UK-India collaborative study on the transfer of low carbon technology:

Phase II Final Report

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Report by SPRU and TERI

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Contents

Executive summary

This report details the findings of Phase II of the UK-India study on low carbon technology transfer. The study was conducted by SPRU (University of Sussex, UK) and TERI (India) between June 2008 and February 2009, with expert review from Margaree Consultants (Canada) and the Institute for Development Studies (UK).

The study focused on three key issues:

1. The development of a decision making guide to help policy makers ensure technology transfer activities have maximum impacts on developing new technological capacity in recipient countries;

2. Further work on intellectual property rights (IPRs), including the development of policies that could help to overcome IPR barriers; and

3. Developing recommendations of how collaborative research, development, demonstration and deployment (R,D,D&D) initiatives between developed and developing countries might contribute to technology transfer.

The study used a case study approach based on five low carbon technologies, namely: wind power; solar PV; hybrid vehicles; energy efficiency in small and medium sized enterprises (SMEs); and integrated gasification combined cycle (IGCC) for power generation. The emphasis throughout the study was on a consultative approach that engaged directly with industry, government and researchers, to yield grounded empirical insights and to raise awareness of the study amongst potential end users. About 200 people provided insights for this report. The majority of informants were based in India. However, where possible, discussions were also held with actors from the industrialized world.

Key findings

Intellectual property rights

An important clarification in relation to IPRs and low carbon technologies is the difference between consumers, or users, of low carbon technologies, and producers of these technologies. Consumers of low carbon technologies are unlikely to experience any specific IPR related barriers to accessing low carbon technologies. The barriers consumers face are more likely to be related to costs (although a part of these higher costs can be due to IP), which are often higher for low carbon technologies than for conventional technologies. For example, it could be imagined that, once the technology becomes commercial, an IGCC power plant might cost 25-30% more than a supercritical coal-fired power plant. But it is difficult to say exactly how much of this extra cost would be related to patents, e.g. it may only be a small percent. For firms wishing to become producers of low carbon technologies on the other hand, the existence of and access to patents is likely to play a much more significant role in terms of the rate at which they are able to access the knowledge necessary to start manufacturing low carbon technologies. Such a situation, for example, seems to be slowing down the rate at which Indian firms are able to develop commercial hybrid vehicle technologies without infringing existing international patents owned by industry leaders like GM and Toyota.

Another important aspect to keep in mind is the distinction between the incremental cost of the low carbon technology and the potential cost of the IPR. In many cases, there will be virtually no demand for the low carbon technology in developing countries unless the incremental cost is covered by international mechanisms such as CDM, by domestic policies such as renewables targets, or energy efficiency standards (which can yield cost savings to the equipment users). This can also be related to different remedies – free IP will only make the low carbon technology competitive if the incremental cost is less than the IPR. In the case of IGCC for example, where IP may only be about 2% of the incremental costs of IGCC over conventional coal technologies, free IP would still make IGCC more expensive than conventional coal coal technologies. Compulsory licensing might be needed, but a way of funding the incremental cost would also be required.

The case studies made it clear that there are often complex numbers of IPRs relating to single low carbon technologies. Whilst IPRs have not prevented Indian companies being active, whether commercially or at the R&D stage, in production related activities across all five case studies analysed in this report, they do seem to slow the rate at which Indian companies can commercially produce low carbon technologies, particularly if they wish to produce at the cutting edge. This may have implications for the rate at which India can generate low carbon technological capacity, which in turn may negatively impact on the overall potential for, and speed at which a country could achieve a transition to a low carbon economic growth trajectory.

This position is well articulated by Sauter and Watson (2008) in relation to the potential for developing country firms to "leapfrog" towards producing technologies at the cutting edge, and the broader implications of this for developing countries' potential for leapfrogging over the high carbon industrial development pathways characteristic of developed economies:

> "...while intellectual property rights (IPRs) are generally considered as a necessary protection by leading firms (Goldemberg 1998), IPRs can at the same time constitute a major impediment for technological leapfrogging. While they do not necessarily prevent the diffusion of cutting edge technologies, they can be used by their owners to keep competitors away from their markets and prevent others to make useful experience for further developments and improvements of

> the technology (Steinmueller 2001). Such learning processes are fundamental for the creation of knowledge and skills – an important element of technological capabilities required for the leapfrogging of industrial development pathways."[1]

This situation suggests that there may be specific instances in specific countries where international policy intervention may be desirable to address situations where IPRs are slowing the rate at which developing country firms can start producing low carbon technologies. In the longer term, the results of this study suggest that international collaboration along the research, development, demonstration and deployment (RDD&D) spectrum represents an important opportunity to avoid situations where IPRs might become a barrier to technology transfer. It is also important to highlight the fact that enabling access for users of low carbon technologies, rather than producers of them, requires carefully tailored financing mechanisms for assisting in meeting higher costs of low carbon technologies relative to conventional technologies. Finally, it must also be recognized that although many commentators stress patents as being the most relevant type of IPR for low carbon technologies, patents do not represent the whole picture. Trade secrets and other tacit knowledge are also very relevant in terms of understanding and acquiring knowledge relating to technologies. Here, once again, there is an important role for international collaborative RDD&D initiatives as a means for promoting knowledge sharing.

International collaborative RDD&D mechanisms

As noted above, international collaboration on RDD&D can play an important role in facilitating long term initiatives that avoid problems with IPRs slowing the rate at which developing country firms can commercially produce cutting edge low carbon technologies. It can also facilitate access to the tacit and other relevant knowledge necessary to manufacture some low carbon technologies, and hence play an important role in developing low carbon technological capacity amongst developing country technology producers, which is important for underpinning sustained, low carbon economic growth.

The case studies analysed in this report highlighted several other important aspects of collaborative RDD&D initiatives. In terms of the benefits of such initiatives, collaborations between Indian and international companies were important in the SME case studies where the relevant technologies needed to be adapted to India-specific conditions to make them appropriate for end users in India. At the technology producer end, international collaborations were observed to speed the rate at which Indian producers were able to move towards producing at the cutting edge. For example, an Indian PV company that collaborated with an international firm took much less time to develop the capabilities necessary to manufacture thin film solar PV than another Indian firm which relied on indigenous R&D.

1 Sauter, R. and Watson, J. (2008) Technological Leapfrogging: A Review of the Evidence Report for UK Department of International Development. SPRU, University of Sussex, December: 13. Available at http://www.sussex.ac.uk/sussexenergygroup/documents/dfid_leapfrogging_reportweb.pdf

In terms of how to develop effective collaborative RDD&D mechanisms, the results of this study emphasise the need for public-private engagement. India's National Hybrid Propulsion Platform (NHPP) is an excellent example of a public-private partnership, although it lacks involvement from international players. The findings of the SME case study also highlighted the need for a needs-based approach to developing RDD&D collaborations that directly involves local actors. This case study also emphasised the importance of making follow-on funding available to ensure that the benefits of collaborative initiatives diffuse amongst wider end users as opposed to ending with those actors involved in initial collaborations.

Although Indian companies were clearly aware of which international companies they would benefit from collaborating with, they rarely mentioned any existing intergovernmental initiatives that aim to foster such collaborations. This suggests a need to better communicate and target international initiatives towards relevant companies in developing countries.

The study suggested that the main incentive for international companies to collaborate with Indian companies was the promise of access to new markets in India. This highlights an important need for domestic policy incentives to boost demand for low carbon technologies, whether end use technologies like hybrid vehicles (e.g. via tax incentives for low carbon vehicles, or emissions limits on new vehicles), or energy generation technologies such as renewables or IGCC (e.g. via feed-in tariffs or incremental cost subsidies). Where companies at the cutting edge of technologies were unwilling to collaborate with Indian firms, some Indian firms tended to look to overcome this barrier by working with second tier companies. For example, a number of companies seeking to manufacture hybrid vehicles were entering into discussions with international firms other than market leaders Toyota.

Policy recommendations

Significant contributions have recently been made in developing potential institutional architecture for facilitating technology transfer under the United Nations Framework Convention on Climate Change (UNFCCC). It is not our intention here to add to this literature. We would instead encourage interested readers to consult the work of E3G and Chatham House in this regard.[2] These policy recommendations concentrate instead on key criteria for successful international collaborative (Research, Development, Demonstration and Deployment) RDD&D initiatives, which is the focus of this report. There are two good reasons for this focus.

Firstly, *based on this study's findings, it is likely that international collaborative RDD&D initiatives will have a significant impact on technological capacity development at the same time as offering creative ways around issues related to IPRs.* Secondly, *early engagement in international collaborative RDD&D initiatives*

2 Tomlinson, S., Zorlu, P. and Langley, C. (2008) Innovation and technology transfer. Framework for a global deal. E3G and Chatham House, London

might also address individual companies' and countries' concerns with maintaining comparative advantages.

As well as the policy recommendations set out below, the main report also provides a guide to decision makers for identifying key issues that international and national policy must address in relation to specific technologies. Finally it makes some India-specific recommendations for potential areas which, based on the case studies analysed in this report, might benefit from international collaborative RDD&D initiatives.

Criteria for establishing successful collaborative RDD&D initiatives

Policy designed to facilitate the establishment of collaborative RDD&D initiatives should be guided by the following criteria.

Identify appropriate participants

- Collaborations must involve both public and private actors and should be facilitated at the international level with the aim of bringing together technology leaders with interested companies in developing countries.

- Collaborations should also aim to strengthen links across different sectors of the domestic economy within developing countries, especially industry/academia/government connections. Each of these players can bring different skills and expertise to the table. This recommendation draws on the triple helix model in innovation studies where industry, the academic sector and governments at various levels (nation, region / state, and local) work together to innovate. The argument is that projects with more sources of leadership and support will be more likely to succeed.

- Industry associations at the local/state levels can play an important role in assisting with the identification of suitable locations for initiating collaborative programmes, while multilateral agencies can facilitate inter-governmental partnerships and bring international technical experts together.

Identify key sectors

- Efforts should focus on establishing initiatives that are specifically designed to address the differing levels of technological capacities that exist in relation to low carbon technologies within specific developing country contexts.

- Using Technology Needs Assessments as a starting point, a multilateral body should commission assessments of the existing technological capacity across specific priority sectors and technologies within a country. This should then be used to assess which sectors would benefit most from the establishment of international RDD&D collaborations. These assessments must also identify which stage of the RDD&D spectrum needs to be focused on. It is likely that this will differ according to the specific industry, technology and/or country context.

Secure engagement

- To facilitate engagement by international firms, clear articulation of the benefits (e.g. new market access, access to knowledge of local technological requirements) is required. Provision of such information could usefully be facilitated by investigations commissioned under the auspices of a multilateral body.

Address intellectual property rights

- Collaborative initiatives require specific, up front agreements as to how IP will be treated.

- Partners may be more likely to commit resources if IP is agreed to be shared.

- Consideration also needs to be given to whether governments or supporting multilateral organisations might want to specify time horizons for IPRs resulting from such collaborations being made publicly available so that wider society might benefit. These time horizons must be long enough to allow partners to initially capitalise to the extent that eventual public availability of IP does not deter actors from engaging.

- Collaborative initiatives should include a specific element aimed at increasing knowledge and awareness of the domestic and global IP system. The fieldwork that supported this study suggested that, although many of the low carbon energy industry experts consulted are aware that India has a domestic patent system (and some had submitted patents in India and elsewhere) and is undertaking major reforms in this area, they were not aware of all specific incentives that the patent office has put in place (e.g. a relaxation of fees for Indian submitters vs. foreign submitters).

Provide Finance

- Sustained financial support is required to ensure any insights or technological advances arising from such collaborations are transferred throughout the sector (as opposed to only benefiting those companies initially involved in the collaboration).

- It is essential that financial mechanisms offer support across the full RDD&D spectrum. All too often funding opportunities have tended to focus on initial R&D and/or commercialisation of fully developed new technologies, whilst failing to support the integral stages of demonstration and subsequent adaptation which occur prior to technologies being ready for commercial adoption. This lack of funding in the middle stages of technology development is often referred to as the "valley of death" as it contributes to promising new technologies never reaching commercialisation.

Decision making guide for identifying optimal transfer arrangements

Policy makers will be aided in attending to the above recommendations via the use of the following framework for decision makers (Figure 1). It begins with questions regarding the existing technological capacity within the recipient country. On the basis of answers to these questions, questions are then raised in relation to: transfer arrangements; temporal considerations; and, incentive structures. These questions should be answered within the context of an understanding of the theoretical discussion in the introduction to this report, and the summary of key findings and policy recommendations in the concluding section of this report. In the main report an applied example is provided of how this decision making guide can work in practice by using it to consider the development of hybrid vehicle manufacturing capabilities in India.

Figure 1. Decision making guide for identifying optimal transfer arrangements for maximising technological capacity development

Existing technological capacity

Is this hardware or software related? Or both? Is the relevant knowledge explicit or tacit? Or both?
What is the nature of the skills required to implement this technology?
What sectors do these skills encompass?
What level of these skills currently exists in the recipient country?
Which sectors need to be targeted for development via the transfer arrangement?
Is there a need to increase connectivity between public, private and research sectors?

Transfer arrangements	Temporal considerations	Incentive structures
Which firms or other actors own the relevant technologies? Are they foreign or domestic? Do patents (or other IPRs e.g. copyrights for computer software) exist? Or have they expired? Have patents been issued at the national and international (triadic – EPO, Japan and US PTO) levels? How willing are these actors to transfer the technology? Are there any IPR issues that need to be negotiated? Are there alternative approaches that might overcome barriers relating to unwillingness of actors to share the technology? This could include approaching second tier firms, or considering domestic technology development. Which activities along the RDD&D spectrum would be most beneficial in plugging any identified skills gaps? Is it possible to negotiate less integrated transfer arrangements with maximum use of host country skills, labour and parts? Is it possible to negotiate specific knowledge transfer and training arrangements as part of the transfer process?	What overall development strategy is technology transfer playing a part in? Is the desire to leapfrog over high carbon development pathways and avoid lock-in to high carbon infrastructure, or is a slower, more iterative development pathway acceptable (with potentially higher opportunities for learning and capacity building)? If barriers are to be overcome via an indigenous development route, what are the implications of this for speed of technology diffusion and associated carbon emissions?	If activities at earlier stages of the RDD&D spectrum are desirable, what incentive structures are in place to bring international, private sector players to the table (e.g. promise of new market access)? And how are these incentives to be communicated to the relevant actors? Are there any policy related barriers, either national or international, that need to be addressed (e.g. tariffs and subsidies, IPR regimes)? Are there any market failures that need to be addressed? Are policies in place to encourage more domestic engagement in technology transfer (e.g. certain % of domestic ownership, products and services only sourced locally, etc.)?

1. Study background

This report contains the findings of Phase II of the UK-India collaboration on low carbon technology transfer. The collaboration began at Gleneagles in July 2005 where the G8 highlighted the importance of strengthening technology cooperation to develop low carbon energy options. Many developing countries pressed for a new approach to international cooperation in the area of clean energy technologies. As a follow-up, the UK Government and the Government of India decided to collaborate on a study to assess the barriers to the transfer of low carbon energy technology between developed and developing countries.

Low carbon technology transfer to developing countries has a central role to play in mitigating[3] carbon emissions from future economic growth and is a key issue in the international climate negotiations under the United Nations Framework Convention on Climate Change (UNFCCC). The promise of access to new technologies is widely recognised as a central incentive for developing nations to support and / or ratify in the UNFCCC in 1992. Although it was nominally designed to facilitate low carbon technology transfer, the success of the Convention in achieving this[4] has been widely questioned with many developing nations left feeling frustrated at the lack of technology transfer in practice.[5], [6] Negotiations on the issue have become increasingly fraught, with clean technology nearly falling off the agenda in Bali 2007 due to disagreements between the United States (US) and G77/China[7].

Despite the high profile of technology transfer within international negotiations, inadequate empirical evidence exists upon which to base policy. The different stages of development of low carbon technologies, from research and development (R&D) through to commercial diffusion, introduce new and unique barriers, opportunities and policy challenges which are not yet properly

3 Technology transfer also occurs in relation to adaptation technologies but the focus of this paper is on technologies for mitigation.

4 Feldman, D. L. 1992. Institutions for managing global climate change. Compliance, fairness, and universal participation. Global Environmental Change 2:43-58

5 It is important to note that a lack of effective technology transfer to the developing world (and particularly least developing countries) is not limited to low carbon technologies. See Foray 2008, cited in Oliva, M. J. 2008. Climate Change, Technology Transfer and Intellectual Property Rights, prepared for the seminar Trade and Climate Change, Copenhagen June 18-20, 2008. Winnipeg: International Institute for Sustainable Development/International Centre for Trade and Sustainable Development: 3, which looks at technology transfer to least developed countries more broadly, within the context of the World Trade Organization (WTO).

6 Khor, M. 2008. Access to Technology, IPRs and Climate Change, Day One Session, European Patent Forum. http://www.epo.org/about-us/events/epf2008/forum/details1/kohr.html

7 The Group of 77, established in 1964, as well as China, often referred to G77/China, is the name of the key bloc of developing nations within the UNFCCC process.

understood.[8] These challenges are confounded by the need for urgent action if dangerous climate change is to be avoided.[9]

A key concern of the UK-India collaboration from which this report has emerged is to contribute to plugging the evidence gap on low carbon technology transfer. The central aim is to provide a grounded, case study led empirical base upon which to test policy proposals and guide the development of effective decision making in this area.

The UK-India collaboration has resulted in two Phases of research to date. This report presents the findings of Phase II of the research, but by way of context a brief summary of Phase I is warranted here.

Phase I reported in 2006[10] and used a combination of literature review and case study research to answer two key questions:

1. What are the barriers to successful technology transfer?

2. What policy incentives and other initiatives might overcome these barriers?

The Phase I study findings were officially launched at the Gleneagles Dialogue meeting held in Mexico and the Regional Sustainable Development Summit in Shirakawa, Japan in October 2006. Following this, the findings of the report were promoted at a side event at the UNFCCC COP in Nairobi. This event was chaired by Dr Pachauri (Chair of the Inter-governmental Panel on Climate Change, IPCC) and included opening representations from the UK Secretary of State, David Miliband MP and the Indian Minister for Environment, Shri Namo Narain Meena. Both ministers gave the study their full endorsement and called for a Phase II study focussing on the areas that the report highlighted as necessary to further understand how to overcome barriers to low carbon technology transfer.

A distinctive feature of the Phase I UK-India study was the approach, which combined insights on technology transfer with insights from work on technological change and development. It is the development of broader technological capacity that will define the ability of countries such as India to absorb and innovate around low carbon technologies in the long term. This long-term technological capacity development is also integral to ensuring countries' economic development. The approach adopted in this Phase II study aims to contribute to developing practical approaches for achieving technology transfer in such a way as to contribute to long-term technological capacity building in recipient countries.

8 Ockwell, D., J. Watson, G. MacKerron, P. Pal, and F. Yamin. 2008. Key policy considerations for facilitating low carbon technology transfer to developing countries. Energy Policy, 36(11): 4104–4115

9 Stern, N. 2006. Stern Review on the economics of climate change. HM Treasury, London; IPCC. 2007. Fourth Assessment Report Climate Change 2007: Synthesis Report Summary for Policymakers. Inter-Governmental Panel on Climate Change, Geneva, Switzerland

10 See http://www.sussex.ac.uk/sussexenergygroup/1-2-9.html for copies of the Phase I executive summary and full report

1.1 Objectives

The scope of Phase II was defined around three main tasks:

1. The development of a decision making guide to help policy makers ensure technology transfer activities have maximum impacts on developing new technological capacity in recipient countries;

2. Further work on intellectual property rights (IPRs), including the development of policies that could help to overcome IPR barriers; and

3. Developing recommendations of how collaborative research, development, demonstration and deployment (R,D,D&D) initiatives between developed and developing countries might contribute to technology transfer.

Detailed descriptions of these three main tasks and the ways in which the tasks relate to one another are provided below.

i. Decision making guide of barriers to low carbon technology transfer

One objective of this study was, via general lessons learnt from the case studies analysed here and in Phase I, to develop a practical framework that decision makers can use to guide them in ensuring that technology transfer activities have maximum possible impacts in developing new low carbon technological capacity in recipient countries.

ii. Intellectual Property Rights (IPRs)

The first phase of work concluded that access to intellectual property rights was important. It also suggested, however, that resolution of IPR issues might be a necessary but not sufficient condition for successful low carbon technology transfer. Particularly in view of the political rhetoric surrounding IPRs, Phase II investigated the issue empirically via various low carbon technology case studies.

iii. Joint research, development, demonstration and deployment (RDD&D)

Joint RDD&D between institutions in developed and developing countries has been identified as one mechanism to build up technological capacity in developing countries. Collaboration in research is growing, at both national and international levels, enhancing the quality of research and increasing diffusion of scientific knowledge.[11] It may also help to overcome IPR barriers to low carbon technology transfer and deployment. Other studies suggest that in the areas of environmental technologies research, results between various partners

11 Ponds, R. 2009. 'the Limits to Internationalization of Scientific Research Collaboration'. *the Journal of Technology Transfer* 34: 76-94: 77.

are increasingly being subjected to proprietary rights (these can be made public), which all project partners are entitled to, to provide more incentives for partners to devote significant resources (time, personnel and funds) to these initiatives. These partnerships are more likely to be successful when the technologies are at an earlier stage of development.[12]

Phase II therefore sought to analyse the extent to which Indian firms had benefited from collaborative RDD&D initiatives. This was then used to guide recommendations for designing future collaborations. In particular, the potential for joint activities that improve technological capacity *and* overcome IPR barriers – was investigated.

