPE21 technologies are thus ideal candidates for adoption by the Indian industry. The BF-BOF production route provides for molten steel manufacture through a convertor; this process entails the generation of a large amount of heated gas which could be used for heat recovery. The heat recovery could be done either by combustion method or a non-combustion method (OG method) resulting in savings of up to 0.8 GJ/t PI (Pig Iron).

Intervention in the form of raw material enhancement could also help in lowering the overall energy consumption in the sector. With the quality of both feedstock (iron ore) and the fuel (coal) available in India being below the world average norms, it becomes necessary that **beneficiation processes** for iron ore and coal are adopted across the plants using domestic supplies. Other efficiency improvement measures that could be widely adopted by the industry include use of tar in blast furnaces; carbon monoxide firing in vertical shaft kilns; and adoption of multi-slit burners. Further, general energy saving practices such as. installation of variable frequency drives; use of high-efficiency motors, pumps, and blowers; improved insulation of furnaces; and replacing electric heaters with fuel-fired heaters could incrementally reduce energy usage in the plants (World Bank, 2010).

Coal

The operational efficiency of the coal-based power generation infrastructure in India has seen improvements in the past few decades through adoption of larger plant sizes, retrofitting of older plants and a panoptic adoption of the sub-critical technology. Currently the Indian plants are using the sub-critical pulverised coal technology with BHEL's 500 megawatt (MW) sub-critical PC units being the standard in the sector. However, the technological limitations of the sub-critical route necessitate adoption of newer power generation technologies. Nonetheless, given the sizeable sub-critical installations, reductions in the emissions and energy intensity of existing power plants should be achieved through adoption of renovation and modernisation technologies.

Economisers, heat exchange devices that use heated exhaust gases from the boiler to heat the feed water, could be employed to improve the energy efficiency of the existing boilers without major retrofits. Installation of an air pre-heater could similarly utilise the heat in flue gas from the boiler to heat the required combustion air before it enters the boiler, thus improving efficiency. For installations which employ boiler technologies that do not warrant the adoption of the above (or other energy saving) measures, adoption of new, efficient boilers is requisite. Another intervention that could be employed in old as well as new plants is that of waste heat recovery. With waste heat representing over 60 percent of the total heat generated through combustion in the power plants, these technologies represent huge mitigation potential. Technologies like cogeneration can help in utilising the waste heat generated during plant operation for domestic or industrial heating applications.

Future growth in the coal-based power generation sector through new plant installations affords a chance to adopt technologies and processes that are state-of-the-art in terms of energy efficiency. New installations in the coal-based power generation sector employing super-critical (SC) and ultra super-critical (USC) PC technology are expected to have higher efficiencies compared to the widely adopted sub-critical plants. According to recent projections, super-critical power plants would account for 60 percent of thermal capacity to be built in 12th Plan and 100 percent in 13th Plan; as a result, super critical units could contribute 50-70 gigawatt (GW) by 2020. India is prioritising larger (660/800 MW) plants based on SC in the near future, while undertaking R&D in newer technologies like the Integrated

Coal Gasification Combined Cycle (IGCC) . In addition to increasing efficiency, better post-combustion clean-up technologies such as flue gas desulfurisers (FGDs) and selective catalytic reducers (SCRs) can also be deployed to reduce the GHG emissions. Fluidised-bed combustion (FBC) boilers offer lower costs compared to the PC units of comparable size and can combust larger pieces of coal compared to the PC units; furthermore, Circular FBC (CFBC) units can even work with lower grade coal, an important merit in the Indian conditions.

IGCC is another clean coal technology that is being pursued to generate power at higher efficiencies with lower emissions. IGCC involves converting coal into a synthetic gas (syngas), removing impurities from the syngas and then using the purified syngas for combustion. Although this technology is yet to be commercialised for Indian coal, the high efficiencies (up to 50 percent) reported using other coals make it an attractive technology option. Technologies such asCoal Energy Application for Gas, Liquid and Electricity (EAGLE), which are variations of IGCC, have demonstrated up to 30 percent reductions in CO_2 emissions upon combining with gas turbine, steam turbine anda fuel battery (NEDO, 2010). Advanced ultra supercritical, a technology touted to be more efficient than the USC technologies is also being developed in the US; though the commercial viability of this technology is still not clear. An important issue associated with the transfer of all these energy efficient technologies is their adoption to the Indian coal and climate conditions.

An adequate support from the transmission and distribution utilities would be required to make the shift towards newer technologies in power generation successful; smarter grid management solutions are required to draw maximum utility out of the power generated. Furthermore, a mechanism and knowledge base for the absorption of the technical know-how associated with these new technologies is required to develop indigenous capabilities, necessitating a better training of the human resources associated with the sector.

Wind

Technologies relating to various aspects of wind turbines may be helpful for enhancing wind power in India. With the ever increasing size of the wind mill blades, research into the materials for blade fabrication is needed to cope with the structural requirements of a modern wind mill. While there have been improvements in generators with the introduction of variable-speed generators and induction generators, further improvements in generation efficiency are possible through further improvements in generator design, for example, through the use of permanent magnets, which itself will need new materials. Other improvements in the overall efficiency of the wind turbines could be realised through incremental improvements in the design and materials for various wind mill components like the gearboxes, shafts, brakes and Yaw drives. At present,R&D into these areas are done in-house by the major manufacturers of wind turbines across the globe.

Another major technology need for the wind industry is the development of better grid compatibility for the wind-based power plants. The requisite technologies in grid control systems would improve the grid resilience thereby providing for better grid integration for the wind farms. European countries, among others, have focused on this issue for their own domestic markets and transfer of both technical knowledge and grid management approaches for integrating wind power into the grid could be helpful. Solutions like the smart grid would further increase the attractiveness of irregular power sources like wind. Micro grids, another promising potential solution for rural/remote areas, require integration of conventional and renewable power – technologies and control systems assisting with such integration could be of value.

A recent evolution in the wind power sector globally has been the increase in the wind farm installations at off-shore locations. The advantage of greater wind power density (WPD) compared to land, lower wind turbulence and the availability of large, uninhabited areas for installation, make offshore generation quite attractive. Nevertheless, these sites would have to be connected to the utility power lines (or to an offshore grid – no such grid exists presently) and the technical expertise required for such offshore installations would have to be developed indigenously. A better WPD mapping of the off-shore locations along with the technical know-how of off-shore farm design and installations is also needed to tap the off-shore generation potential in India. This includes ocean floor mapping, designing foundations for turbines (or floating turbines), and laying of submarine cables. Modern simulation tools could be leveraged to better understand the wind characteristics of a potential site as well as the power flow analysis of an installation for a better understanding of the transmission scenarios.

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Further, the capital requirements for large wind farms (more so in the offshore farms) would necessitate financial solutions to provide for the capital needs of the sector. For example, since most of the wind project developers in India are manufacturers, they have limited working capital. A revolving fund to support the development of such projects could promote the deployment of this technology.

Lastly, there is a dearth of trained manpower in the country for manufacturing of wind turbines, installation, operations, and maintenance. A ramp up of wind power deployment will require large training programmes which could be set up through academic collaborations between industrialised country and local institutes.

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