Existing or potential areas for international collaboration on RDD&D were also an area of focus of the study. Some argue that national innovation policies, "fundamentally designed around national competitiveness priorities, not to produce global public goods", work against effective cooperation in this area.[13] They suggest that international RDD&D initiatives be prioritised, noting that current collaborative R&D between countries is relatively weak, although a few examples exist such as international cooperation on long term technologies including nuclear fusion. These researchers assert that actions at the multilateral level are an important way to augment national policies and encourage international cooperation.[14]

Although international collaboration is increasing, both generally and in the area of low carbon energy technologies, the majority of cooperation is between industrialized countries.[15]

12 Lee, B. 2008. 'Stream 5 IPRs and the Diffusion of Climate Technologies ' in House, C. (ed.) *Chatham House Project on Trade, Financing and Climate Change: Building a Positive Agenda for Developing Countries*. London: Chatham House.

13 Tomlinson, S., Pelin Zorlu and Claire Langley 2008. 'Innovation and Technology Transfer – Framework for a Global Climate Deal' in House, E.G.a.C. (ed.). London E3G and Chatham House: 8.

14 Tomlinson, S., Pelin Zorlu and Claire Langley 2008. 'Innovation and Technology Transfer – Framework for a Global Climate Deal' in House, E.G.a.C. (ed.). London E3G and Chatham House: 8-10.

15 For further details on a study examining clean coal patents and international collaborations, see Lee, B. 2008. 'Stream 5 IPRs and the Diffusion of Climate Technologies ' in House, C. (ed.) *Chatham House Project on Trade, Financing and Climate Change: Building a Positive Agenda for Developing Countries.* London: Chatham House.Lee (2008), citing work done by Cust et al. (2008), where multilateral cooperation has increased from 1998-2007.

2. Study methods and approach

Central to the approach taken in this study was an emphasis on understanding the most effective approach to developing new technological capacity in India. This was informed by the analysis in Phase I which highlighted the centrality of technological capacity to sustained, low carbon growth in developing countries.

A case study approach was adopted, whereby it was sought to ground the analysis in real world examples of Indian firms currently working, or seeking to work with specific low carbon technologies. This allowed the study team to test various ideas and assumptions that characterise policy discussions on low carbon technology transfer, and analyse the extent to which they reflect the reality faced by India firms working with low carbon technologies.

The emphasis throughout the study was on a consultative approach that engaged directly with industry, government and researchers, both to yield grounded empirical insights and to raise awareness of the study amongst potential end users. About 200 people provided insights for this report. The majority of informants were based in India. However, where possible, discussions were also held with actors from the industrialized world.

The methodology was broken down into three stages:

1. Scoping phase

2. Data collection

3. Analysis

The stages are outlined in detail below.

2.0 Scoping phase

The key focus of the scoping phase was, via a detailed selection process, to identify a small number of energy technology case studies that would provide empirically grounded insights across all three of the study's key areas of focus. The remainder of this section describes the process by which the case studies were selected.

Meetings and workshops

The choice of potential case studies was initially informed by a number of meetings and workshops. At the very outset of the study, a Steering Group consisting of Indian and UK policy representatives was convened. This provided a starting point for case study identification and, following the detailed process described below, the five case studies selected were all ones that were identified by the Steering Group in that initial meeting.

Two other meetings/workshops were important in informing the case study selection. These were a workshop held at a side event of the UNFCCC COP in Bali in December 2007 and an internal project kick-off meeting held in March 2008 via video conference between TERI and SPRU.

This process resulted in a very broad list of potential case studies and relevant initiatives that might warrant consideration during the study. These are detailed in **Annex 1.**

Assessment process underpinning case study selection

Selection criteria

The following criteria formed the basis for filtering the potential case studies listed above.

The case studies needed to inform all three of the study aims, namely:

1. Development of a decision making guide of barriers to low carbon technology transfer;

2. Conduct further work on intellectual property rights (IPRs), including the development of policies that could help to overcome IPR barriers; and

3. Develop recommendations of mechanisms and technologies to foster joint research, development, demonstration and deployment (RDD&D) between developed and developing countries.

Key issues that the study team used to guide their selection were:

- How much information is likely to be readily available regarding the technology?

- How likely is it that industry representatives in India and in the host country will speak openly with the project team?

- Are there any technologies or sectors (e.g. Indian SMEs or the Phase I case studies) that the research team has existing expertise in / knowledge of and that would therefore be likely to yield greater insights or easier access to industry via existing contacts?

More specifically, for the IPR case studies, there was a need to consider the following:

- Energy technologies, not necessarily low carbon
- Technologies where IPRs have been prohibitive
- Technologies where IPRs have not been prohibitive
- Comparisons with other sectors e.g. pharmaceuticals, steel

Selection process

Using the above criteria to guide their analysis, a process was agreed that would maximise the level of scrutiny that the original list of possible case studies was subjected to and provide an in built process of expert peer review. This consisted of TERI and SPRU working separately to produce a list of case studies that the teams at each institution independently believed to have the most potential to yield useful insights. These were then written up, together with the rationale for each institution's selection, and shared with the partner institution. A face-to-face meeting between TERI and SPRU was then held at the University of Sussex at which each team presented their case study selection and, following in depth discussion, a final list of five case studies was agreed upon.

In the event, all three case studies suggested by TERI were also independently suggested by SPRU for similar reasons. SPRU also suggested three additional potential case studies that were, via discussion at the meeting with TERI, filtered down to two additional case studies. This brought the final number of technology case studies to five. The case study selection and the rationale for these choices are detailed below.

Selected case studies

As a result of the process outlined in above, the following cases studies were selected to provide the basis for the study.

Integrated gasification combined cycle (IGCC) for power generation

India has large reserves of coal relative to its current production levels with a reserves-to-production, R/P, ratio of 217. This compares favourably with

India's R/P for crude oil which is 20.7 and its R/P for natural gas which is 36.2.[16] One limitation of Indian coal is its high ash content (around 50%). This adds additional energy requirements for cleaning and transporting coal for power generation. Coal meets around 60% of commercial energy needs and around 70% of electricity generated in India comes from coal.[17] This implies that coal is likely to play an important part in India's energy mix at least in the short to medium term.

The introduction of technologies that can reduce CO2 emissions from coal is therefore important in reducing carbon emissions. IGCC is one of the most promising coal based power generation technologies with the potential for significantly lower carbon emissions per kWh of electricity generated. Emissions of other pollutants such as SO2 and NOx are also lower with IGCC.

IGCC was one of the case studies in Phase I of the UK-India study. The Phase I study identified key international and Indian players in relation to IGCC and areas where technology transfer barriers are likely to exist. In Phase II it was sought to build on the broad review conducted in Phase I, and focus specifically on the pulverised fluidised bed gasification (PFBG) system which is thought to have highest potential for compatibility with high ash Indian coal. This technology is also currently the subject of demonstration and therefore provides a strong basis for analysing collaborative RDD&D initiatives in the context of a pre-commercial technology. This demonstration also enabled the study team to analyse how IPR issues are being dealt with in the context of these kinds of pre-commercial technologies.

Carbon Capture and Storage (CCS) in the context of IGCC

CCS was considered inappropriate as a focus for a case study in its own right because CCS incorporates a number of different technologies, which would all need to be assessed. The current focus on CCS in India is on R&D, but there may be scope in the future for work in this area.

Nevertheless, CCS is recognised as an important technology that has the potential to significantly reduce emissions of CO2 from fossil fuel power generation. Without CCS it will be significantly harder to reduce emissions to avoid dangerous climate change, and emission reductions will cost more overall. The Stern Review estimates that to limit global warming to +20C without CCS will increase costs by more than 60%.

Energy efficient technology adoption in Indian SMEs

The SME (small and medium enterprise) sector occupies a position of prominence in the Indian economy, contributing more than 50% of the industrial

16 British Petroleum (BP) Statistical Review of World Energy June 2006, http://www.bp.com/sectiongenericarticle.do?categoryId=9010939&contentId=7021564

17 The Energy and Resources Institute (TERI), 1998, Energy Data Directory & Year Book, 1997/98

production in value added terms. The sector accounts for one third of exports and employs the largest manpower next to agriculture. SMEs mostly remain isolated from technological developments taking place in their respective industries and hence continue using traditional, often obsolete, technologies.

There is a need to develop specific and focused RDD&D programs for adoption of cleaner technologies by SMEs. This is important considering the fact that the SMEs in general do not have the inherent financial and technical capacity to undertake research or adaptation activities to enable them to improve their energy and environmental performance.

This case study aimed to build on past work conducted by TERI on energy efficiency among Indian SMEs. It focussed in particular on two successful RDD&D projects undertaken for the foundry and glass SME sub-sectors in India. Both projects involved the transfer of technologies developed in the UK – Divided Blast Cupola (DBC) furnace for the foundry industry developed by BCIRA (British Cast Iron Research Association) and natural gas fired pot furnace for the glass industry developed by British Glass. The projects involved technology adaptation to local conditions, technology demonstration and capacity building for Indian project proponents. Interestingly, both projects were funded by the Swiss Agency for Development and Cooperation.

This case study provides a useful juxtaposition with the IGCC case study for two reasons. Firstly, it focuses on sectors involving numerous small actors rather than a few larger players. Secondly, the issues involved focus more on "softer" aspects of technology transfer, such as the absorptive capacity of Indian firms, the diffusion of existing commercial technologies, access to finance and knowledge flows. It raises important questions with regard to how policy can deal with technology transfer in the context of more diffuse sectors.

Wind energy

Current installed wind capacity in India exceeds that of nuclear and is growing rapidly. The huge success of the wind sector in India provides an invaluable opportunity to understand the factors underpinning this success. Important insights can be gained with regard to how private sector actors have dealt with potential IPR issues and the extent to which these issues may or may not have retarded the acquisition of technology at or close to the international best practice frontier. Insights were also sought into the way that collaborations between developed and developing country firms have enabled Indian companies to occupy world leading positions. Wind also provided an opportunity for understanding the way in which public policy for stimulating demand for a technology interacts with policy more specifically concerned with facilitating international technology transfer. In terms of technological scale, this and the solar PV case study detailed below provided an intermediate focus between IGCC and SMEs.

Solar PV

The cost of solar PV has meant that its uptake is still limited in developing countries such as India. Interestingly, however, most of the growth in PV manufacture in India has been oriented towards the export market, often to Germany which currently leads the world in terms of installed capacity. This provides an interesting case where some flows are south-north as opposed to north-south. Interesting insights were therefore anticipated via exploring how this situation developed. Important questions did, however, need to be asked, such as whether Indian companies have access to cutting edge design, where the IPR ownership lies, whether key components are manufactured outside India and then assembled by Indian companies.

Hybrid vehicles

Transport, and private mobility in particular, is one of the fastest growing sectors in terms of greenhouse gas emissions. Whilst the current level of car ownership in India is far below that of most developed nations, India's transport sector is predicted to show the highest rate of growth in energy demand of any sector over the next 30 years .[18] At a world level, fuel for transport accounts for some 32% of final energy use. Almost all of this energy is in the form of oil with transport accounting for 60% of total oil usage.[19] Introducing policies and technologies that can mitigate transport related carbon emissions is therefore a priority.

The inclusion of hybrid vehicles in the study, as well as addressing an important sector, also ensures that at least one end use technology is included. The way that hybrid vehicle technologies have developed globally raises a host of interesting issues with regard to IPR and collaborative RDD&D initiatives. There are also several important questions that need to be asked in relation to the likelihood of developing country companies gaining access to the knowledge that underpins these technologies. Questions also arise in relation to the way that the technology has developed via conglomerations of large international players, the strategies that these companies have pursued, and the means by which countries such as India might gain access to this technology now and in the future.

Hybrid vehicles formed one of the case studies in Phase I of the UK-India study. This was extremely useful in terms of developing a picture of who the key players are globally and in India and identifying the key questions that need to be asked in relation to this technology in a technology transfer context. However, the time scale of Phase I did not allow enough time to access the right people in the industry that could comment on these questions, or, more importantly, sufficient engagement with Indian companies engaged in relevant initiatives in this sector. Phase II therefore sought to rectify this.

18 TERI. 2006. Energy for the future: making development sustainable. Report for the Ministry of Environment and Forests, Government of India. TERI, New Delhi: 2.

19 IEA. 2006. Advanced Materials for Transportation. in. International Energy Agency

2.1 Data collection

Once the case studies had been selected, primary responsibility for each case study was divided between TERI and SPRU as follows:

- IGCC – TERI
- Wind – TERI
- SMEs – TERI
- Solar PV – SPRU
- Hybrid vehicles – SPRU

However, a member of the SPRU team was based at TERI for a significant part of the data collection phase, thus enabling TERI and SPRU to work closely with one another and co-operate across all of the case studies.

Data collection focused on both primary and secondary sources, including:

1. Face-to-face and phone interviews with key players in the low carbon energy sector. The bulk of these interviews occurred during October-November 2008, however a few occurred in January-February 2009. Interviewees were asked questions regarding the present status of technology development in their organization and future plans, issues and apprehensions related to Intellectual Property Rights (IPRs), perceived risks and constraints, collaborative RDD&D initiatives, and government engagement with their sector. Furthermore, the questions were designed to serve as posts, to guide discussions, to create a more informal atmosphere. For a list of the specific interview questions, please see **Annex 2**.

2. Presentations and side line informal discussions with participants at six meetings and workshops:

   a) A side event at the UNFCCC 13th Convention Of the Parties in Bali December 2007;

   b) National Conference-cum-Exhibition, "Solar PV: Emerging Viable Options with Technology and Policy Thrusts", India Habitat Centre, New Delhi, October 30, 2008

   c) Workshop on "National Hybrid Propulsion Platform (NHPP)", Mahindra and Mahindra, Mumbai November 24-25, 2008[20];

20 There were approx. 75-100 people at the first meeting, but about 20 people provided information. There were about 20 participants at the second meeting, and almost all participants provided information.

d) A workshop with around 20 representatives from industry, government and academic institutions working in the case study sectors, held at The Energy and Resources Institute (TERI), New Delhi, India November 28, 2008;

e) A side event at the 14th Conference of the Parties in Poland, December 2008;

f) A side event of the Delhi Sustainable Development Summit, February 2009.

3. Desk-based analysis of academic and grey literature.

As noted earlier, about 200 people provided insights for this report. The majority of informants were based in India. However, where possible, discussions were also held with actors from the industrialized world, including those who gave a cross-cutting perspective, and those in the IGCC, hybrid vehicles and EE technologies for SMEs case studies. 19 people were consulted for their views on all or some of the case studies and / or the report in general (cross cutting views). For the PV case study, SPRU consulted 30 people. For the hybrid vehicles case study, SPRU consulted 23 individuals. The SME case study was based on evidence from TERI's previous in depth work in this area. TERI consulted with 5 people from 5 different organisations (3 private companies and 2 Indian Government departments) for the IGCC cases study, and 4 people from 3 different private companies for the wind case study.

2.2 Analysis

The results of the interviews, workshops, meetings and literature reviewed in relation to each case study were then analysed with a focus on insights revealed of relevance to the three main focus areas of the study. This was then used to generalise on key considerations in relation to IPRs and RDD&D. It also informed development of the decision making guide. The key considerations were then drawn upon to develop policy recommendations. This process ensured that the recommendations contained in this report were properly grounded in empirical evidence collected from actors involved with low carbon technologies.

3. Contextual overview

3.0 Low carbon technology transfer

This section will give a brief overview of the debate on technology development and transfer as part of a climate change mitigation strategy. Although some of this information was discussed in Phase I, this section provides readers with important context on this issue. This will explain the different types of technology transfer including vertical transfer (often rather simplistically characterized as transfer of technology from the laboratory or test bed into commercial use) and horizontal transfer (transfer from one geographical and/or firm context to another). It will also note that horizontal technology transfer – which is what most of the debate with respect to climate change focuses on – often needs to be combined with vertical transfer to be effective. In doing so, the section will note that there are different technology transfer flows that can be occur. These range from the transfer of capital equipment to the transfer of underlying technological knowledge that would allow developing countries to develop independent capabilities in low carbon technologies.

The term 'technology transfer' can mean many different things. It has been defined and measured in many different ways and assessed against a wide range of criteria.[21] Technology transfer has therefore attracted attention from a broad range of perspectives including business, law, finance, microeconomics, international trade, international political economy, environment, geography, anthropology, education, communication, and labour studies.[22] This has produced an equally wide range of frameworks and models of technology transfer, but to date no overarching theories have emerged. In his review of research and theory on technology transfer, Bozeman,[23] states that:

> "In the study of technology transfer, the neophyte and the veteran researcher are easily distinguished. The neophyte is the one who is not confused. Anyone studying technology transfer understands just how complicated it can be."

Nevertheless, there are several key definitions, distinctions and insights that have emerged from the broader literature on technology transfer that are

21 Schnepp, O., von Glinow, M.A. and Bhambri, A. 1990. United States – China Technology Transfer. New Jersey: Prentice Hall.

22 IPCC 2000. Methodological and technological issues in technology transfer. Cambridge: Cambridge University Press.

23 Bozeman, B. 2000. 'Technology transfer and public policy: a review of research and theory'. Research Policy 29: 627-655.

relevant when considering the transfer of low carbon technologies between developed and developing countries.

Schnepp et al.[24] define technology transfer as "... a process by which expertise or knowledge related to some aspect of technology is passed from one user to another for the purpose of economic gain." Technology transfer is a term that relates to any type of technology, not just low carbon technology. Within the current climate of environmental concern, however, the economic gain that Schnepp et al. speak about in their definition of technological transfer can be interpreted in a wider context that includes the economic benefits provided by the environment as a source of natural resources that feed into the economic process and a sink for emissions that result from the economic process. In the case of the transfer of low carbon technology, these economic benefits are associated with the mitigation of the future costs associated with climate change[25]. As with any technology transfer, however, low carbon technologies may also yield financial benefits to the companies involved in the transfer process.

3.1 Types of technology transfer

One important distinction in the literature on technology transfer is between vertical technology transfer (the transfer of technologies from the research and development (R&D) stage through to commercialisation) and horizontal technology transfer (the transfer from one geographical location to another). Schnepp et al.'s[26] definition quoted above refers to horizontal technology transfer. In reality, this distinction between horizontal and vertical technological transfer is unlikely to be so distinct. Transfer of low carbon technology between developed and developing countries, which this study is primarily interested in, likely to involve elements of both. The transfer of technology from one country to the next represents horizontal transfer. But this transfer may also involve a degree of vertical transfer as many low carbon technologies are currently pre-commercial or supported technologies and undergo development towards commercialisation within the new country context.

Technology transfer may also take the form of internalised or externalised transfers by trans-national companies.[27] Internalised transfers usually form part of a package of foreign direct investment (FDI) where access is provided to a range of technological, organisational and knowledge assets as well as marketing experience and brand names. Externalised transfers are those made

24 Schnepp, O., von Glinow, M.A. and Bhambri, A. 1990. United States – China Technology Transfer. New Jersey: Prentice Hall: 3.

25 See Ockwell, D. and Lovett, J.C. 2005. 'Fire assisted pastoralism vs. sustainable forestry – The implications of missing markets for carbon in determining optimal land use in the wet-dry tropics of Australia'. Journal of Environmental Management 75: 1-9

26 Schnepp, O., von Glinow, M.A. and Bhambri, A. 1990. United States – China Technology Transfer. New Jersey: Prentice Hall.: 3

27 Ivarsson, I. and Alvstam, C.G. 2005. 'Technology transfer from TNCs to local suppliers in developing countries: A study of AB Volvo's truck and bus plants in Brazil, China, India, and Mexico'. World Development 33: 1325-1344.

to firms outside the direct ownership or control of the company transferring the technology. This occurs through initiatives such as minority joint ventures, franchising, distribution agreements, sales of capital goods, licenses, sub-contracting, or original-equipment-manufacturing arrangements. R&D can also generate beneficial external linkages within recipient countries but is depends on the availability of adequate R&D facilities.

3.2 The centrality of knowledge transfer

A key insight to emerge from the literature is that technology transfer is not just a process of capital equipment supply from one firm to another. Comprehensive technology transfer also includes the transfer of skills and know-how for installing, operating and maintaining technology hardware, and knowledge for understanding this technology so that further independent innovation is possible by recipient firms.[28] This process can be broken down into two stages. The first stage is the supply of technology to recipient countries. This can be split into three separate technology flows, namely:

a) Capital goods and equipment

b) Skills and know-how for operating and maintaining equipment

c) Knowledge and expertise for generating and managing technological change

The second stage involves building on these three technology flows to develop new capacity within the recipient country. This capacity consists of both new production capacity and new technological capacity. It is this new capacity for production and technological innovation that is most likely to ensure successful technology transfer and long term advances in technology development in recipient countries.[29]

Within the economics literature there is a divide on how technology transfer translates into new technological capacity within recipient countries. The long-term importance of knowledge for developing new capacity within technology importing countries is universally accepted. The divide relates to how this knowledge is generated. Traditionally, knowledge was believed to be generated through 'accumulation theories'.[30] They assume that the learning that underpins capacity building within developing countries automatically follows capital investments. In this view, capacity building in developing countries would be

28 Bell, M. 1990. 'Continuing Industrialisation, Climate Change and International Technology Transfer'. University of Sussex: SPRU.

29 Worrell, E., van Berkel, R., Fengqi, Z., Menke, C., Schaeffer, R. and Williams, R.O. 2001. 'Technology transfer of energy efficient technologies in industry: a review of trends and policy issues'. Energy Policy 20: 29-43.

30 Ivarsson, I. and Alvstam, C.G. 2005. 'Technology transfer from TNCs to local suppliers in developing countries: A study of AB Volvo's truck and bus plants in Brazil, China, India, and Mexico'. World Development 33: 1325-1344; Nelson, R.R. and Pack, H. 1999. 'The Asian miracle and modern growth theory'. Economic Journal 109: 416-436.

encouraged by increased capital investment facilitated, for example, by a more competitive economic policy environment.

More recently, however, 'assimilation theories' of technology transfer have gained greater support from the empirical evidence on technology transfer.[31] Assimilation theories stress that learning is a key factor in making capital investments successful. Knowledge transfer therefore becomes central to successful capacity building in recipient countries. The availability of knowledge as part of the technology transfer process is not, however, enough on its own. Assimilation theorists also stress the importance of risk taking and entrepreneurship by firms in recipient countries to facilitate learning. The generation of inter-firm linkages through regular local production by foreign operators is also seen as integral to knowledge generation with external linkages resulting in technological upgrading among local suppliers. In this sense, external technology transfers are more likely to generate new technological capacity in recipient countries than internal transfers which might simply exploit low labour costs.[32] Competing in international export markets may also be an issue here in driving awareness of international standards and contracting with developed country firms who demand and facilitate high standards.[33]

As well as highlighting the importance of using local suppliers, the assimilation view of technology transfer implies that all three flows of technology (flows A, B and C) are important for enabling recipient countries to develop their own technological capabilities. This has been problematic in the past, as the predominant type of technology supply to developing countries has tended to focus on the first of these: capital goods and equipment.[34] For example, a database of international aid to China's energy sector compiled by Evans[35] showed that 80% was focussed on funding construction of new thermal and hydro-power plants. The primary aim of this aid was to finance the export of equipment supplied by foreign firms.[36]

31 Ivarsson, I. and Alvstam, C.G. 2005. 'Technology transfer from TNCs to local suppliers in developing countries: A study of AB Volvo's truck and bus plants in Brazil, China, India, and Mexico'. World Development 33: 1325-1344; Nelson, R.R. and Pack, H. 1999. 'The Asian miracle and modern growth theory'. Economic Journal 109: 416-436; Worrell, E., van Berkel, R., Fengqi, Z., Menke, C., Schaeffer, R. and Williams, R.O. 2001. 'Technology transfer of energy efficient technologies in industry: a review of trends and policy issues'. Energy Policy 20: 29-43.

32 Ivarsson, I. and Alvstam, C.G. 2005. 'Technology transfer from TNCs to local suppliers in developing countries: A study of AB Volvo's truck and bus plants in Brazil, China, India, and Mexico'. World Development 33: 1325-1344.

33 Nelson, R.R. and Pack, H. 1999. 'The Asian miracle and modern growth theory'. Economic Journal 109: 416-436.

34 Bell, M. 1997. 'Technology transfer to transition countries: are there lessons from the experience of the post-war industrializing countries?' in Dyker, D.A. (ed.) The technology of transition: Science and technology policies for transition countries. Budapest: Central European University Press; Watson, J., Oldham, G., MacKerron, G., Thomas, S. and Xue, L. 2000. 'The Transfer of Cleaner Coal Technologies to China: A UK Perspective'. London: DTI.

35 Evans, P.C. 1999b. 'Japan's Green Aid Plan: The Limits of State-Led Technology Transfer'. Asian Survey 39: 825-844.

36 Watson, J., Oldham, G., MacKerron, G., Thomas, S. and Xue, L. 2000. 'The Transfer of Cleaner Coal Technologies to China: A UK Perspective'. London: DTI.

Saad and Zawdie[37] also point out how the transfer of plant and equipment to developing countries has often been based on 'turnkey' and 'product-in-hand' contracts that focus on boosting industrial growth rather than fostering innovation. They also highlight the fact that restrictive terms of contracts between trans-national companies and firms based in developing countries have limited the scope for fostering innovation through 'reverse engineering'. A good example of this is licensing within the global power plant equipment industry.[38] The leading companies in this industry provide licenses to developing country firms for the manufacture of equipment such as gas turbines. However, these licenses exclude the manufacture of the most 'high tech' components such as the first row of turbine blades which incorporate advanced materials, cooling technologies and manufacturing techniques.

Moreover, technology transfer has often conformed to a linear model of relationships between technology suppliers and importers, which precludes knowledge sharing. From the perspective of encouraging the long-term adoption of low carbon technologies in developing countries, it is therefore important that technology transfer includes flows of skills and knowledge as well as capital goods and equipment. Successful examples of purely knowledge-based technology do exist. For example, a joint initiative between China and the Netherlands which established an intelligent transport systems training centre in China is reported to have made a promising initial impact on tackling congestion in Shanghai.[39]

Others have also recognized the importance of focusing on all three technology flows. For example, Tomlinson, Zorlu and Langley (2008) argue that developing countries require a broader approach to increase innovative capacity, rather than a narrow approach to technology transfer. They further suggest that developing countries focus on three areas for innovative capacity including disruptive innovation, or those technologies which are very different from the current technologies that dominate (e.g. small scale power generation with thin film solar cells), orphan areas of research, or those areas of research often neglected by the industrialized world as they are more beneficial to the needs of developing rather than industrialized countries (e.g. small scale desalination, drought-resistant African crops), and adaptive innovation, (e.g. adapting gasifiers to be better suited for local coal sources).[40]

While these areas of research are important areas for consideration, there is also a need for developing countries to focus on incremental innovation, where user and producer interfaces are even more important in developing

37 Saad, M. and Zawdie, G. 2005. 'From technology transfer to the emergence of a triple helix culture: The experience of Algeria in innovation and technological capability development'. Technology Analysis & Strategic Management 17: 89-103.

38 Watson, J. 1997. 'Constructing success in the electric power industry: Combined cycle gas turbines and fluidised beds' SPRU. Brighton: University of Sussex.

39 van Zuylen, H.J. and Chen, Y.S. 2003. 'Technology transfer of intelligent transport systems – China and the Netherlands' Transportation Management and Public Policy 2003.

40 Tomlinson, S., Pelin Zorlu and Claire Langley 2008. 'Innovation and Technology Transfer – Framework for a Global Climate Deal' in House, E.G.a.C. (ed.). London E3G and Chatham House.: 11.

innovations, rather than disruptive or radical innovations where the work of Science and Technology institutes may be more dominant, at least initially.[41]

As highlighted by the IPCC's[42] report on technology transfer, this increasing awareness of the centrality of developing knowledge-based capacity within developing countries has led many people to feel uncomfortable with the term "technology transfer". They argue that it encourages a view of technology as an object and transfer as a one off transaction that maintains dependency on host country suppliers. Suggested alternative terms include 'technology cooperation',[43] 'technology diffusion'[44] and 'technology communication'.[45] These tend to emphasise technology transfer as a more dispersed, uncoordinated process that occurs over time with a central emphasis on a two-way relationship between technology suppliers and importers.[46]

3.3 Knowledge transfer and intellectual property rights (IPRs)

One issue in the area of low carbon technology transfer that has provoked particularly thorny debate between developed and developing countries, and which epitomises the lack of empirical evidence available to guide decision making, is the issue of intellectual property rights (IPRs). IPRs are legal rights over ideas, creative processes and products. They include copyrights, trademarks, and patents – where holders can prevent the use of these technologies; thus patents are likely the most important type of IPRs within this context.[47] Private firms hold the majority of patents.[48]

41 Bunders, B., Marjolein Joske and Jacqueline Zweekhorst 1999. 'the Triple Helix Enriched with the User Perspective: a View from Bangladesh'. *Journal of Technology Transfer* 25: 2350246.: 242
42 IPCC 2000. Methodological and technological issues in technology transfer. Cambridge: Cambridge University Press, Section 1.4.
43 Heaton, G.R., Banks, R.D. and Ditz, D.W. 1994. 'Missing Links: Technology and Environmental Improvement in the Industrializing World'. Washington DC.: World Resources Institute; Martinot, E., Sinton, J.E. and Haddad, B.M. 1997. 'International technology transfer for climate change mitigation and the cases of Russia and China'. Annual Review of Energy and the Environment 22: 357-401.
44 Grubler, A. and Nakicenovic, N. 1991. 'Long Waves, Technology Diffusion and Substitution.' Review 14: 313-342.
45 Robinson, R.D. 1991. The International Communication of Technology: A Book of Readings. New York: Taylor and Francis.
46 IPCC 2000. Methodological and technological issues in technology transfer. Cambridge: Cambridge University Press, Section 1.4.
47 Harvey, I. 2008. Intellectual Property Rights: The Catalyst to Deliver Low Carbon Technologies. Breaking the Climate Deadlock, Briefing Paper. Ian Harvey and the Climate Group, London: 5. Other IPRs include copyrights, which could be particularly relevant in the case of software used for low carbon energy technologies and Plant Variety Protection, relevant for both mitigation (e.g. biofuels) and adaptation (e.g. drought-resistant varieties of crops) Abbott, F. 2008. 'Innovation and Technology Transfer to Address Climate Change: Lessons from Global Policy Development on Intellectual Property and Public Health' *United Nations Framework Convention on Climate Change, Conference of the Parties* 14 (COP14). Poznan.: 6
48 Tomlinson, S., Pelin Zorlu and Claire Langley 2008. 'Innovation and Technology Transfer – Framework for a Global Climate Deal' in House, E.G.a.C. (ed.). London E3G and Chatham House.: 25.

There are essentially two sides to this debate. On one side commentators assert that low carbon technologies are a form of public good,[49] contributing as they do to the mitigation of future carbon emissions, and that the IPRs to these technologies should therefore be bought up by an international fund and made freely available to developing countries. Where companies were unwilling to sell IP relating to low carbon technologies, such a fund might need to be supported by compulsory licensing, where the government, not the patent owner, sets the terms of a technology license and grants a company a non-exclusive license to use or sell a patented technology.[50] Advocates of this view often cite similar agreements made in relation to certain anti-retroviral drugs for treating Human Immunodeficiency Virus / Acquired Immunodeficiency Syndrome (HIV/AIDS) in the pharmaceutical industry. Various mechanisms have been created to address intellectual property rights (IPRs) in the other areas in those instances in which they have affected access to these technologies. These options, examined in more detail in following sub-sections, include compulsory licenses, the creation of a multilateral fund, and a joint statement the World Trade Organization (WTO) and World Health Organization (WHO).

Several commentators have, however, cautioned about the comparability between these case studies, or the pharmaceutical examples given above, and low carbon technologies. These commentators[51] highlight the fact that in the case of pharmaceuticals and bioengineering, the technologies in question are sometimes subject to single patents and the cost of replication once patents are accessed is low. This is not the case for many low carbon technologies, and is certainly not the case for any of the case studies examined in this study. Instead, many low carbon technologies are subject to a myriad of different patents relating to different parts and processes. Consider, for example, the number of patents that are of relevant to hybrid vehicles, covering everything from batteries, and electric motors through to computer software. Or consider wind turbines where patents might exist in relation to the materials necessary for engineering turbine blades, through to gearboxes and transmission mechanisms. In this context an individual patent does not constitute a large part of the overall cost of manufacturing these technologies. It is also less straight forward to identify what the relevant patents are. The vast number of patents relating to low carbon technologies also raises questions as to the applicability of a adopting a case by case approach to addressing IP, as was adopted under the Montreal Protocol where there were relatively few patents relating to relevant chemicals for replacing ozone depleting substances.[52] Nevertheless, the experiences of these options utilized to address IP under

49 Note that, despite constant reference to low carbon technologies being "public goods", they are not 'pure' public goods by definition because if they were everyone would have access to them – they have a few of the characteristics of public goods, but are in practice rival and excludable

50 Wood, J.a.R.D. 2005. 'Compulsory Licensing on Patents in the US, China, Japan, Germany and India' *1st IPO-JIPA Asian Practice International Congress*. Seattle.

51 See, for example, Tomlinson, S., Pelin Zorlu and Claire Langley 2008. 'Innovation and Technology Transfer – Framework for a Global Climate Deal' in House, E.G.a.C. (ed.). London E3G and Chatham House: 117

52 Andersen, Stephen O., K. Madhava Sarma and Kristen Taddonio, 2007. Technology Transfer for the Ozone Layer: Lessons for Climate Change. London: Earthscan

certain circumstances can inform decisions made within the low carbon energy technology context.

On the other side of the IPR debate are those that argue that low carbon technology transfer will be better facilitated if developing countries tighten up their legal frameworks for IPR protection, and the enforcement thereof.[53] Many observers and parties to the IPR debate are pinning their hopes on further empirical analysis providing a basis for guiding new policy responses or for supporting the maintenance of the status quo. Various actors form alliances to better their negotiating position. For example, India, Brazil and South Africa (IBSA), in their trilateral cooperative arrangement, have specifically agreed to work together to coordinate their positions on technology transfer in the Multilateral Environmental Agreements (MEAs).[54]

However, as noted by some including Abbott, it is desirable that "the time and energy needed to negotiate changes to international IPR rules be expended only if genuine practical constraints are identified, and that negotiations not be initiated based on flawed assumptions".[55] Before exploring IPRs in any more depth, however, it is worth raising a note of caution. As some of the authors of this report have argued elsewhere,[56] it is possible that a political divide between developed and developing countries, rooted in differing motivations for becoming party to the UNFCCC, will manifest itself in different interpretations of the policy implications of the same empirical evidence on IPRs and technology transfer. That said, the level of empirical research that has been conducted to date on IPRs and low carbon technology transfer is extremely sparse, implying definite value be attached to further empirical research in this area. As stated in a recent report by E3G and Chatham House:

> "Extensive interviews with technology experts and companies showed that most views were guided by anecdote and assumption, rather than evidence...there is currently no sound basis for any definitive statements that IPR is – or is not – a barrier to low carbon technology diffusion across the transfer of key [low carbon] technologies."[57]

53 In the UN climate negotiations in 2008, these polarities continued to surface as some developing countries including India and China asserted the need to address IP issues within the discussions on technology, while some industrialized countries, such as the United States, espoused the view that IP was a catalyst and not a barrier for technology transfer Oliva, M.J. 2008. 'Climate Change, Technology Transfer and Intellectual Property Rights, prepared for the seminar Trade and Climate Change, Copenhagen June 18-20, 2008': Winnipeg: International Institute for Sustainable Development/ International Centre for Trade and Sustainable Development.: 4.

54 India, B., South Africa (IBSA) Plan of Action 2004. 'IBSA Plan of Action': IBSA., para. 15

55 Abbott, F. 2008. 'Innovation and Technology Transfer to Address Climate Change: Lessons from Global Policy Development on Intellectual Property and Public Health' *United Nations Framework Convention on Climate Change, Conference of the Parties* 14 (COP14). Poznan.: 4.

56 David G. Ockwell, Alexandra Mallett, Ruediger Haum and Jim Watson (in review) "Intellectual property rights and low carbon technology transfer: the two polarities of diffusion and development", Global Environmental Change, available at http://www.sussex.ac.uk/sussexenergygroup/documents/ockwell_et_al_conflicting_discourses_of_dev_diffusion.pdf

57 Tomlinson, S., Pelin Zorlu and Claire Langley 2008. 'Innovation and Technology Transfer – Framework for a Global Climate Deal' in House, E.G.a.C. (ed.). London E3G and Chatham House.: 14

Some have also suggested a quantitative examination of patents for low carbon energy technologies can shed further insights into this field. However, undertaking a quantitative exercise in this area is difficult because

> "Climate technologies are too heterogeneous to be subject to any across-the-board generalizations. [Moreover], unlike other heterogeneous technologies like nanotechnology, the U.S. Patent and Trademark Office (PTO) [as well as other patent databases] do not recognize green technology as a class. Thus it is not necessarily easy to find reliable quantitative information about patent rights in these technology families."[58]

Nevertheless, a cursory examination of the Organization for Economic Cooperation and Development (OECD) patent database (PATSTAT), which includes statistics on Science and Technology patents (although 'green technology' is not a category as noted above) submitted to the European Patent Office (EPO), among others, the dominance of OECD countries is particularly telling.

As indicated in the table below (Table 3.1), of the over 127, 000 science and technology patents submitted to the EPO in 2005, only 557 (0.4%) were from India. When looking at the sub-category of electricity (which includes all forms, and not just renewables), the differences are stark (59 (0.2%) patents from India vs. over 25 000 worldwide in 2005).

58 Lee, B. 2008. 'Stream 5 IPRs and the Diffusion of Climate Technologies ' in House, C. (ed.) *Chatham House Project on Trade, Financing and Climate Change: Building a Positive Agenda for Developing Countries.* London: Chatham House.

Table 3.1 – Science and Technology Patent Applications to the European Patent Office (EPO) by Year[59]

Patents Office & Triadic Patents Families		Patent Applications to the European Patent Office						
Reference country		Inventor(s) Country(ies) of Residence						
Reference Date		Priority Date						
Time		1999	2000	2001	2002	2003	2004	2005
Main IPC classes & selected technology domains	Country							
TOTAL Patents	Australia	942.3	991.9	938.9	975.2	1 004.4	1 071.7	1 055.5
	Finland	1 412.1	1 405.8	1 382.8	1 256.1	1 263.7	1 340.4	1 279.1
	Germany	20 882.9	21 973.6	21 713.1	21 449.1	21 700.9	22 571.1	23 141.9
	Japan	18 647.0	21 561.5	19 737.5	20 030.5	21 077.0	22 063.8	20 802.4
	Switzerland	2 487.1	2 704.3	2 768.5	2 624.5	2 716.7	2 974.1	3 044.3
	United States	30 279.7	30 867.1	30 023.6	31 080.0	31 553.2	32 708.0	33 470.1
	European Union of twenty seven	48 807.0	51 226.0	50 775.1	50 403.5	51 575.5	53 764.7	54 617.9
	OECD – Total	104 335.8	110 819.7	108 021.3	109 672.9	113 513.1	119 597.6	120 843.3
	World	106 934.0	114 068.0	111 510.0	113 571.0	118 099.0	124 560.0	127 031.0
	China	185.3	319.5	411.5	558.1	816.3	967.0	1 599.0
	India	146.7	177.5	271.4	442.0	505.3	504.1	557.0

59 In this database Science and Technology includes nanotechnology, electricity, chemicals, agriculture, biology, among others. Source: (OECD), O.f.E.C.a.D. 2009. 'OECD Stat Extracts – Patents by Main IPC' in OECD (ed.). Paris: OECD.

Electricity Patents	Australia	90.8	84.2	113.5	100.1	105.7	94.0	109.1
	Finland	687.1	638.3	602.9	552.2	516.1	547.7	529.7
	Germany	3 395.0	3 685.2	3 407.2	3 292.3	3 177.1	3 271.1	3 430.3
	Japan	5 094.6	5 850.0	4 983.7	5 001.1	5 392.1	5 497.2	5 145.1
	Switzerland	297.3	363.8	402.9	336.5	309.0	359.4	331.2
	United States	5 918.5	5 839.6	5 445.8	5 827.9	5 951.7	6 038.6	6 470.7
	European Union of twenty seven	8 981.4	9 521.0	9 344.1	8 665.7	8 329.0	8 673.6	8 999.5
	OECD – Total	21 102.7	22 464.2	21 240.4	21 277.8	21 942.7	23 148.4	24 097.8
	World	21 532.0	23 045.0	21 929.0	22 064.0	22 811.0	24 222.0	25 728.0
	China	30.8	82.9	121.9	195.3	292.7	470.3	824.0
	India	10.4	17.3	25.8	33.4	45.2	61.5	59.0

Data extracted on 2009/02/12 17:52 from OECD.Stat

Note – Fractional counts applied for patents with multiple inventors/applicants:
When several inventors from different countries invented a patent, the respective contributions of each country are taken into account. This is done in order to eliminate multiple counting of such patents.

For example, a patent co-invented by 1 French, 1 American and 2 German residents will be counted as:

- 1/4 of a patent for France,
- 1/4 of a patent for USA,
- 1/4 of a patent for Germany

3.1.1 Global Trends in IPRs

A number of scholars have argued that Intellectual Property Rights (IPRs) are becoming increasingly complex and more comprehensive, spanning from technological products to living organisms, privately and publicly funded research results, and various products and services.[60]

The previously held dominant view regarding IPRs and developing countries (up until the 1980s), espoused by the majority of those from the developing world, as well as leading experts from industrialized countries, was that strong IPRs held no advantage for developing countries as the bulk of recipients of these IPRs – through patents, copyrights, etc. – were from industrialized nations. The argument was that developing countries should be afforded special status regarding IPRs as their welfare would improve with low IPR protection and there would be little negative impact on the industrialized world.[61]

However, a shift in opinion among industrialized nations occurred in the 1980s, where emphasis was placed on having stronger IPR regimes in developing countries – manifested in the Trade Related Aspects of Intellectual Property Rights (TRIPS)[62] agreement of 1994. This agreement, emphasizing strong IPR protection, requires both process and product patents in countries under Article 27, regardless of the technology, although it allows countries the ability to refuse to patent plants and animals. Moreover, adherence to TRIPS was made a requirement to join the World Trade Organization (WTO). TRIPS affords developing countries more time to comply with the measures (e.g. under Article 65, India was given until 2005 to comply). Despite this extra time, with limited exceptions, TRIPS treats developing countries and industrialized countries as equivalent. Some 'carrots' offered to developing countries who made strong IPRs a priority were trade benefits.[63]

Opinion within industrialized countries also shifted on how knowledge was to be appropriated and shared. For instance, the 1980 Bayh-Dole Act in the United States gave universities IPRs on results of research that had been publicly funded.[64] The argument is that scientists are aware that, while changing with the Internet, often, to gain access to cutting-edge information and technologies (e.g. to be invited to conferences, take part in projects, get access to research funds), one's reputation and credibility needs to be established through publishing, and taking part in previous research projects. In essence, scientists are becoming

60 Forero-Pineda, C. 2006. 'The impact of stronger intellectual property rights on science and technology in developing countries'. *Research Policy* 35: 808-824.: 808.

61 Ibid.: 809.

62 TRIPS, or the agreement on Trade Related Aspects of Intellectual Property Rights, aims to create uniform IPR protection across developed and developing countries. It is administered by the WTO and has brought IPRs into international trade negotiations for the first time. Developing countries were given longer to conform to the agreement than industrialized countries and least developed countries have until 2013 to conform, and 2016 for pharmaceutical patents.

63 Forero-Pineda, C. 2006. 'The impact of stronger intellectual property rights on science and technology in developing countries'. *Research Policy* 35: 808-824.: 814 and 820, Ragavan, S. 2001. 'Patent Amendments in India in the Wake of TRIPS'. CASRIP Newsletter.: 1.

64 Forero-Pineda, C. 2006. 'The impact of stronger intellectual property rights on science and technology in developing countries'. *Research Policy* 35: 808-824.: 809.

more entrepreneur-like[65]. Scientists know that to publish, access research funds, etc., they need to "play the game". In this vein, there will be more of an incentive to innovate if national IPR systems recognize the work of the individual scientist, firm, etc.[66]

Countries that recognize IPRs and patents will lead to more competitive behaviour among these actors through the quest to increase a firm's or research institution's "inventions".[67] With respect to IPR patents and research institutions, depending on the area of study, they may become concerned that other entities will copy their invention. Although in theory these research institutions are not concerned with making a profit, less recognized "inventions" and research specialties often lead to fewer research dollars which they need to survive.[68]

At the same time, support for collaboration to ensure that indigenous knowledge (e.g. herbs and plants and 'traditional' medicines from developing countries) through IPR remains in the hands of developing countries is espoused by a number of major developing countries, including the India, Brazil, South Africa (IBSA) bloc, versus an explicit agreement to disregard IPR.[69] Some argue that this support comes from alliances between companies from developed and developing counties to persuade developing country governments to adopt stronger IPR protection.

Nevertheless, concerns about the impacts of strong IPRs on developing countries[70] – especially in the area of pharmaceuticals where flexibility was allowed and even encouraged – has lead the WTO and the World Health Organization (WHO) to stress their support for differential pricing, where companies can charge different rates for drugs in industrialized countries versus the developing world, as long as there is no risk of leakage of these products back into their core markets.[71]

Although the global trend is shifting towards support for strong IP regimes, some multinational corporations (MNCs) have tended to develop and / or encourage the importation of technologies that have a 'natural' patent in an effort to ensure their profit is maximized. Douthwaite's examination of various innovations, including a rice harvester, show that the Kubota mechanical rice

65 Gibbons, M.e.a. 1994. *The New Production of Knowledge: the Dynamics of Science and Research in Contemporary Societies*. London: Sage Publications.: 23.

66 Mani, S. 2002. *Government, Innovation and Technology Policy: an International Comparative Analysis.* Cheltenham, UK: Edward Edgar Publishing Ltd.: 29.

67 Gibbons, M.e.a. 1994. *The New Production of Knowledge: the Dynamics of Science and Research in Contemporary Societies*. London: Sage Publications.: 26.

68 Ibid.: 16

69 India, B., South Africa (IBSA) Plan of Action 2004. 'IBSA Plan of Action': IBSA., para. 22

70 For example, up until January 2003, one HIV / AIDS drug manufacturer was charging US$2 000 per year higher in Guatemala versus in Switzerland. In 2001 in South Africa, the price of one generic version of an antiretroviral (stavudine) developed at Yale but licensed to Bristol-Myers Squibb (BMS), was 34 times less than the BMS version of the drug using the brand name Zerit, ' t Hoen, E. 2003. 'The Responsibility of Research Universities to Promote Access to Essential Medicines'. *Yale Journal of Health Policy, Law and Ethics* III: 293-300.: 294-295.

71 Forero-Pineda 2006: 815.

reaper, a Japanese technology introduced to harvest rice in the Philippines, is simply too expensive, complex, and difficult to maintain and repair locally.[72]

3.3.2 India and IPRs

Under the previous global regime that saw strong IPRs as hindering innovation in developing countries, India, with its 1970 Indian Patent Act (IPA) focused on granting patents to processes "relating to food, medicine and chemical processes" rather than product patents, which allowed flexibility in producing similar products, as long as potential patent holders could prove that the process they used was distinct. Other developing countries also adopted this model.[73]

However, under the new prevailing model emphasizing strong IPRs globally, and to comply with TRIPs, the Indian government passed the First Patent Amendment Act in 1999. Many countries including the United States recognize that India has shifted its position in support of a stronger IP regime, especially with the creation of permanent legislation to comply with TRIP, creating product patents, in 2005.[74]

Patent Rules aimed at making the system simple, transparent and effective were notified in May 2006. Patent filing has increased manifold since then from less than 13 000 in 2003-04 to more than 35 000 in 2007-08. However, it has only been less than four years since India has undertaken these major reforms. One India IPR expert noted that "it was only a matter of time" and that submissions from Indians to their domestic patent system would increase, the number of Indians knowledgeable about this topic would increase, etc. Some have claimed that India is trying to catch up with China who has been seriously working on this issue since TRIPS in 1994.[75]

At the same time, as noted above, many Indians and foreigners recognize the recent efforts being undertaken by the Government of India (GoI) to demonstrate that they are moving towards a stronger IP regime, especially since 2005. The GoI has been actively pursuing an awareness campaign and is undertaking major training initiatives, including the opening up of the National Intellectual Property Training Institute in Nagpur on IPRs.[76] Bilateral cooperation agreements on IPRs have been signed with leasing countries such as UK, France, Australia, US, Japan, Germany and Switzerland. The Indian Patent Office has been recognised as an International Searching Authority and an International Preliminary Examining Authority (IPEA) under the Patent Cooperation Treaty (PCT) of the World Intellectual Property Organisation (WIPO).

72 Douthwaite, B. 2002. *Enabling Innovation*. London: Zed.: 62
73 Ragavan, S. 2001. 'Patent Amendments in India in the Wake of TRIPS'. *CASRIP Newsletter.*: 1; Forero-Pineda, C. 2006. 'The impact of stronger intellectual property rights on science and technology in developing countries'. *Research Policy* 35: 808-824.: 814
74 Representative, U.S.T. 2005. 'USTR Special 301 report – Adequacy and Effectiveness of intellectual property right (IPR) protection by U.S. trading partners'. Washington: USTR.: 27
75 Interview, one Indian IP expert, November 2008
76 Interviews, IPO officers and industry experts, October and November 2008

This recognition has put India in an exclusive group of 15 countries that are recognised as world leaders in the field of IPRs.

To date, India has not instituted a compulsory license, although under the 2005 Amendments to the Patent Act one may be granted after three years of issuing a patent under a number of circumstances, including if "'reasonable requirements of the public are not satisfied' (they are not available to the public at a reasonable price, they prejudice or harm existing domestic trade or industry, or they fail to develop the market for exports)."[77]

Finally, it is worth pointing out that a number of informants indicated that one advantage India has is its inheritance of the British legal system, with checks and balances, courts and due processes, which has been in place for many years.[78] While IP law is important, enforcement of the law is critical.

3.3.3 Two sides of the IPR debate

There are essentially two sides to the IPR debate in relation to low carbon technology transfer. Firstly, drawing on assumed parallels with the pharmaceutical industry and access to, for example, anti-retroviral drugs[79], some observers claim that a lack of access to IPRs for new low carbon technologies is a key barrier to their transfer and deployment in developing countries.

For example, one reason why projects involving Concentrating Solar Power (CSP) technologies funded by the Global Environment Facility (GEF) have been slow to develop is due to the fact that the price offered by bidders was more than the GEF had anticipated (e.g. despite GEF interest in developing CSP projects in Mexico, Morocco, Egypt and India, none of these projects are under construction). One reason for these high prices could be due to intellectual property rights (IPRs).[80] However, it is difficult to say with certainty what role IPRs may have had here. Another reason for the slow development of these projects is due to the fact that the industry is still considered nascent and fragile. At the time these projects were being put forward, there was little comparable investment elsewhere globally. According to Miller "the GEF experience also suggests that technology commercialisation is also more likely to succeed in developing countries, when linked to larger technology developments, particularly those in the industrialized countries."[81]

77 Wood, J.a.R.D. 2005. 'Compulsory Licensing on Patents in the US, China, Japan, Germany and India' *1st IPO-JIPA Asian Practice International Congress*. Seattle.

78 Informal discussions, key informants, October and November 2008

79 Anti-retroviral drugs are the class of drugs prescribed to treat those with HIV / AIDS. For further discussion on this see for example ' t Hoen, E. 2003. 'The Responsibility of Research Universities to Promote Access to Essential Medicines'. *Yale Journal of Health Policy, Law and Ethics* III: 293-300.

80 Philibert, personal communication, December 2007; Justus, D.a.P., Cedric 2005. 'International Energy Technology Collaboration and Climate Change Mitigation – Synthesis Report'. Paris: International Energy Agency (IEA).

81 Miller, A. 2007. 'the Global Environment Facility program to commercialize new energy technologies'. *Energy for Sustainable Development* XI: 5-12.: 11.

Proponents that assert IPRs are preventing the transfer and development of these technologies in developing countries see low carbon technologies as a form of a public good (due to their contributing to avoiding future carbon emissions) that should be freely available. Proponents of this argument highlight how IPRs can prohibit access to new technologies by, for example, enabling firms that own patented technologies to keep prices prohibitively high. They also observe how IPRs can reduce the scope for imitation which, in countries such as South Korea and Japan, and even the United States, has been a key source of learning and technological change.[82]

However, as noted earlier, translating experiences from the global pharmaceutical regime to the global climate change regime must take a number of differences into account. First of all, in pharmaceuticals, often a single patent determines its use, versus low carbon technologies where several patents often exist in relation to different components and technological developments.[83] Secondly, many note that patent protection is particularly important in the pharmaceutical industry due to the nature of the products and processes, which consist of a combination of high R&D costs and low reverse engineering costs. Scholars also argue that much information on foundational technologies for low carbon energy technologies is out in the open and that "what we know now seems to suggest that innovation in [low carbon energy technologies] is less likely than in the pharmaceutical field to block market entry because incremental innovations are more likely than foundational innovations to leave room for alternative technological pathways".[84]

At the same time, a number of researchers argue that the current global IP regime does not encourage low carbon energy technology transfer enough. They have examined ways to address IPRs directly through the TRIPS agreement including: 1) various provisions under the current TRIPS agreement, including through the preamble, Articles 6, 7, and 8 among others, should they be considered a barrier for climate technology transfer to developing countries; 2) modifying TRIPS to give developing countries more flexibility for their domestic IP laws and low carbon energy technologies; or through 3) unrelated institutions, including a world competition agreement.[85]

Such arguments have played out in the negotiations under the auspices of the UNFCCC where calls have been made for **multilateral funds** to be created to buy up IPRs (e.g. negotiate technology licenses, make licenses compulsory,

82 UNCTAD-ICTSD. 2003. Intellectual Property Rights: Implications for Development. International Centre for Trade and Sustainable Development (ICTSD) and United Nations Conference on Trade and Development (UNCTAD), Geneva, Switzerland: 85.

83 Harvey, I. 2008. Intellectual Property Rights: The Catalyst to Deliver Low Carbon Technologies. Breaking the Climate Deadlock, Briefing Paper. Ian Harvey and the Climate Group, London: 9.

84 Abbott, F. 2008. 'Innovation and Technology Transfer to Address Climate Change: Lessons from Global Policy Development on Intellectual Property and Public Health' *United Nations Framework Convention on Climate Change, Conference of the Parties 14 (COP14).* Poznan.: 7.

85 For an extensive review of the potential for transferring climate technologies to developing countries under TRIPS please see Littleton, M. 2008. 'the TRIPS Agreement and Transfer of Climate-Change-Related Technologies to Developing Countries' in (UNDESA), U.N.D.o.E.a.S.A. (ed.) DESA Working Papers. New York, NY: UNDESA.

or buy down the costs of several technologies to make them more widely accessible) for low carbon technologies and make them freely available to developing countries.[86] This is one of the key suggestions put forth by the Government of India (GoI) in their submission on a Technology Transfer Mechanism to the UNFCCC, which will be discussed in further detail in Section 3.10.

An example often cited by proponents of this view is the case where the GEF purchased the needed IP to manufacture efficient industrial coal-fired boilers in China. This project provided funding for nine Chinese boiler manufacturers to produce model units from advanced boiler technologies, and then the equipment to mass-produce these more efficient boilers.[87]

At the same time, the effectiveness of this approach is not clear. Some argue that it took a long time to get the licenses, which had an impact on project implementation, and that GEF had to approach second-tier firms as leading international boiler makers did not take part as the terms offered were considered too restrictive. In addition, it is not really clear how much direct effect this project had on boiler efficiency in China.[88]

Critics of such a fund also highlight the fact that access to a patent is unlikely to prove sufficient to enable access to that technology. Undisclosed tacit knowledge, trade secrets and intricate expertise associated with patents is often essential to understanding and working with new technologies.[89] Phase I found that it is not clear that having access to patents will equate to increasing technological capacity. A study on compulsory licensing in several countries including the United States, Japan, Germany, China and India indicates that having compulsory licensing available as an option may be enough of an incentive for those holding patents to license their technology; arguing that despite detailed legislative guidelines in these countries, compulsory licensing has not been used frequently in practice outside of the anti-trust area.[90]

86 See, for example, Third World Network. 2008. Brief Note on Technology, IPR and Climate Change. Third World Network, Bangkok, 23 Feb 2008. Available at www.twnside.org.sg/title2/climate/briefings/BP.bangkok.2.doc

87 Ghosh, Personal Communication, November 2008; Justus, D.a.P., Cedric 2005. 'International Energy Technology Collaboration and Climate Change Mitigation – Synthesis Report'. Paris: International Energy Agency (IEA).: 11

88 Ockwell, D., Watson, J., MacKerron, G., Pal, P. and Yamin, F. 2006. 'UK-India Collaboration to Identify the Barriers to the Transfer of Low Carbon Energy Technology'. London: Report by the Sussex Energy Group (SPRU, University of Sussex), TERI and IDS for the UK Department for Environment, Food and Rural Affairs.: 48-49.

89 UNCTAD-ICTSD. 2003. Intellectual Property Rights: Implications for Development. International Centre for Trade and Sustainable Development (ICTSD) and United Nations Conference on Trade and Development (UNCTAD), Geneva, Switzerland:86, Lee, B. 2008. 'Stream 5 IPRs and the Diffusion of Climate Technologies ' in House, C. (ed.) *Chatham House Project on Trade, Financing and Climate Change: Building a Positive Agenda for Developing Countries*. London: Chatham HouseWood, J.a.R.D. 2005. 'Compulsory Licensing on Patents in the US, China, Japan, Germany and India' 1st IPO-JIPA Asian Practice International Congress. Seattle.

90 Wood, J.a.R.D. 2005. 'Compulsory Licensing on Patents in the US, China, Japan, Germany and India' 1st *IPO-JIPA Asian Practice International Congress*. Seattle.

Nevertheless, patent ownership is strongly skewed towards industrialized countries[91] suggesting that, especially within the context of stronger IPR regulations under TRIPS, it may well become increasingly difficult for developing countries to access clean technologies under these terms. For example, China estimates that over 85% of the patents in many high technology economic sectors are owned by firms in industrialized countries.[92]

Another idea to address IPRs is through the **creation of a patent pool**, which "is an agreement between two or more patent owners to license one or more of their patents to one another or third parties. It is usually a collection of patents essential to a specific area of technology that are held and administered by an independent entity that manufactures or licences the patents to third parties for a royalty payment, which is then distributed amongst the pool's patent owners."[93] Patent pools, such as those in the mobile phone and computer industries, have created competition, driving prices down and allowing companies to negotiate cross-licenses amongst each other.[94]

The opposite end of the IPR debate revolves around a claim that a lack of IPR law or the enforcement thereof in developing countries is the main barrier to low carbon technology transfer. Further, IPRs are asserted to be central to innovation and encouraging the diffusion of technologies as patents force inventors to disclose their technology publicly[95]. The argument is made that trans-national companies (TNCs) are unlikely to deploy cutting edge technologies that they have spent significant resources developing in countries where they cannot ensure adequate patent protection. IPRs are seen as a catalyst rather than a barrier to the creation and deployment of low carbon technologies, providing the incentive needed for businesses to invest in risky ventures, giving legal clarity and certainty, and stopping others from blocking the use of a technology by follow-on derivative inventions.[96] This argument is reflected in the TRIPS agreement, one of its stated rationales being that the protection and enforcement of IPRs will contribute to both increased FDI and the transfer and dissemination of technology.[97]

Moving beyond low carbon energy technologies and speaking more generally, some studies demonstrate a positive correlation between technology transfer and strong IPRs. For example, the OECD conducted a macro econometric analysis examining IPRs (through patent rights and applications) and technology transfer (through merchandise and service imports and inward Foreign

91 IPCC. 2000. Methodological and technological issues in technology transfer. Cambridge University Press, Cambridge: 98.

92 Tomlinson, S., Pelin Zorlu and Claire Langley 2008. 'Innovation and Technology Transfer – Framework for a Global Climate Deal' in House, E.G.a.C. (ed.). London E3G and Chatham House.: 8.

93 Modell, N. 2003. 'Swallow the Pill and Jump into the Patent Pool' *Law*. Kent: Kent.: 9.

94 Harvey, I. 2008. 'Intellectual Property Rights: The Catalyst to Deliver Low Carbon Technologies. Breaking the Climate Deadlock, Briefing Paper'. London: Ian Harvey and the Climate Group: 9.

95 Ibid.: 6.

96 Ibid.: 3., Justus, D.a.P., Cedric 2005. 'International Energy Technology Collaboration and Climate Change Mitigation – Synthesis Report'. Paris: International Energy Agency (IEA): 8, 11 and 25.

97 UNCTAD-ICTSD. 2003. Intellectual Property Rights: Implications for Development. International Centre for Trade and Sustainable Development (ICTSD) and United Nations Conference on Trade and Development (UNCTAD), Geneva, Switzerland: 85.

Direct Investment (FDI)) to many developing countries, as well as the rapidly industrializing economies Brazil, Russia, India and China, termed the BRICs. They found that stronger IPRs lead to an increase in inflows of high-technology products (e.g. computer and information technology, chemicals, aerospace). They further assert that stronger IPRs can also stimulate local innovation, which they measure through developing country applications for patents (by both residents and non-residents). Applications for patents by developing country firms as well as expenditure on R&D in these countries increase, as the strength of patent rights increase.[98]

By contrast, some such as Forero-Pineda argue that, more often than not, the trade benefits afforded to developing countries that join the WTO come at the cost of technological development, as the goods and services provided by Developing countries are often of low "technological content". He cites the case of Mexico where there was a distinct reduction in patent activities from domestic sources after patent reforms in that country in 1994, emphasizing robust patent protection. He examines a study on the Mexican pharmaceutical sector, which indicates that although foreign investment increased after these reforms, Mexican companies have yielded very few new technologies.[99]

One possible route forward in addressing IPR issues in the context of technology transfer is **international collaboration on low carbon technology development**. This could be on the basis of international collaborative R&D initiatives on technologies at a very early stage of development. As these technologies would be collaboratively developed, the IPRs could be structured to benefit the various partners involved, including with the aim of making the IPR available as a free or low cost public good. This kind of international collaborative R&D based approach has the added benefit of enabling knowledge sharing between collaborators which could aid long term capacity building in developing countries. The idea of a Global Research Alliance was put forward by the UK Commission on Intellectual Property Rights as a way of linking developmental objectives (capacity strengthening and sustainable development) with the more commercially driven IPR framework.[100]

In cases of technologies covered by existing IPRs, international initiatives and international funds, such as those established under the UN Framework Convention on Climate Change, could potentially play a role in negotiating licences or buying down the costs of specific technologies to make them more widely accessible. Insights from how global private/public partnerships have addressed issues of access to proprietary technologies in other sectors, such as public health, might also provide a novel approach to the issue of technology transfer.

98 Park, W.G. and Lippoldt, D.C. 2008. 'Technology Transfer and the Economic Implications of the Strengthening of Intellectual Property Rights in Developing Countries. OECD Trade Policy Working Papers, No. 62'. Paris: OECD.: 5.

99 Forero-Pineda, C. 2006. 'The impact of stronger intellectual property rights on science and technology in developing countries'. *Research Policy* 35: 808-824.: 814 and 816.

100 UK Commission on Intellectual Property Rights 2002. 'Integrating Intellectual Property Rights and Development Policy'. London: Report of the Commission on Intellectual Property Rights.

The potential for new kinds of global public/private partnerships, drawing on the experiences of global arrangements that have been agreed internationally to support access to anti-retroviral drugs for low-income countries, have not been fully explored in the climate context. More detailed work analyzing the potential application of these approaches to low carbon technologies, bearing in mind the unique features of climate change, might create a fresh approach to discussions – hence the explicit focus on collaborative RDD&D initiatives in this study.

Regardless of the approach taken to encourage technology transfer, the general consensus is that policies at the domestic and international levels can be important drivers for innovation and diffusion of technologies. This is particularly the case for low carbon energy technologies in developing countries, as there is often little or no demand for these technologies unless there are government policies to create a demand. Scholars and practitioners agree that both technology-push and demand-pull policies are necessary to encourage innovation, including in the area of low carbon energy technologies, although debates remain regarding how much emphasis (e.g. allocation of funds and resources) should be placed on one set of policies versus the other.[101]

Nemet (2007) provides a thorough examination of both push and pull types of policies and their implications for innovation for low carbon energy technologies. In his examination of the resources allocated on various R&D programs in the United States, Nemet comes to the conclusion that although R&D alone will not ensure the adoption of new low carbon energy technologies, it is a pivotal aspect of an innovation-based energy strategy; one that transforms markets and reduces barriers to their demonstration and diffusion.[102] At the same time, based on evidence from California's wind industry, although demand-pull type of policies at the federal and state levels in the 1970s and 1980s encouraged diffusion and learning-by-using --- including billions of dollars of private investment -- it is not clear that these policies stimulated inventive activity (measured by patentable activity), claiming that policy uncertainties reduce investments in innovation. He further argues, based on evidence from the PV industry, that 'learning-by-doing' only partially explains the rapid cost reductions in this industry – other factors include public and private sector R&D efforts, knowledge spillovers, among others. Thus, innovation policies need to go beyond targeting gaining experience only among firms.[103] In other words, his research supports the notion that efforts to encourage technology diffusion and innovation through policies should consist of various policy aspects, and draw from a broad suite of options.

Conflicting discourses of diffusion and development

As mentioned above, it is highly likely that the political disagreement on the treatment of IPRs in the context of the UNFCCC negotiations is rooted in

101 Nemet, G. 2007, "Policy and Innovation in Low-Carbon Energy Technologies", PhD Dissertation, Berkeley, CA: Energy and Resources Group, University of California: 22.

102 Ibid.: 62.

103 Ibid.: 165-166 and 197.

opposing political discourses[104] that have emerged from a historical north-south divide concerning the motivation for involvement in an international climate agreement (or, for that matter, environmental agreements *per se*). These two discourses can be characterised as two conflicting discourses of "diffusion" and "development".

For developed nations the key motivating factor for becoming party to the UNFCCC negotiations was, *a la* Stern,[105] recognition of a need for global action to mitigate carbon emissions so as to avoid the future costs of climate change. Developing countries, on the other hand are acutely aware that the majority of the current stock of atmospheric greenhouse gases, and hence the majority of associated warming over the next few decades, is a result of the economic activity of developed nations over the last two hundred years. On this basis they feel fully justified in pursuing a primary goal of economic development and poverty alleviation. Any involvement in an international climate agreement is tempered by the caveat that emissions reductions should not be pursued at the expense of such development.

This report also highlighted the fact that environmental problems in developing countries were at least in part a result of economic and technological deficiencies in the south. Recognition of a north-south economic/technological divide has, in the context of the UNFCCC, played out in the idea of common but differentiated responsibilities where developing nations are not subject to binding emissions targets. But not putting the brakes on economic development was not in itself a justification for developing country involvement in the UNFCCC. The main carrot came via the idea of "Activities Implemented Jointly", including Joint Implementation (JI)[106] and the Clean Development Mechanism (CDM), and in particular the idea that industrialized countries would meet some of their emissions through the transfer of new, clean technologies to developing countries.[107]

A north-south gap historically exists in terms of technology ownership[108] and technological capacity, with industrialized countries having a clear technological advantage. Developing country governments understand that increased access to technology is one of the pre-requisites of economic growth, self-reliant

104 Ockwell, D., and Y. Rydin. 2006. Conflicting discourses of knowledge: Understanding the policy adoption of pro-burning knowledge claims in Cape York Peninsula, Australia. Environmental Politics 15:379-398.
105 Stern, N. 2006. Stern Review on the economics of climate change. HM Treasury, London
106 Bush, E. J., and L. D. D. Harvey. 1997. Joint implementation and the ultimate objective of the United Nations Framework Convention on Climate Change. Global Environmental Change 7:265-285.; Kim, L. 1998. Crisis construction and organizational learning: Capability building in catching-up at Hyundai Motor. Organization Science 9:506-521.
107 Gupta, J. 1997. The Climate Change Convention and Developing Countries: From Conflict to Consensus? Kluwer Academic Publisher, Dordrecht; Grubb, M., C. Vrolijk, and D. Brack. 2001. The Kyoto Protocol A Guide and Assessment, 2. edition. The Royal Institute of International Affairs, London; Neumayer, E. 2002. Multilateral Environmental Agreements, Trade and Development: Issues and Policy Options concerning Compliance and Enforcement. London School of Economics, London; Ravindranath, N. H., and J. Sathaye. 2002. Climate Change and Developing Countries. Kluwer Academic Publishers, Dordrect: 253.
108 Missbach, A. 1999. Das Klima zwischen Nord und Süd. Eine regulationstheoretische Untersuchung des Nord-Süd-Konflikts in der Klimapolitik der Vereinten Nationen. Westfälisches Dampfboot, Münster.

development, and poverty alleviation. By becoming party to the UNFCCC, developing countries therefore saw an opportunity to access new, low carbon technology and thus contribute to reducing their technological dependency on the north[109] and become technology producers and innovators in their own right. Developing countries recognise the role that new technologies and technological change within existing industries can play in improving competitive advantage through increased factor productivity and/or the development of new, competitive products and broadening the industrial base of a country via the establishment of new industry sectors with associated employment benefits, profits and public income through taxes[110]. Access to new technology not only offers the possibility of moving up the value chain, it also provides opportunities to diversify into new products similar to the ones originally imported.[111]

As noted in Phase I and in the discussion on the centrality of knowledge flows in the technology transfer process, Bell's model[112], suggesting the importance of Flows A (capital goods, services and designs), B (skills and know-how), *and* C (knowledge, expertise and experience) in the technology transfer process, offers a useful starting point for understanding the various issues and processes that are at play here. 'Technology' first needs to be understood as both 'hardware' (physical equipment) and 'software' (knowledge and processes). Although, as Bell points out, there is no sharp distinction between C- and B-type flows, C-type flows are significantly different from, and additional to, the knowledge needed to operate a production facility. While flows A and B lead to the creation of new production capacities in the recipient country, C-type flows enable the additional benefit of augmenting technological capacity. This includes the capacity to adapt the technology to local, changing needs, to replicate it, enhance it and eventually create a new product; recognizing that this process may take a few decades. The development of new technological capacity is thus central to a firm, industry or country's ability to improve their competitive advantage and expand existing industries and the overall industrial base[113]. Hence the contribution of low carbon technology transfer to developing new technological capacity is a central concern for developing countries within the context of their economic development priority.

But while developing countries see low carbon technology transfer as a means of strengthening their technological capacity and contributing to their economic *development*, industrialized nations approach the issue from a very different perspective. As highlighted above, industrialized nations' motivation for

109 Roberts, J. T., and B. C. Parks. 2007. A climate of Injustice Global Inequality, North-South Politics, and Climate Policy. The MIT Press, Cambridge.

110 Lall, S. 1998. Investment, technology and international competitiveness. in J. H. Dunning and K. A. Hamdan, editors. The New Globalism and Developing Countries. United Nations University, Tokyo, New York, Paris; Gereffi, G. 2001. Beyond the producer-driven/buyer-driven dichotomy – The evolution of global value chains in the Internet era. Ids Bulletin-Institute of Development Studies 32:30

111 Bell, M. 1997. Technology transfer to transition countries: are there lessons from the experience of the post-war industrializing countries? in D. A. Dyker, editor. The technology of transition: Science and technology policies for transition countries. Central European University Press, Budapest.

112 Ibid.

113 Criscuolo, P. and R. Narula (2008). A novel approach to national technological accumulation and absorptive capacity: aggregating Cohen and Levinthal. The European Journal of Development Research 20(1): 56 – 73.

involvement in the UNFCCC is first and foremost the mitigation of greenhouse gas emissions. From this perspective, the primary objective of transferring low carbon technologies to developing countries is to achieve rapid and widespread *diffusion* of these technologies so as to reduce the emissions associated with future economic development in these countries. The impact of this diffusion on technological capacity and economic development is not a priority. In fact, despite the political rhetoric on poverty alleviation, industrialized countries, and certainly firms in those countries at the forefront of advanced low carbon technologies, have a vested interest in maintaining a level of completive advantage over developing countries.

The notion of diffusion under this discourse is more about diffusion at a superficial level. For example, it is possible to imagine how a technology such as solar PV cells could be put into widespread use, hence delivering emissions reductions, by supplying it 100 per cent via sales from industrialized to developing countries.[114] This might be sufficient in environmental terms but would not fulfil a developing nationís interest in technological capacity development by, for example, ëlearningí how to manufacture solar cells with the same level of efficiency as imported cells, or, for example, how to slice silicon. There are other issues to consider including technology operations, maintenance, after sales service, and the scope for incremental improvement ñ as well as the issue of costs of imported technology. These are all reasons why a focus on diffusion is too limited.

This idea of differentiated efficiency between imported and domestically produced low carbon technologies in developing countries represents another important divide between the development and diffusion discourses. As discussed further below in relation to IPRs, the diffusion discourse would see the widespread use of slightly less efficient, domestically produced technologies as a desirable outcome of technology transfer activities that have contributed to the development of domestic manufacturing capacity. From the perspective of the development discourse, on the other hand, such an outcome would be sub-optimal. The desire instead would be to develop sufficient domestic technological capacity so as to be able to manufacture a number of cutting edge, internationally competitive technologies.

The divide between the discourses of development and diffusion is central to the lack of agreement between industrialized and developing countries within the negotiations on low carbon technology transfer under the UNFCCC. As Forsyth[115] puts it: “Technology transfer has become a symbol of the long-standing resentments between North and South...”

114 As long as the basic cost barrier is overcome – which is made more significant if developed country firms are selling to developing country customers

115 Forsyth, T. 1999. International Investment and Climate Change: Energy Technologies for Developing Countries. RIIA and Earthscan, London: 60.

3.4 IPRs and low carbon technology transfer: empirical evidence to date

Empirical evidence available to date on IPRs in the context of low carbon technology transfer is extremely limited. In addition to the present study, only six other attempts to engage with the issue have been identified. The first, by Barton,[116] tackles it via a case study based review of the markets for three renewable technologies (solar PV, wind and biofuels). The second, by Lewis,[117] presents an in depth analysis of the wind power industry in China and India and is drawn on extensively in Barton's analysis. In the third, Harvey[118] addresses this issue by examining IPRs more generally among developing countries, homing in on the potential role of China and international institutions, such as the World Trade Organization (WTO). The International Centre for Trade and Sustainable Development (ICTSD) has carried out two studies that examine the role of intellectual property for climate technologies. The first document,[119] entitled "Climate Change and Trade on the Road to Copenhagen" dedicates a chapter to the potential role of IPRs. The second,[120] "Climate Change, Technology Transfer and Intellectual Property Rights", provides an overview of the issues, drawing from evidence from studies of technology (not necessarily low carbon) transfer to developing countries and discusses how IP might be dealt with under the UNFCCC process.

The final study is Ockwell et al.[121] which formed Phase I of the current study. On a case study basis, this was able to make some tentative suggestions of IPR relevant insights, but did not have enough of an explicit IPR focus to be able to explore these in any depth. The case studies studied in Phase I were integrated gasification combined cycle (IGCC) for power generation, LED lighting, hybrid vehicles, biomass generation and improving the combustion efficiency of existing power stations.

116 Barton, J. H. 2007. Intellectual Property and Access to Clean Technologies in Developing Countries. An Analysis of Solar Photovoltaic, Biofuel and Wind Technologies. International Centre for Trade and Sustainable Development (ICTSD), Geneva, Switzerland

117 Lewis, J. I. 2007. Technology Acquisition and Innovation in the Developing World: Wind Turbine Development in China and India. Studies in comparative international development 42:208-232.

118 Harvey, I. 2008. Intellectual Property Rights: The Catalyst to Deliver Low Carbon Technologies. Breaking the Climate Deadlock, Briefing Paper. Ian Harvey and the Climate Group, London

119 ICTSD. 2008. Climate Change and Trade on the Road to Copenhagen. ICTSD Trade and Sustainable Energy Series Issue Paper No.3. Forthcoming from the International Centre for Trade and Sustainable Development, Geneva, Switzerland, Ch.4

120 Oliva, M. J. 2008. Climate Change, Technology Transfer and Intellectual Property Rights, prepared for the seminar Trade and Climate Change, Copenhagen June 18-20, 2008. Winnipeg: International Institute for Sustainable

121 Ockwell, D., J. Watson, G. MacKerron, P. Pal, and F. Yamin. 2006. UK-India Collaboration to Identify the Barriers to the Transfer of Low Carbon Energy Technology. Report by the Sussex Energy Group (SPRU, University of Sussex), TERI and IDS for the UK Department for Environment, Food and Rural Affairs, London. http://www.sussex.ac.uk/sussexenergygroup/1-2-9.html; Ockwell, D., J. Watson, G. MacKerron, P. Pal, and F. Yamin. 2008. Key policy considerations for facilitating low carbon technology transfer to developing countries. Energy Policy, 36 (11): 4104-4115

Access to low carbon technologies

The above studies found that developing country firms had access to all the technologies examined. IGCC and hybrid vehicles in India were, however, still at the R&D stage and seemed to be driven by indigenous R&D rather than access to internationally owned patented, or previously patented, technologies. Indian LED manufacturers were also not yet working with white LED lighting, which is currently at the cutting edge of LED technology, although their Chinese counterparts are.

Harvey's study also affirms that developing countries generally have access to low carbon technologies. He asserts that companies often do not bother filing for patents in least industrialized countries, as they focus their patenting efforts on more substantial markets. He also argues that companies are willing to sell products at a lower price in developing countries if there is no concern about leakage, or that the lower cost products will end up back in their main markets. Thus, many of those interested in using low carbon technologies in developing counties can do so.[122] He suggests a series of options in those instances where IPRs may be hindering access to low carbon technologies in least developed countries. These options include licensing at zero cost or on favourable terms and / or government subsidizing the cost of using a patented technology.

The first ICTSD study indicates that there has been no comprehensive study of the potential impact of IPRs on climate technologies. It also states that, in addition Barton's study, two studies done by the European Patent Office (EPO), on biofuels and wind respectively, noted that patents have been increasing in both areas.[123] The ICTSD study done by Oliva asserts that there is no definitive answer regarding whether IPRs hinder or assist the transfer of climate technologies. Like Harvey, Oliva proposes the use of existing tools within TRIPS to assist technology transfer in the climate regime in cases where IPRs may have a negative effect, but these suggestions – such as exemptions to patentability, patent rights, or compulsory licensing – are different than those proposed by Harvey.

Importantly, developing country firms were generally not observed to have access to the most cutting edge technologies within the sectors examined. One exception is a Chinese firm, Sichuan FAW, that has gained access to Toyota's cutting edge hybrid vehicle technology via a joint venture arrangement. The extent to which they have access to the underlying knowledge is, however,

122 Harvey, I. 2008. Intellectual Property Rights: The Catalyst to Deliver Low Carbon Technologies. Breaking the Climate Deadlock, Briefing Paper. Ian Harvey and the Climate Group, London: 9.

123 ICTSD. 2008. Climate Change and Trade on the Road to Copenhagen. ICTSD Trade and Sustainable Energy Series Issue Paper No.3. Forthcoming from the International Centre for Trade and Sustainable Development, Geneva, Switzerland: 36.

questionable as Toyota currently manufactures its Hybrid Synergydrive drivetrains in Japan and ships them to China for assembly.[124]

Barton and Lewis' analysis demonstrates how access to wind technologies in India and China has been facilitated via the acquisition of licenses from developed country firms and, in the case of India, also by strategic acquisition of developed country firms. In the case of solar PV, China has pursued a strong policy of indigenous technology development, whereas India's access has principally been via a joint venture with BP Solar, suggesting future solar PV activity in India will be dependent on BP Solar's international market strategy. For biofuels, Barton notes significant indigenous ethanol industries in China, India, Pakistan, Japan, Thailand and Malaysia as well as the notable success of Brazil in this sector.

Barton makes an important contribution in his analysis by highlighting the role that industry structure plays in determining access to new technologies. He argues that, whilst at least two of the renewable technologies that he studies (wind and solar PV) have a moderately concentrated market, dominated by a limited number of large players, the industries are loosely structured enough to allow for new entrants, and future market opportunities in developing countries are likely to incentivise technology diffusion. Barton also highlights the relevance of the economics of access to these technologies. Because there is sufficient international competition in wind for example, getting a license is not prohibitively expensive for developing country firms.

Access to the cutting edge

Despite the overall optimistic tone of Barton's analysis, 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. Companies owning patents to new thin film solar PV technologies and new enzymes being developed for biofuel production may be hesitant to make these available to developing country firms, and the industries are concentrated enough that developed country firms could price developing country firms out of the market. Similar issues in terms of access to the know how behind cutting edge technologies were also raised by Indian firms in relation to IGCC and LED lighting in the Ockwell et al. study. Kohr[125] also suggests – using experiences from the Montreal Protocol – that access to cutting edge technologies by developing countries is limited.

124 Ockwell, D., J. Watson, G. MacKerron, P. Pal, and F. Yamin. 2006. UK-India Collaboration to Identify the Barriers to the Transfer of Low Carbon Energy Technology. Report by the Sussex Energy Group (SPRU, University of Sussex), TERI and IDS for the UK Department for Environment, Food and Rural Affairs, London. http://www.sussex.ac.uk/sussexenergygroup/1-2-9.html; Ockwell, D., J. Watson, G. MacKerron, P. Pal, and F. Yamin. 2008. Key policy considerations for facilitating low carbon technology transfer to developing countries. Energy Policy, 36 (11): 4104-4115

125 Khor, M. 2008. Access to Technology, IPRs and Climate Change, Day One Session, European Patent Forum. http://www.epo.org/about-us/events/epf2008/forum/details1/kohr.html

To some extent Suzlon, India's most successful wind technology manufacturer with the fifth biggest share of the global market, has overcome these issues by buying majority shares in developed country firms to gain access to cutting edge technologies such as variable speed turbines. Having said this, Barton identifies wind as the riskiest area in terms of access to future cutting edge technologies and markets for these. He cites the case of the US where GE has successfully used litigation over patent infringement to block foreign access to the market.

This point is reinforced by Lewis who explains how Suzlon and China's leading wind technology manufacturer, Goldwind, acquired access to wind technology by licence purchases from second tier developed country firms. This, she argues, was due to the disincentive for leading companies to license to potential developing country competitors; a concern accentuated by the cheaper labour and materials available in developing countries. The only companies willing to sell licenses to use their technologies are therefore smaller companies with less to lose in terms of competition and more to gain in license fees. Lewis notes, however, that this does not necessarily imply technological inferiority compared to larger companies, but the fact that the technology has been used less implies less operational experience, which could present opportunities to perfect and prove the technologies.

Another issue for developing country firms highlighted by Barton is that, even where they are not working at the cutting edge, access to finance for new technologies could be an issue. Venture capital funds tend to favour new start-ups with strong proprietary positions with regard to patented new technologies.

3.5 Current Arrangements for Technology Transfer in the UNFCCC

Technology transfer usually takes place within the private sector. As such, the mechanisms by which low carbon technology transfer is facilitated in the private sector are no different to the mechanisms that are routinely used for the transfer of other kinds of technology. These include, for example, joint ventures and foreign direct investment (FDI). The implications of climate change are global, implying a clear incentive for government involvement in facilitating, or speeding up the process of low carbon energy technology transfer. There are two main reasons for government involvement in technology transfer at the international level:

1. Reducing carbon emissions contributes to reducing the economic, social and environmental costs of climate change. The external costs of carbon emissions are not yet fully reflected in mechanisms that price carbon such as the European emissions trading scheme and the Clean Development Mechanism; and

2. Many low carbon technologies are currently at pre-commercial or supported commercial stages of development and many therefore require some form of government support to facilitate their wider adoption.[126]

The need for international action to facilitate the transfer of low carbon technologies is explicitly recognised by Article 4.5 of the UN Framework Convention on Climate Change (UNFCCC – "the Convention"):

> 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.

Commitments for industrialized countries to transfer technology to the developing world were also reiterated in the Buenos Aires Plan of Action at COP4 in 1998.

3.5.1 The Marrakesh Accords

As part of the Marrakesh Accords at COP7[127], a framework was established with the aim of facilitating actions to implement Article 4.5 of the Convention[128]. The framework has five themes:

3.5.2 Technology needs & needs assessments

This involves an analysis by recipient countries of their perceived priority low carbon technology needs against which technology transfer initiatives under the Convention can be targeted.

126 These are often termed as market failures, including environmental externalities and a lack of ability of firms to appropriate gains from research and development. In addition, some suggest the need to go well beyond these market failures to address system failures and other related issues. See Watson, J. (2008) *'Setting Priorities in Energy Innovation Policy: Lessons for the UK.'* ETIP Discussion Paper. Cambridge, MA: Belfer Center for Science and International Affairs, Kennedy School of Government, Harvard University, October for example.

127 COP refers to a Convention of the Parties to the UNFCCC. These are held annually.

128 See the annex to decision 4/CP.7 http://unfccc.int/resource/docs/cop7/13a01.pdf#page=22

3.5.3 Technology information

A web portal under an initiative known as TT:CLEAR[129] has been established to facilitate the flow of information between different stakeholders, including technology recipients and suppliers.

3.5.4 Enabling environments

Action is needed at national levels to remove potential barriers to technology transfer. Such action includes implementing fair trade policies, removal of technical, legal and administrative barriers, creating stable macro-economic conditions and transparent, enforceable regulatory frameworks.

3.5.5 Capacity building

Technological capacity building in developing countries is essential to the long term uptake and development of low carbon technologies in developing countries. This part of the framework seeks to encourage the strengthening and development of technical and scientific skills, capabilities and institutions in developing countries.

3.6 Mechanisms for technology transfer

The Marrakesh Accords established an Expert Group on Technology Transfer (EGTT). The EGTT is nominally responsible for the implementation of Article 4.5 of the Convention within the context of this five part framework. EGTT members are nominated by the parties. Its 20 members are drawn from developing nations, small island nations, Annex I Parties (i.e. developed nations) and relevant international organisations. The EGTT has been involved in the development and collation of Technology Needs Assessments and the creation and administration of the TT:CLEAR information clearing house. The EGTT's mandate was due to expire in 2006. Due to disagreement among the Parties, particularly between developed and developing countries, as to how to proceed following its expiry, it was agreed at COP12 that the EGTT should be kept alive for one more year pending another discussion at COP13 in 2007.

The UNFCCC introduced an initiative known as TT:CLEAR as part of its technology sub programme. Under Article 4.5 of the Convention, the technology sub programme has the main goal of improving the flow of, access to and quality of information relating to the development and transfer of environmentally sound technologies (ESTs). TT:CLEAR essentially acts as a clearing house for information on the availability of environmentally sound technologies. Activities currently being undertaken as part of TT:CLEAR include:[130]

129 See http://ttclear.unfccc.int/ttclear/jsp/index.jsp
130 UNFCCC. 2005. Annual report of the Expert Group on Technology Transfer for 2005. Subsidiary Body For Scientific and Technological Advice, UNFCCC, Bonn, Germany.

- Working to develop current understanding of enabling environments for technology transfer, which includes cooperating with business, industry and public–private partnerships to organise sector-specific workshops.

- Developing innovative financing options for increasing developing countries' capacities for undertaking technology needs assessments and developing project proposals.

- Exploring possible ways to enhance synergy with other global conventions and processes where technology transfer and capacity-building for technology transfer are considered, including the Convention on Biological Diversity (CBD), the United Nations Convention to Combat Desertification, and the Montreal Protocol.

- Working to develop innovative options to finance the development and transfer of technologies

- Working to understand key issues relating to technologies for adaptation to climate change.

A central objective of TT:CLEAR has been to work with developing countries to produce individual Technology Needs Assessments. These are country-driven assessments of perceived technological needs for mitigating and responding to climate change. Whilst India has provided some information on perceived technology needs to the UNFCCC as part of its initial national communication, it has not yet produced a full Technology Needs Assessment.[131]

3.7 The Bali Action Plan and the Poznań Technology Transfer Strategy

The Bali Action Plan agreed at the 13th Convention of the Parties (COP) to the UNFCCC, which sets out a road map for the UNFCCC negotiations in the lead up to Copenhagen in 2009, placed an increased emphasis on the role of technology development and transfer for implementation of the UNFCCC up to and beyond 2012. This emphasis continued at COP14 where one of the few advances made at the COP was the agreement of the Poznań Strategic Programme on Technology Transfer. Based on a proposal by the GEF (Global Environmental Facility), the Strategy charges the GEF, in close cooperation with implementing agencies, with the task of "improving the efficiency of technology transfer by properly recognising relevant needs of developing countries".[132] The

131 UNFCCC. 2006. Synthesis report on technology needs identified by Parties not included in Annex I to the Convention: Note by the secretariat FCCC/SBSTA/2006/INF.1. United Nations Framework Convention on Climate Change, Subsidiary Body for Scientific and Technical Advice.

132 Government of Poland reports of COP14, 2008, "Late-night conclusion of the Poznań summit", available at http://www.cop14.gov.pl/index.php?mode=aktualnosci_extended&action=main&menu=1&id=104&lang=EN, posted 13/12/08

GEF proposed that they would ramp up their efforts on technology transfer for climate technologies (with a target funding level of $35 million).

The Clean Development Mechanism (CDM)

The arrangements outlined above have an important role to play in the long-term facilitation of low carbon technology transfer. At present, however, the Clean Development Mechanism (CDM) under the Kyoto Protocol of the UNFCCC is the only concrete mechanism that provides the potential for low carbon technology transfer. The CDM has an ambitious remit. It allows mitigation actions that contribute to sustainable development in developing countries to generate Certified Emissions Reductions (CERs) that can be used by Annex I Parties to meet their national emissions limitation commitments. The CDM does not have an explicit technology transfer remit but it is recognised that it might facilitate technology transfer to developing countries where emissions reduction projects involve technologies not currently available in host countries. Host countries can establish technology transfer requirements for CDM projects.

An analysis of all of the 860 registered CDM projects at the time by Haites *et al*. (2006) demonstrates that around a third of these projects intend to include the transfer of either equipment or hardware or both. An analysis of 63 CDM projects registered by January 1st 2006 by de Coninck[133] (2006) found that almost 50% of projects used technology from outside of the host country. According to Haites *et al*.'s (2006) analysis, projects involving technology transfer account for around two thirds of emissions reductions achieved under the CDM (see the final column of Table 3.2). The plans for technology transfer vary significantly by project type and host country. In India, for example, only 7.3% of CDM projects plan to involve some element of technology transfer compared to 55.1% in China and much as 83.3% in Malaysia (see the penultimate column of Table 3.2). This suggests that host country approval processes can increase the rate of technology transfer under the CDM – under the CDM host country governments must approve potential projects on the basis of them conforming to host country laws as well as the national priorities that host countries may state as part of the CDM process. It is therefore possible for a country to influence the extent of technology transfer involved in CDM projects via this approval process.[134] These results also suggest that local technology is preferred for some types of emission reduction projects. Given the expanding role of the CDM in the future climate regime, more detailed analysis of host country approval processes for CDM may provide useful insights on how the CDM can deliver more technology transfer.

133 de Coninck, H. 2006. Technology Transfer in the Clean Development Mechanism (CDM). Amsterdam: Energy Research Centre of the Netherlands.

134 Haites, E., Duan, M. and Seres, S. 2006. 'Technology Transfer by CDM Projects'. Toronto, Canada: Margaree Consultants Inc.

Table 3.2 Technology Transfer for CDM Projects in Selected Host Countries[135]

Host Country	Number of Projects	Estimated Emission Reductions ($ktCO_2e/yr$)	Average Project Size ($ktCO_2e/yr$)	Technology Transfer Claims as Percent of Number of Projects	Annual Emission Reductions
Argentina	9	3,579	398	77.8%	99.4%
Brazil	160	20,471	128	33.1%	74.1%
Chile	23	3,720	162	17.4%	44.8%
China	69	52,996	768	55.1%	75.9%
Honduras	19	446	23	57.9%	57.5%
India	329	26,595	81	7.3%	34.4%
South Korea	12	12,556	1,046	50.0%	88.2%
Malaysia	18	2,343	130	83.3%	94.8%
Mexico	54	7,303	135	85.2%	91.4%
Nigeria	2	4,044	2,022	0%	0%
Philippines	22	388	18	63.6%	72.8%
Other Host Countries	137	14,930	109	49.6%	50.9%
Total	854	149,369	175	33.5%	65.5%

These statistics on the CDM suggest that the CDM does have the potential to help facilitate the transfer of low carbon technologies. It must be emphasised, however, that the CDM is at an early stage of implementation and it is therefore too early to judge the actual level of technology transfer that it will facilitate and also what kind of technology transfer is achieved. Is it mainly just hardware transfer as the data imply, or do many of these CDM projects also include collaborative agreements, which are delivering improvements in the technological capacity of developing country firms? The strengths and weaknesses of this aspect of the CDM will need closer study as projects are implemented.

Irrespective of the CDM's impact on technology transfer, it is already widely recognised that this mechanism will not facilitate all of the potential low carbon technology deployment in developing countries. A range of national and international routes for additional finance have been developed which include a mix of public and private initiatives.[136] Multilateral institutions such as the World Bank are thought to have a particularly important role to play. The Bank has outlined some of the additional multilateral finance mechanisms that could be implemented.[137] On July 1, 2008, the World Bank Board of Directors agreed to finance two Climate Investment Funds (CIF) – a Clean Technology Fund and a Strategic Climate Fund. The funds will be dispersed as grants, highly concessional loans and / or risk mitigation tools. Furthermore, in September

135 Ibid.

136 TERI 2006. 'Climate Change and Technology Transfer: Status Review Paper Report to British High Commission'. New Delhi: TERI..

137 World-Bank 2006. 'Clean Energy and Development: Towards an Investment Framework': World Bank.

2008, ten leading World Bank donors, including the United States, France, the United Kingdom, Germany and Japan, pledged money towards these Funds.[138]

The Montreal Protocol on substances that deplete the ozone layer is an example of an international agreement that facilitated the transfer of cleaner technology. Technology transfer related specifically to technology geared towards reducing emissions of CFCs (chlorofluorocarbons) and other ozone depleting substances. Via the establishment of a multilateral fund under the Protocol, 5000 projects were established in 139 developing countries that either dealt directly with technology transfer or capacity building.[139] This is cited as having eliminated a substantial proportion of worldwide production and consumption of ozone depleting substances.[140]

A final initiative worth mentioning here is the Asia-Pacific Partnership on Clean Development and Climate. This is a partnership between the US, Australia, China, India, Japan and the Republic of Korea that focuses on the development and deployment of clean technology. The Partnership has set up several taskforces covering a range of industrial sectors around which it is planned to focus efforts to develop and deploy clean technologies. One of these focuses on technologies for cleaner fossil energy, including carbon capture and storage. The Partnership is based on non-binding agreements and is at too early a stage to be able to judge its practical success in facilitating technology transfer.[141]

3.10 Technology Transfer: The Indian context

India is the second most populous country in the world. Occupying 2.4% of the world's geographical area it is home to nearly 17% of the global population.[142] With 250 million people living on less than US$1 per day and about 550 million people without access to electricity[143] India's per capita contribution to global greenhouse gas (GHG) emissions is relatively low at present. In 2002, for example, India's per capita carbon emissions (tonnes of carbon per capita) from fuel combustion were estimated at 0.97 compared to global per capita carbon emissions of 3.89, or the EU's 8.41 and US' 19.66.[144] India is, however, a rapidly

138 For further details, please see information about the CIF at http://go.worldbank.org/58OVAGT860 and the Press Release, September 26, 2008 "Donor Nations Pledge Over $US 6.1 Billion to Climate Investment Funds", World Bank, Washington, D.C. http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,contentMDK:21916602~pagePK:34370~piPK:34424~theSitePK:4607,00.html

139 TERI 2007. 'Exploring opportunities for technology transfer to developing countries for climate change mitigation'. Delhi: TERI..

140 See http://www.multilateralfund.org/ for precise figures and more on the implementation of the Montreal Protocol

141 See http://www.asiapacificpartnership.org/

142 Jung, T. Y., S. Anchna, K. Tamura, T. Sudo, R. Watanabe, K. Shimada, and H. Kimura. 2005. Asian Perspectives on Climate Regime Beyond 2012 Concerns, Interests and Priorities. Institute for Global Environmental Strategies, Hayama, Japan.

143 Ibid.

144 OECD, and IEA. 2004. CO2 Emissions from Fuel Combustion: highlights (1971-2002). Organisation for Economic Cooperation and Development / International Energy Agency, Paris; TERI. 2006. Energy for the future: making development sustainable. Report for the Ministry of Environment and Forests, Government of India. TERI, New Delhi: xiii

developing nation and is faced with the challenge of sustaining its economic growth while dealing with the global threat of climate change. Maintaining a high growth rate is essential for increasing living standards of the vast majority of the population and reducing their vulnerability to the impacts of climate change.

In line with its economic development, India has a rapidly expanding middle and higher income population. As the country works towards the eradication of poverty under its Eleventh Five Year Plan (2007-12) and focuses on faster and inclusive economic growth, it is hoped that the standard of living in the country will continue to increase. Whilst the eradication of poverty and achieving real improvements in the standard of living is of utmost importance for India, this also implies important future challenges as demand for energy continues to increase rapidly. Between 1990 and 2005, India saw a 99% increase in total carbon emissions compared to increases of 115% in China, 21% in the US and 4% in Europe.[145] Assuming sustained economic growth and continued reliance on domestic coal, business as usual predictions suggest economy-wide energy related carbon dioxide emissions in India will increase to 5.5 billion tonnes by 2031[146] compared to 1 billion tonnes in 2004.[147] Total primary energy demand is projected to increase to 3 to 4 times of the 2004 level by 2031/32.[148] The adoption of low carbon technology in India therefore has an important potential role to play as part of global efforts to mitigate climate change.

Due, amongst other things, to its heavy reliance on agriculture, India is one of the nations likely to be most heavily effected by future climate change. This provides additional impetus for India to engage with global efforts to reduce GHG emissions. India has ratified the UNFCCC, but, as a developing country, has no obligations under the convention to reduce GHG emissions. It has, however, opted to introduce a number of policies aimed at reducing carbon emissions. Whilst these policies have had some success,[149] Indian industry is still considerably more energy intensive than many industrialized countries.[150]

India has large domestic coal reserves which currently meet 52% of its domestic energy needs.[151] Coal production in India grew to more than 431 million tonnes in 2006/07 rendering it the third-largest producer of coal after China and the USA.[152] The increasing use of coal in India is set to continue into the future

145 IEA, 2007. CO2 emissions from fuel combustion (2007 Edition), International Energy Agency

146 Integrated Energy Policy, Planning Commission, GoI, 2006

147 Ibid.: 50

148 Ibid.: xiii.

149 Jung, T. Y., S. Anchna, K. Tamura, T. Sudo, R. Watanabe, K. Shimada, and H. Kimura. 2005. Asian Perspectives on Climate Regime Beyond 2012 Concerns, Interests and Priorities. Institute for Global Environmental Strategies, Hayama, Japan.

150 Chandler, W., R. Schaeffer, Z. Dadi, P. R. Shukla, F. Tudela, O. Davidson, and S. Alpan-Atamer. 2002. Climate change mitigation in developing countries: Brazil, China, India, Mexico, South Africa, and Turkey. Pew Centre on Global Climate Change, Arlington, VA.

151 Jung, T. Y., S. Anchna, K. Tamura, T. Sudo, R. Watanabe, K. Shimada, and H. Kimura. 2005. Asian Perspectives on Climate Regime Beyond 2012 Concerns, Interests and Priorities. Institute for Global Environmental Strategies, Hayama, Japan.

152 TEDDY, 2007. TERI Energy Data Directory & Yearbook 2007. Published by The Energy and Resources Institute, New Delhi

with an estimated doubling of domestic coal production and increasing coal imports over the next 30 years.[153] Indian coal also has high levels of impurities thus requiring additional energy for transport and processing. India has seen marked success in initiatives aimed at transferring certain renewable energy technologies, especially wind and solar power.[154] But with the abundance of domestic coal reserves, coal is likely to remain the mainstay of the Indian energy sector making the development of advanced clean coal technologies a central concern.[155]

There is also high dependence on biomass, from trees and woody shrubs, for domestic energy production in India, especially in rural areas.[156] This can represent a carbon neutral source of energy as the carbon released during combustion is equal to that sequestered by the biomass during its growth and, once released during burning, may subsequently be sequestered by other woody biomass. As with many other natural resources that are traditionally communally managed, however, forests and woodlands are subject to increasing pressures, such as drives towards privatisation, which can erode the traditional management regimes that previously ensured their sustainable management.[157] The breakdown of traditional management regime can lead to unsustainable levels of biomass extraction meaning this biomass no longer represents a carbon neutral source of energy. This highlights the need for adoption of advanced biomass technologies in India.

Due to its reliance on coal and biomass, energy production in India is very carbon intensive at present.[158] Another concern in terms of carbon emissions in India is its transport sector. India's transport sector is predicted to show the highest growth in energy demand of any sector over the next 30 years.[159] Introducing policies and technologies that can mitigate carbon emissions related to this sector is therefore also important. As India's energy demands increase, minimising carbon emissions will present challenges for the nation

153 TERI. 2006. Energy for the future: making development sustainable. Report for the Ministry of Environment and Forests, Government of India. TERI, New Delhi: 2.

154 IPCC. 2000. Methodological and technological issues in technology transfer. Cambridge University Press, Cambridge.

155 TERI. 2006. Energy for the future: making development sustainable. Report for the Ministry of Environment and Forests, Government of India. TERI, New Delhi: 1.

156 Ibid.; Jung, T. Y., S. Anchna, K. Tamura, T. Sudo, R. Watanabe, K. Shimada, and H. Kimura. 2005. Asian Perspectives on Climate Regime Beyond 2012 Concerns, Interests and Priorities. Institute for Global Environmental Strategies, Hayama, Japan.

157 Lovett, J. C., C. H. Quinn, D. G. Ockwell, and R. Gregorowski. 2006. Two cultures and tragedy of the commons. African Journal of Ecology 44:1-5.

158 Coal is the most carbon intensive of the fossil fuels; nearly twice as much as natural gas and about 20% more than oil. For specifics, please see Husain, 2008, "European Carbon Cap and Trade: Implications on North American Natural Gas Demand", LDC/IGUA Forum, October 2008, Toronto, Canada: 9 http://www.igua.ca/files/conference/12%20Husain%20Societe%20Generale.pdf
Increasing coal use and economic growth in India and China is largely responsible for their increase of global carbon dioxide emissions – from 13% of the world's share of carbon emissions in 1990 to accounting for 23% of global carbon emissions in 2005. U.S. Department of Energy, Energy Information Administration, 2008, Synopsis of Chapter 7 – Energy-Related Carbon Dioxide Emissions, World Energy Outlook, http://www.eia.doe.gov/oiaf/ieo/emissions.html

159 TERI. 2006. Energy for the future: making development sustainable. Report for the Ministry of Environment and Forests, Government of India. TERI, New Delhi: 2.

and the broader international community. Low carbon technology transfer therefore has a high potential role to play in addressing these challenges.

The available evidence indicates that IP is not a pervasive barrier to technology transfer. But there could be times when IP is a barrier to the transfer of specific technologies to some countries. A variety of options are already available under TRIPS to deal with such situations, but other approaches might prove necessary.

3.10.1 Key Federal-Level Energy and Climate Change Initiatives in India

India has been undertaking various efforts in order to achieve a sustainable development path that simultaneously advances economic and environmental objectives. In the area of climate change and low carbon energy technology transfer, and energy more broadly, some of the key initiatives include:

a ***National Action Plan for Climate Change (NAPCC)*** that has been formulated by the Government of India in June 2008. The NAPCC hinges on the development and use of new technologies. The following eight missions form the core of the NAPCC.

- National Solar Mission
- National Mission for Enhanced Energy Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for Sustaining the Himalayan Ecosystem
- National Mission for Green India
- National Mission for Sustainable Agriculture
- National Mission on Strategic Knowledge for Climate Change. [160]

Details of each of the eight missions can be found in the document, although the **National Solar Mission** will be discussed further in the PV case study. Details on the **National Mission for Enhanced Energy Efficiency (NMEEE)** – relevant to the energy efficient technologies in the SME sector case study – are included below:

160 National Action Plan on Climate Change, Government of India, 2008

To enhance energy efficiency, the National Mission on Enhanced Energy Efficiency (NMEEE) – one of the eight missions under the NAPCC, proposes four new initiatives:

1. A market based mechanism to enhance cost effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities, through certification of energy savings that could be traded.

2. Accelerating the shift to energy efficient appliances in designated sectors through innovative measures to make the products more affordable.

3. Creating mechanisms that would help finance demand side management (DSM) programs in all sectors by capturing future energy savings.

4. Developing fiscal instruments to promote energy efficiency.

In addition, the Mission also proposes certain specific policies and programs to promote energy efficiency in a few sectors/areas. These include:

- Restructuring of subsidies in the fertilizer sector so as to provide adequate incentives to units to undertake energy efficiency investments

- Promote technology up-gradation in the SME sector by developing sector specific programs for different industry clusters

- Accelerated depreciation and reduced VAT proposed for energy efficient equipment

The document recognizes the need for technology transfer, financing mechanisms and capacity building that would be required to achieve energy efficiency in the industry sector. NMEEE specifically recognizes the knowledge gap that exists in the micro, small and medium enterprises (MSME) sector and proposes development of (sub) sector-specific integrated programmes for technology development and adoption in small-scale industries. The Mission mentions that a number of GHG mitigation options exist for the industry sector and that the estimated energy saving potential in many plants is of the order of 5–15%. The document also estimates that various schemes and programmes initiated by the Government of India would result in energy savings of 10,000 MW by the end of 11th Five Year Plan.

The Government of India – Submission to the UNFCCC on a Technology Transfer Mechanism, November 2008. Arguing that current institutional arrangements under the UNFCCC are inadequate in facilitating the transfer of low carbon energy technologies to developing countries, the GoI has put forth a proposal for a Technology Transfer Mechanism. This mechanism would be under the authority and guidance of the COP and would consist of several institutional arrangements including:

1. an Executive Body on Technology – which would serve as a subsidiary body of the Convention, and would consist of four groups including a strategic planning committee, technical panels, a verification group, and a Secretariat; and

2. a Multilateral Climate Technology Fund (MCTF) – this would serve as the financial arm to the activities of the Executive Body (including administrative costs of the Executive Body, and technology transfer project costs). The Fund would be financed by additional assessed contributions of Annex II Parties and could include bilateral and regional cooperation.

The work of the Executive Body would stem from a Technology Action Plan, which would identify specific policies, actions and funding requirements for all relevant technologies in three classifications (public domain technologies, patented technologies and future technologies). Activities would include all stages of the technology cycle – research, development, transfer and diffusion. Specifics on the proposal and activities that would be eligible can be found in the submission.[161]

Energy Conservation Act, 2001

The major policy introduced in India addressing energy efficiency issues in the industry sector is 'The Energy Conservation Act, 2001', which came into effect through the Gazette Notification on October 01, 2001. The Energy Conservation Act 2001 provides the legal mandate for the implementation of energy efficiency measures through the institutional framework of the BEE (Bureau of Energy Efficiency).

The Act provides the government (both central and state) with the powers to enact regulations, establishing energy standards for buildings, equipment, and industrial processes; and to classify any class of energy users as "designated consumers" and any class of equipment or appliances as "specified" equipment/appliances. It would be mandatory for designated consumers/ specified equipment manufacturers to comply with the energy standards notified by the government. The government can also require these entities to undergo periodic energy audits, carried out by energy auditors who have been accredited for this purpose. The Act also enables the government to make the display of energy labels (providing energy consumption information) mandatory

161 See Government of India, Submission to the UNFCCC on a Technology Transfer Mechanism, http://www.indiaenvironmentportal.org.in/files/indiatechtransfer171008.pdf

on specified equipment/ appliances. The Act also seeks to create a Central Energy Conservation Fund. This Fund would meet the implementation costs of the Energy Conservation Act. In addition, the Fund would provide resources for information dissemination, training, and for steps to encourage the preferential use of energy-efficient equipment and appliances.

The Act also created the Bureau of Energy Efficiency (BEE) to implement the provisions of the Act.

Integrated Energy Policy Report, was completed in August 2006 by an Expert Committee on Energy, with the aim of providing guidance for India's energy policy; some recommendations fed into the 11th five-year development plan of India (2007-2012). The report is a comprehensive examination of India's existing and expected future energy demand and supply. In addition, the report takes an in-depth look at energy security and various policy options (e.g. subsidies, taxation). The report scrutinizes relevant energy issues including household energy security, coal and power sector policies, energy R&D, environment and energy linkages, energy efficiency or demand side management policies, as well as policies for renewables and non-conventional energy sources. For example, the report specifically mentions that the government focus energy R&D efforts, through a National Energy Fund (NEF) on IGCC, solar PV and hybrid vehicles, among others. Other suggestions include those offered by President Kalam in 2005, in his vision for India's energy independence. Some options put forth include include support for hybrid vehicles and solar PV (e.g. increasing the efficiency of solar PV from 15% to 50% without increasing the cost) as ways to reduce India's oil consumption.[162]

162 Integrated Energy Policy Report, 2006, Planning Commission: xxiv-xxv and 105 and 51-53.

4. New empirical analysis: Technology case studies

4.1 PV case study – SPRU

This case study was conducted and written by the SPRU team and is based principally on interviews conducted between October and November 2008, with some information from a few interviews done in autumn 2007.

4.0.1 Background

There are two basic Photovoltaic (PV) solar technologies, solar cells and solar collectors. Solar cells convert solar insolation into electricity while solar collectors convert insolation into heat. This case study focuses on solar cells, also called solar PV because PV (photovoltaic) describes the process that converts sunlight into energy. Solar PV is currently the fastest growing area in the energy sector, with forecasts of four-fold growth by 2011.[163]

Solar cells are composed of two layers of different semiconductors united by a junction. The semiconductor layers are called wafers and are usually made from silicon. The efficiency of commercial cells ranges from 12 to 16 per cent, although cell manufactures and research institutions have achieved higher efficiencies[164]. Cell efficiency is a common indicator of the technological capabilities of PV cell manufacturers, as achieving higher efficiencies requires knowledge of different discrete production processes.

Two types of solar cells are used in 90 per cent of all applications: monocrystalline silicon solar sells and multicrystalline silicon solar cells. Both are often referred to as First Generation solar cells. Monocrystaline cells achieve slightly higher efficiencies than multicrystaliine cells (see Table 4.1 further down for specifics).

The main metric used to determine costs for PV technologies is the cost per Watt of peak electricity generation capacity. As the silicon-wafers are roughly 40 per cent of the cost of a cell, R&D to reduce cost focuses on improving the efficiency of silicon cells or on cheaper alternatives to silicon. Efficiency improvements can be achieved as one moves from a single junction (two layers) to a multi junction (three or more layers) – each layer added increases efficiency

163 (ISA), P. a. I. S. A. (2008). Solar PV Industry: Global and Indian Scenario. New Delhi, ISA: 174.

164 A solar cell's energy conversion efficiency is the percentage of power converted (from absorbed light to electrical energy) and collected, when a solar cell is connected to an electrical circuit.

as it improves the ability to capture more energy from the solar spectrum to convert into electricity.[165]

The most common alternatives to silicon are so called thin film cells (also called Second Generation solar cells). The thin film wafer is made of amorphous silicon (a-Si, still silicon, but in a different form), or the polycrystalline materials: cadmium telluride (CdTe) and copper indium (gallium) diselenide (CIS or CIGS). All materials are strong light absorbers and wafers can be much thinner compared to silicon wafers. However, thin film efficiencies have been much lower than those of silicon cells (see Table 4.1). But the lower efficiencies of thin film cells are offset by much lower production costs. Some research is also being undertaken regarding other options such as the application of nanotechnologies onto PV cells.[166]

Table 4.1: Typical and maximum module and cell conversion efficiencies at standard test conditions

Type	Typical module efficiency [%]	Maximum recorded module efficiency [%]	Maximum recorded laboratory efficiency [%]	Generation
Single crystalline silicon	12-15	22.7	24.7	1st
Multicrystalline silicon	11-14	15.3	19.8	1st
Amorphous silicon	5-7	-	12.7	2nd
Cadmium telluride	-	10.5	16.0	2nd
CIGS	-	12.1	18.2	2nd

Source: www.iea-pvps.org/pv/index.htm

The PV Value Chain

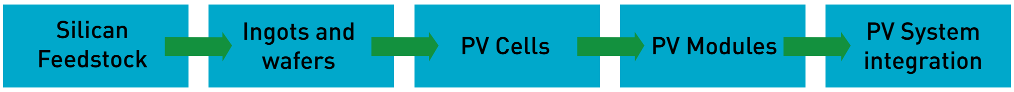
The PV value chain can be separated into five main components, which depend on each other: silicon feedstock production, ingot casting and wafer slicing, cell and module production, system integration and sales (see Figure 4.1). Feeding

165 Interview, one PV representative, November 2008

166 ISE, F. (2007). Solarzellen. Freiburg, Fraunhofer Institut für Solare Energiesysteme., Platform, E. P. T. (2007). The Status of the PV Industry. *Photovoltaic Fact Sheets*. Brussels, European Photovoltaic Industry Association: 1.   , SEARCH Foundation and Government of India, M. o. N. a. R. E. (2008). *Various presentations and discussions*. Solar PV: Emerging Viable Option with Technology and Policy Thrusts, India Habitat Centre, New Delhi.

into module production as well as system integration are the value chains for other components. These are usually referred to as balance of system (BOS) comprising structures, enclosures, wiring, switchgear, fuses, ground fault detectors, charge controllers, and batteries. In addition, invertors are also required in some cases to convert the Direct Current (DC) electricity generated into Alternating Current (AC) electricity.[167]

Figure 4.1 – The Solar PV Value Chain[168]



Source: ISA–NMCC 2008

Feedstock production comprises the production of PV grade silicon. The production of PV grade silicon feedatock is highly concentrated. In 2006, four companies produced sixty per cent of the worldwide output.[169] A small number of companies, mainly in China and Russia, produced the remaining amount. Ingot casting, which makes the minerals into shapes better suited for processing, and wafer slicing is undertaken by a slightly larger number of firms situated for the most part in Europe and Japan.[170]

More companies produce solar cells but production is again concentrated in Europe, the US and Japan with the exception of a significant increase in cell production in China.[171] Module manufacturing is even less concentrated and systems are usually integrated in the country of manufacture or in the country of application if the modules are exported.

As noted above, ninety per cent of PV cells still use silicon crystalline wafers, a technology first used in the 1970s and now considered mature.[172] Experts assume that silicon cells will dominate production in the foreseeable future. Jäger-Waldau states "Up to now the main advantage of this technology was that complete production lines could be bought, installed and be up and producing within a relatively short time-frame. This predictable production start-up scenario constitutes a low-risk placement with high expectations for return on investments"[173] Van der Sark et al indicate that silicon cells will dominate "due to the vested interests in this technology and the experience built up over the years".[174]

167 SEARCH Foundation and Government of India, M. o. N. a. R. E. (2008). *Various presentations and discussions*. Solar PV: Emerging Viable Option with Technology and Policy Thrusts, India Habitat Centre, New Delhi.; Interview, Environ, November 2008.

168 (ISA), P. a. I. S. A. (2008). Solar PV Industry: Global and Indian Scenario. New Delhi, ISA: 12.

169 Wacker (Germany), REC Solar Grade Silicon and Hemlock Semiconductor Corporation (USA), Tokuyama (Japan).

170 (IEA), I. E. A. (2007). Trends in Photovoltaic Applications Survey Report of selected IEA countries between 1992 and 2006. *Report IEA-PVPS*. P. P. S. Programme. Paris, IEA: T1-16.

171 Platform, E. P. T. (2007). The Status of the PV Industry. *Photovoltaic Fact Sheets*. Brussels, European Photovoltaic Industry Association: 1.

172 Jäger-Waldau, A. (2006). PV Status Report 2006. E. C. J. R. Centre, Ispra.

173 Jäger-Waldau, A. (2007). PV Status Report 2007. E. C. J. R. Centre, Ispra.: 6.

174 Sark, W. v., G. Brandsen, et al. (2007). "Analysis of the Silicon Market: Will thin fims profit?" Energy Policy 35: 3121 – 3125.

Mature production technology for silicon cells is available on the market without licences since related patents have expired.[175] More advanced technology might be patented and break-through research is likely to be the result of and potentially owned by research and development institutions.

Advances are being made in a number of areas including Building Integrated Photovoltaic (BIPV) where PV systems are integrated directly into a building (e.g. roof, window). Further improvements are needed for this technology. Desired improvements include grid parity and better ability to deal with temperature increases, because efficiency decreases[176] if the temperature of the PV system becomes too high.[177] Other advances are solar cells consisting of various lower cost materials (sometimes termed Third and / or Fourth Generation), including organic PV (OPV) where organic materials rather then minerals are used to produce electricity – however efficiencies are very low (0.3%), and dye sensitised PV, where dyes sensitive to some of the solar spectrum are used. However, the material degrades from UV light and efficiencies are a little over 8%.[178]

PV systems can be connected to the grid, or be completely independent with proper battery storage. PV systems can also provide back up to the electricity grid; be an alternative electricity generator to be used when grid electricity is not available, too unreliable, and / or too expensive.

While patents and IPRs have expired on the majority of mature silicon solar cell technology, they remain in other areas of the PV value chain (e.g. making PV-grade silicon, etc.), as well as other emerging areas (e.g. Third Generation PV technology). Indian firms and research institutes have been working across the board with respect to these technologies. To date, as discussed in detail below, most Indian companies have focused on producing silicon solar modules, the fourth stage of the value chain. This is changing however, as an increasing number of Indian firms are planning on producing the entire PV value chain and are expanding into other areas, such as thin film technology.

175 Siemer, J. (2005). "Saving Intellectual Property: Patents for photovoltaic applications." *Photon International.*

176 Ashok Lall, TVB school of studies, Presentation, SEARCH Foundation and Government of India, M. o. N. a. R. E. (2008). *Various presentations and discussions*. Solar PV: Emerging Viable Option with Technology and Policy Thrusts, India Habitat Centre, New Delhi.

177 This is the case globally, not just in India. The energy output of a PV system is often predicted using assumptions from Standard Test Conditions (STC) of 1000W/m2, 25 degrees Celsius and air mass 1.5 global. However, a module can often operate in temperatures ranging from – 10 to + 80 degrees Celsius, and its power output will decrease as the temperature of the module increases TamizhMani, G., L. Dignard-Bailey, D. Thevenard, D.G. Howell (1998). *Influence of Low-light Module Performance on the Energy Production of Canadian Grid-Connected PV Systems.* Renewable Energy Technologies in Cold Climates, Montreal: 1.

178 Focus, R. E. (2008). Advances in PV. *Renewable Energy Focus.*; SEARCH Foundation and Government of India, M. o. N. a. R. E. (2008). *Various presentations and discussions.* Solar PV: Emerging Viable Option with Technology and Policy Thrusts, India Habitat Centre, New Delhi.

Current level of deployment in India

Solar PV manufacturing is increasingly being conducted in developing countries. These countries, especially China and India, are expected to provide a larger part of the manufacturing base for PV technology by 2011-12.[179]

The beginnings of the Indian PV industry date back to the early seventies when the Indian government mandated the state electronic companies to develop and produce solar cells and modules. The Indian government started at the same time to fund public R&D projects within Indian universities. The industry grew slowly until the mid-nineties mainly through procurement by the Indian Department of Telecom as well as the Indian Railway and other government corporations.[180] In the mid-nineties, procurement through the mentioned institutions stopped as PV technologies were replaced with alternatives.

Faced with the loss of sales to government corporations, manufacturers started to export PV modules to make use of their excess production capacities.[181] At the same time, the Indian government expanded its demonstration and rural electrification program and tried to integrate private actors into solar PV based rural electrification. Export and rural electrification provided commercial alternatives for the Indian PV industry, the former being more significant than the later. Existing production capacity could however not be completely put to use.[182]

According to the majority of industry experts, in the past, the Indian solar PV industry was driven by the activities of governments, Non-Governmental Organizations (NGOs) and International Organizations (IOs), including rural electrification programs and Corporate Social Responsibility (CSR) programs. By and large, the private sector involved in PV focused on exports, as the domestic market was not deemed profitable. However, the situation has changed since early 2007, due to two recent government policies, which will be discussed in detail in the section entitled "Policy Implications". Since then more companies have become interested in producing PV systems for the domestic as well as international markets. At present, about 75% of capacity is for exports while the rest is for the domestic market.[183] The majority of these exports are for European markets, especially Germany, as well as Japan and the United States.

Comprehensive, publicly available studies on the Indian solar PV industry do not exist. Private companies undertake market research on a regular basis. Companies are state-run, joint sector, or private sector companies.

179 (ISA), P. a. I. S. A. (2008). Solar PV Industry: Global and Indian Scenario. New Delhi, ISA: 174.
180 Sastry, E. V. R. (1997). "The Photovoltaic Programme in India: An overview." *Solar Energy Materials and Solar Cells* **47**: 63-69., Bhargava, B. (2001). "Overview of photovoltaic technologies in India." *Solar Energy Materials and Solar Cells* **67**: 639-646.
181 Srinivasan, S. (2005). "Segmentation of the Indian Photovoltaic Market." *Renewable and Sustainable Energy Reviews* **9**: 215-227.
182 Interview, one PV company, October 2007
183 Interviews, industry experts, October and November 2008

Private firms include firms of complete Indian ownership, joint ventures with multinationals and foreign owned subsidiaries.[184]

Due to the recent interest in the industry, it is difficult to pinpoint the current number of PV companies operating in India.[185] However, prior to the end of 2007, there were 19 companies producing wafers, cells, modules and systems in India.[186] The majority of companies in India produce First Generation (crystalline silicon) cells and / or module – stages 3 and 4 of the value chain. Two of the key players in India are:

- Tata BP Solar, a joint venture between British firm BP (51%) and Tata Power Company (49%), in operation since 1989, with annual turnover of about US$200 – 250 million. Tata BP Solar is expanding its capacity to 180 MW, with a plan to increase capacity to 300 MW by 2010;[187] and

- Moser Baer Photo Voltaic Ltd., created in 2005, a subsidiary of Moser Baer, has 40 MW capacity to produce solar cells, with the aim of increasing capacity to 240 MW, and 40 MW capacity, with plans to increase capacity to 200 MW. The company is also constructing a 200 MW thin film manufacturing plant.[188]

Other companies include Central Electronics Limited (CEL), KSK Energy, Maharishi Solar, HighHindVac (HHV), Environ, SemIndia Systems, Titan, Bharat Heavy Electricals Limited (BHEL), Signet Solar, among others. Many existing firms have plans to increase capacity.[189]

Larger energy firms are also expressing an interest in the sector. For instance, Lanco Infratech created Lanco Solar in October 2008, with plans to manufacture the entire value chain in the PV process and invested US$ 1 billion to do so. However, recently Lanco indicated they are holding off plans to enter the solar energy industry.[190] Suzlon Energy, a world-renowned Indian wind energy firm, also indicated in November 2008 that they would be investing in solar power, identifying sites in Rajastan and Gujarat, but revealing few details about the investment.[191] Reliance Industries Limited (RIL) had also indicated plans to invest in PV with a 1GW plant, but with the global economic downturn in autumn

184 Srinivasan, S. (2005). "Segmentation of the Indian Photovoltaic Market." *Renewable and Sustainable Energy Reviews* **9**: 215-227.

185 For instance, two interviewees indicated that their businesses had only officially been in operation for less than one year. Moreover, these companies were in the process of building manufacturing plants (acquiring the necessary permits, personnel, equipment, etc.).

186 (ISA), P. a. I. S. A. (2008). Solar PV Industry: Global and Indian Scenario. New Delhi, ISA: 174. Haum, R. (2008). Unpublished PhD Research University of Sussex, SPRU.

187 (ISA), P. a. I. S. A. (2008). Solar PV Industry: Global and Indian Scenario. New Delhi, ISA: 174. Solar, T. B. (2008). "webpage information." Retrieved January 12, 2009, from www.tatabpsolar.com., Interview, one PV company, November 2008

188 (MBPVL), M. B. a. M. B. P. V. L. (2008). "Strategic Partnerships." Retrieved January 20th, 2009, from http://www.moserbaerpv.in/strategic_partnerships.asp.; Interviews, industry experts, October and November 2008

189 Interviews, industry experts, October and November 2008

190 Sreekala, G. (2008). Lanco to foray into solar energy. *the Economic Times*. Hyderabad: 1., Online, S. I. (2009). "Solar India Online January 2009 Newsletter." Retrieved January 30, 2009.

191 Standard, B. (2008). Suzlon Energy to Foray into Solar Power. *Business Standard.*

2008, decided to hold off on their plans. In addition, international groups like the Clinton Foundation have been seeking potential Indian investors for PV applications in India.[192]

The Indian PV companies vary in their level of integration. Some companies just cover one step of the PV value chain while others cover up to three. A few companies including Moser Baer and Environ have indicated plans to produce the entire PV value chain. An increasing number of companies are involved with or exploring thin film solar technology including Titan, Signet Solar, Moser Baer PV Ltd., KSK Surya Energy, and HindHighVac (HHV).[193] Despite this, companies involved in First Generation solar PV technology dominate India's solar PV industry. Respondents indicated that they were particularly focusing on silicon technology, as it is a technology that is well known and because the main mineral required to produce silicon was plentiful. One firm also noted that they were 'wedded' to that technology in the near to medium term, due to the amount of infrastructure, equipment and personnel investments already made in this area.[194] There was also a minority opinion by some government officials, academic researchers and some firms, that there was a need to access and master state of the art technologies to develop technological capacity within the country.[195]

4.0.2 Intellectual property rights

With respect to IPRs and photovoltaics in India, the following aspects must be considered. First of all, as noted above, ***mature production technology to make silicon cells is available on the market without licences since related patents have expired.***[196] This is particularly relevant in the case of India as the majority of PV firms at present are producing First Generation silicon cells and / or modules. In addition, there are two considerations; first that with respect to areas of PV technologies where IPRs and patents remain, ***they are held by a concentrated set of foreign companies rather than domestic players in India***. The second consideration is that ***the Government of India is actively encouraging the development of the PV industry in India***.

Do firms consider IPRs to be an issue in terms of working with this technology in India?

Interviewees indicated that ***to date, IPRs have not been much of an issue for many Indian firms***. They have been able to acquire the necessary technology from foreign firms without problems. Also, because demand for PV technology

192 (ISA), P. a. I. S. A. (2008). Solar PV Industry: Global and Indian Scenario. New Delhi, ISA: 174, Online, S. I. (2008). "Solar India Online December 2008 Newsletter." Retrieved December 31, 2008, 2008, Personal Communication, one infrastructure firm, November 2008.

193 (ISA), P. a. I. S. A. (2008). Solar PV Industry: Global and Indian Scenario. New Delhi, ISA: 174.; Interviews, industry experts, October and November 2008

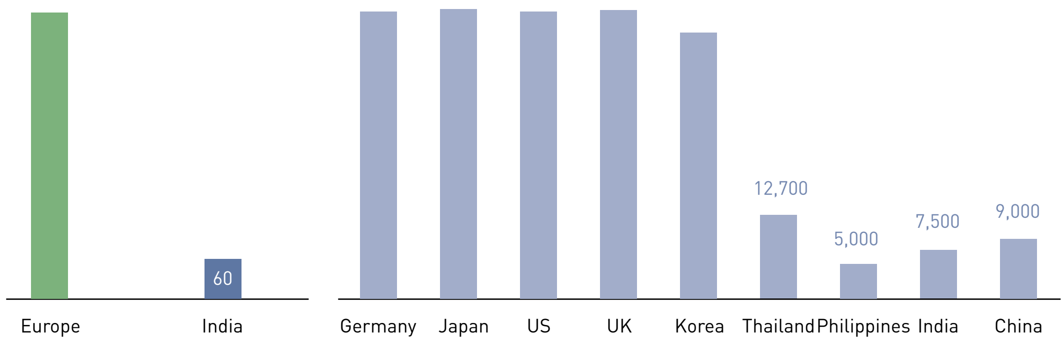
194 Interview, one PV firm, November 2008

195 Interviews, industry experts, October and November 2008

196 Siemer, J. (2005). "Saving Intellectual Property: Patents for photovoltaic applications." *Photon International.*

has been growing so rapidly, there is enough room for new entrants.[197] Only one Indian firm indicated IPR challenges in technology acquisition for making polisilicon, noting that there were only 7 or 8 players worldwide with this technology, and in the area of thin film solar cells.[198] As noted above, the IPRs for equipment and processes to make solar cells largely stay with foreign firms. Having said this, the Indian PV industry has developed a reputation as being able to produce the same, good quality product at a lower cost for various reasons, such as having excellent calibre engineers and other technicians with significantly lower salaries.[199]

Figure 4.3 – Relative Technical Labour Costs[200]



Indian Brand Equity Foundation (Feb 2007), Prices and Earnings. UBS (July 2006)

However, many industry representatives also indicated that *IPRs and patents could play a more prominent role in the future*. In India, module making has been more labour-intensive, and semi-automated, but these processes are becoming more automated, thus increasing the potential for IPRs to affect technology access. In addition, IPRs may hinder technology access by some Indian firms, such as Moser Baer and Environ, as they embark on production of the entire PV value chain and / or produce thin film solar cells. This is because the technologies involved in the upstream processes of the PV value chain – especially those involved in producing PV grade silicon -- are highly concentrated.

Some interviewees noted that companies involved at the initial stages of the value chain have a vested interest in restricting access to these technologies. The price of silicon increased from US$25 per kilogram in 2003, to US$250 –

197 Interviews, industry experts, October and November 2008
198 Interview, one PV firm, October 2008
199 Interviews, industry experts, October and November 2008
200 See KPMG (2007). India Automotive Study 2007, Domestic Growth and Global Aspirations. . KPMG. New Delhi, KPMG: 18 for further details

and some spot prices for PV grade silicon reached US$300 – 450 / kg in 2008.[201] Although companies that make PV grade silicon have announced plans for additional capacity, they have not implemented these expansions yet.[202] Having said this, as Indian firms are only starting to get involved in the upstream processes, it is not clear what their key challenges will be to access this technology.

The role of IPRs on working with the technology may depend on how concentrated relevant parts of the value chain are. It is not clear what role IPRs play with respect to the concentration of upstream stages (making PV-grade silicon and ingots and wafers) of the PV value chain. Other reasons for the concentration could include the high cost of building competitive production facilities and / or the expertise required to produce consistently high quality silicon at a competitive cost.

Indian firms' key market is exports, although the potential for domestic opportunities is also raising interest. In terms of IPRs, a number of Indian firms have trademarks on their products, but foreign firms own the majority of patents on the technologies. However, there are a few instances where some Indian and subsidiary companies operating in India have filed patents. One company indicated they had filed two patents in the United States, and another noted they had filed a patent in the Indian Patent Office. Unitran, a systems integrated in Mumbai, has patented its system in Germany.[203]

No company expressed a concern about patent or trademark infringement from others. Respondents indicated that they were not worried about these issues because their key export markets were in places like Europe, Japan and the United States. The specifics as to why this was not a concern were not provided. However, one interviewee noted "why would they even bother copying this technology, when they are already that much farther ahead [than us] anyway".[204] Another respondent noted that although they have not been concerned about IPRs and patent infringement in other markets to date, this might become more of an issue if they were to export to China.[205]

How have Indian firms and / or Indians been able to address access to IPRs?

Numerous strategies have been undertaken to address access to IPRs.

201 On the other hand, some reports predict that by 2012, there will be an oversupply of silicon, as existing firms are increasing production and more companies are becoming involved in production Winegarner, R. (2008). Report II – A Comprehensive Report on the Most Pressing Issue Affecting the Growth in Both the Photovoltaic and Semiconductor Industries S. I. a. P. Reports. Healdsburg, California, Sage Concepts.

202 Economist, t. (2008). Silicon Rally – One Shortage in the Solar-Panel Business Gives Way to Another. *the Economist*., Winegarner, R. (2008). Report II – A Comprehensive Report on the Most Pressing Issue Affecting the Growth in Both the Photovoltaic and Semiconductor Industries S. I. a. P. Reports. Healdsburg, California, Sage Concepts.; Interview, one PV manufacturer, October 2008

203 SEARCH Foundation and Government of India, M. o. N. a. R. E. (2008). *Various presentations and discussions*. Solar PV: Emerging Viable Option with Technology and Policy Thrusts, India Habitat Centre, New Delhi.; Interviews, two PV firms, October and November 2008

204 Interview, one PV company, October 2008

205 Interview, one PV company, October 2008

In the first instance, IPRs have not been an issue for those firms involved in mature PV silicon technology as those patents have been expired. For technologies in which IPRs and / patents remain, like the other case studies, Indian firms have mainly taken three approaches, in order of prevalence:

1. licensing

2. collaboration and acquisition

3. in-house R&D

Licensing

The most common way in which firms acquired technology was through purchasing the necessary licenses. Nearly all companies noted that they had no difficulties in acquiring the technology. Some international firms such as First Solar and NanoSolar were not selling equipment or expertise, but enough other players existed that were selling these technologies. Although the relevant IPRs remain with the company selling the license, Indian firms did not view this as a hindrance to technology transfer. All firms knew of the emerging technologies and developments in PV (dye sensitised, BIPV, nanotechnologies, polymers used in cells from corn, Gretzel cell, etc.) but the majority of firms were fine with waiting until the technology became more mature versus being actively involved in this process.[206] One interview respondent commented:

> "Why reinvent the wheel?" Pointing to his laptop, he stated "Why should I spend time trying to build my own computer, because the time spent in doing that, I will still be behind the curve because those companies at the cutting edge are not going to stop – by the time I catch up, the frontier technology will be that much farther. Take India's niche in spirituality –why create a completely separate system of yoga [in the West] when you can draw from an art that has been existence for thousands of years".[207]

Collaboration and Acquisition

The second manner in which Indian firms address IPR issues is through collaboration. For instance, Tata Power, through Tata BP Solar, one of the most successful Indo-British joint ventures to date, was able to access the knowledge and expertise of BP. Moser Baer PV Ltd. is also working in partnership with Applied Materials, a firm that produces solar cell manufacturing equipment. In 2006, Moser Baer PV Ltd. gained "significant equity"[208] in a number of

206 Interviews, Industry experts, October and November 2008
207 Interview, one PV company manufacturer, October 2008
208 It is not clear if this amount constituted majority ownership (i.e. acquisition versus partnerships).

American firms including Solaria and Stion Corporation, involved in frontier PV technology.[209]

Collaboration between personnel is also occurring. According to one industry expert, if one looked at the names of the researchers doing work on PV in the United States (from firms and government institutions), over 60-70% of leading personnel are of Indian origin.[210] In addition, another interviewee noted that he had recently returned to India after having spent time abroad in Germany, learning more about the technology. Some Indian firms have acquired personnel who have spent periods of time studying and / or working abroad and when these people have moved to India, they have been able to draw upon these networks.[211]

Other Indian firms are a subsidiary of an international PV firm, allowing some access to the knowledge held by the mother company. In these instances, the parent company has collaborative arrangements with universities in that country (e.g. the United States). However, as indicated in Phase I, "less integrated approaches to technology transfer that include the use of recipient country manufacturers to supply parts and labour are more likely to improve technological capacity within recipient countries".[212]

Collaboration is also occurring on a smaller scale – including individual projects where advances are being made. For example, a university architecture professor spoke about his experience on a PV project at the India conference on Solar PV. He was interested in BIPV and approached Siemens about a potential project. Siemens deemed it too expensive, so a group of professors and students came up with BIPV options on their own in consultation with other researchers in India and elsewhere (e.g. a professor working at an Israeli university).[213]

In-house R&D

The final but least common manner in which Indian firms address access to IPRs is through in-house research and development. One PV firm noted that it is starting to develop more capacity in the area, by creating a team working on innovation.[214] Another PV manufacturer involved in thin film solar cells, HHV, developed the majority of its technology indigenously. Dr. Barua, one of the founders of the company, began his research at a university in Kolkata and did his PhD research on thin film. He received support from one of the Indian Institutes of Science to work on a program within the Indian government-owned

209 (MBPVL), M. B. a. M. B. P. V. L. (2008). "Strategic Partnerships." Retrieved January 20th, 2009, from http://www.moserbaerpv.in/strategic_partnerships.asp.

210 Interview, one PV manufacturer, October 2008

211 Interviews, industry representatives, October and November 2008;

212 Haum, R. (2008). Unpublished PhD Research University of Sussex, SPRU.
Ockwell, D., J. Watson, et al. (2006). UK-India Collaboration to Identify the Barriers to the Transfer of Low Carbon Energy Technology. London, Report by the Sussex Energy Group (SPRU, University of Sussex), TERI and IDS for the UK Department for Environment, Food and Rural Affairs: 8.

213 Krishnan, Presentation, SEARCH Foundation and Government of India, M. o. N. a. R. E. (2008). *Various presentations and discussions*. Solar PV: Emerging Viable Option with Technology and Policy Thrusts, India Habitat Centre, New Delhi..

214 Interview, one PV firm, November 2008

firm Bharat Heavy Electricals Limited (BHEL). However, the program was cut. In 2002, he and five team members turned their attention to making advances in thin film technology within HHV. After 6 – 7 years of R&D they expect to have operations in place with efficiencies of 6.5% by April 2009.[215]

In contrast, Moser Baer Photo Voltaic Limited (MBPVL), another Indian firm planning on manufacturing thin film PV, was incorporated in 2005 and announced thin film plans in 2008, after partnering with some American firms working in this area. However, MBPVL, is a subsidiary of Moser Baer, an Indian firm that is the second largest producer of optical storage devices world wide.[216] As a larger company, it has more resources (personnel, financial and technical) available to offer other organizations it is interested in partnering with.

4.0.3 Collaborative research, development, demonstration and diffusion (RDD&D)

This section first describes the prominent RDD&D actions being pursued by Indian firms, and then investigates the implications these actions have on facilitating or hindering technology transfer.

Collaboration between Indian firms and foreign organizations occurs in two ways in solar PV. The first is through independent actions taken by PV manufacturers, through a series of bilateral discussions and arrangements. Indian firms are leading this process by conducting their own research and targeting appropriate manufacturers of equipment and entering long-term collaborative arrangements. These arrangements range from joint ventures, such as Tata BP Solar, where talks began in the mid-1980s, to memoranda of understanding, to more informal agreements. Only one firm , Tata BP Solar, indicated that it is actively engaged in creating awareness about this technology in the community. Moreover, Indian firms are tapping into the Indian diaspora community, allowing them access to networks overseas.

The advantage of this approach is that Indian firms actively drive the process, and so play more of a leadership role in the technology transfer process. On the other hand, identifying the appropriate companies and / or personnel independently often takes more time, and so likely affects the rate of technology diffusion. This is especially an issue for companies conducting in-house R&D through mainly indigenous channels. Despite this, the majority of Indian firms did not see this as an issue.

When asked about the potential to partner with universities, Indian PV firms recognized that some of the Indian technical institutes are actively engaged in research, and that some of this research is excellent. According to Dr. Kumar, Lanco Solar, IIT Delhi had achieved some of the best efficiencies in the world with respect to non-silicon solar cell technology, stemming from research in the

215 Interview, HHV, November 2008

216 (MBPVL), M. B. a. M. B. P. V. L. (2008). "Strategic Partnerships." Retrieved January 20th, 2009, from http://www.moserbaerpv.in/strategic_partnerships.asp.

1980s.[217] A few *ad hoc* examples exist. However, the general consensus amongst respondents was that there is a disconnection between how the private sector and academia operate. One interviewee noted that

> "The mentality of academic institutes is different. Their approach to timelines and achieving results is not in sync with the private sector.... researchers present papers, attend workshops, but they are unable to answer the question 'how can you deploy this tomorrow'?"[218]

The second way is through a number of indigenous intermediary groups, which seek to create awareness and facilitate interaction among key players in the industry. Through seminars, exhibitions, online material and studies, cooperation is increasing. Three of the key groups operating at the national level are the most active trade association, the Indian Semiconductors Association (ISA) under their PV section; SolarIndiaOnline, a small group of people actively engaged in creating an online "one stop shop" for PV players to turn to for events, key information including government policies, etc.; and the Renewable Energy Action Forum (REAF), a Bangalore group of key players from diverse backgrounds including industry, academic institutes and the United Nations.[219] The existence of these groups is encouraging; however, they are all relatively new. For example, the oldest group, the ISA – PV section has only been in operation since 2004.[220]

4.0.4 Policy implications

Although nascent, most PV industry experts agree that the Indian PV industry began as a result of government policies including rural electrification and government procurement policies. These policies are at various levels of government. For instance, a number of respondents indicated West Bengal's state government, which has done a lot of work promoting PV.[221]

Many informants also argue that recent PV industry development is largely driven by two additional relatively new national policies:

1. The GoI's Semiconductor Policy Guidelines in September 2007, which is essentially a tax holiday until March 2010. The Policy Guidelines include a Special Incentive Package Scheme (SIPS) (a 20% or 25% subsidy for capital costs) for setting up semiconductor fabrication and other ecosystem units, including PV, and Special Economic Zones (SEZs), where numerous tax breaks are available and PV manufacturing is an eligible activity.[222]

217 Kumar, presentation, SEARCH Foundation and Government of India, M. o. N. a. R. E. (2008). *Various presentations and discussions*. Solar PV: Emerging Viable Option with Technology and Policy Thrusts, India Habitat Centre, New Delhi..
218 Interview, one PV manufacturer, November 2008
219 Interview, industry representatives, October and November 2008
220 Interview, one trade association representative, November 2008
221 Interviews, industry experts, October and November 2008
222 For specific details see (ISA), P. a. I. S. A. (2008). Solar PV Industry: Global and Indian Scenario. New Delhi, ISA: 141-142.

2. Electricity Generation Based Incentives (GBI) – here the Ministry of New and Renewable Energy (MNRE) will provide a subsidy for grid connected PV power plants. The limit for the subsidy is up to 1MW per project, 5MW per developer in the country, and 10 MW per state, up to a total of 50 MW countrywide. The MNRE will guarantee PV project developers a tariff of 15 rupees per kWh. In some cases the MNRE will need to pay the difference between their guarantee and what the state electricity agency offers. For example, at present the state electricity organization offers four rupees per kWh in West Bengal while in Gujarat, the state electricity organization offers a little over 15 rupees per kWh.[223]

A number of government policies at the state level have also recently been introduced to encourage PV use including Punjab, West Bengal, Rajastan and Haryana.[224]

Also, Solar Energy is one of the eight missions in the Government of India's National Action Plan on Climate Change, a key area in which the GoI is prioritising climate change efforts. One of the Mission's aims is to have local PV integrated production in place at a level of 1 000 MW / annum from 2007-2017.[225]

The majority of informants **saw the two recent policies as important steps in encouraging development of the PV sector** – both manufacturing and use – in India. However, many argued that these **policies were not enough** and that the GoI had a long way to go to really ensure India would be a key global player in this industry. For example, some criticized the fact that the GBI had numerous ceilings, including the 50MW limit in the country and the 5 MW limit per developer, and that the GBI was only for 10 years, versus other countries' feed in tariff policies, like Germany's where PV project developers are guaranteed a rate for 20 years. In addition, one interviewee also raised the question of providing electricity for poverty alleviation. He noted that this subsidized power (with the large investors focusing on huge plants in isolated areas in Rajastan and Gujarat to provide power to urban centres) would target the wealthy of India rather than the rural poor.[226]

Although there was consensus amongst all interviewees that these government policies would help to support the industry, some noted that these policies and programs were not well known, were sometimes complex and operated in isolation, being run by various departments, etc.[227]

Discussions with officers working at the India Patent Office (IPO) indicated that the GoI has numerous incentives in place to encourage Indian firms and individuals to file patents, such as a relaxation of fees. In addition, the GoI

223 Ibid.: 142-144.; Interviews, industry experts, October and November 2008;
224 For details see (ISA), P. a. I. S. A. (2008). Solar PV Industry: Global and Indian Scenario. New Delhi, ISA: 144-145.
225 India, G. o. (2008). National Action Plan on Climate Change (NAPCC). New Delhi, Government of India: 22.
226 Interview, one PV manufacturer, November 2008
227 Interviews, Industry experts, October and November 2008

has been actively pursuing an awareness campaign and is undertaking major training initiatives, including the opening of the National Intellectual Property Training Institute on IPRs in Nagpur. However it is not clear that PV industry experts are aware of these policies as none made specific reference to them.[228]

With respect to government support for RDD&D in the area of PV, there are a few *ad hoc* examples (e.g. state Ministries of New and Renewable Energy), but no broad policy on a large scale.

In addition, the NAPCC indicates that "another aspect of the solar mission would be to launch a major R&D programme, which could draw upon international cooperation as well, to enable to creation of more affordable, more convenient solar power systems, and to promote innovations that enable the storage of solar power for sustained, long term use".[229] Within the area of PVs, the GoI has indicated proposed R&D activities to increase solar cell efficiency to 15% at a commercial level, to improve modules to have higher packing density and suitability for solar roofs, and improve lightweight modules to be used in applications such as solar lanterns.[230]

Discussions continue to refine these points further. However, because details on how these R&D activities, as well as other aims within the Solar Mission, will occur are scarce (e.g. which institutions, which incentives), it is difficult to ascertain the potential for this policy to encourage development transfer of solar PV technology. Furthermore, the majority of PV industry players were not involved in this process.[231]

Regarding policies to support technological capacity, there are almost no policies in place to encourage collaboration at the national or international level. However, a number of interviewees indicated that India's investment in their National Systems of Innovation (NSI), especially their IITs and IIC, with world class reputations for research and teaching, have provided Indians involved in these organizations with the necessary reputation to work and / or study abroad, fostering links between those people at home with the Indian diaspora abroad.

Only one informant noted a government program under the Confederation of Indian Industries (CII) to encourage collaboration amongst Indians conducting research with other countries (e.g. Canada, Israel).[232]

Moreover, the NAPCC specifically mentions the potential for collaboration to occur between Indians and institutions in other countries, with the resulting IPRs being shared. The GoI also recognizes the need for technology transfer

228 Interviews, IPO officers and PV industry experts, October and November 2008
229 India, G. o. (2008). National Action Plan on Climate Change (NAPCC). New Delhi, Government of India: 3.
230 Ibid.: 21.
231 Interviews, industry experts, October and November 2008
232 Interview, SolarIndiaOnline, October 2008

and the need to provide support to entrepreneurs to demonstrate solar PV technology to help develop the sector in India.[233]

Indian firms are the most dominant player in fostering links with other partners, whether international or domestic. This has important implications for the potential for technological capacity development, which often occurs as a result of acquisition of new knowledge and expertise, usually via interactions with others.

4.0.5 Conclusions

On IPRs and PV technology, the patents have expired for mature silicon solar cell technology, which is what the majority of Indian firms use. For this reason, IPRs have not prevented Indian firms from accessing the technology they require. At the same time, patents do exist in other areas of the value chain (e.g. producing PV grade silicon) and in other types of PV. These IPRs are held by a concentrated number of foreign firms. As an increasing number of Indian firms are expanding their operations to include production of the entire PV value chain, and as some firms move into more cutting edge technology (e.g. thin film), IPRs are likely going to play more of a role on technology access.

Indian firms are undertaking numerous strategies to acquire technology including in-house R&D, licensing, and partnerships and acquisition. Those strategies that involve knowledge and expertise from international sources appear to have had more successful technology transfer and diffusion.

On collaborative RDD&D initiatives, the two main drivers are 1) Indian industry, which identifies and approaches appropriate international partners, and 2) Indian intermediary groups, such as the ISA, REAF and SolarIndiaOnline, which are creating links for industry players to examine relevant policies, companies and other pertinent information. Linkages initiated by Indian companies tend to involve larger Indian firms. Therefore, there may be a role for government to encourage international collaboration between foreign partners and smaller Indian firms.

4.1 Hybrid Vehicles Case Study – SPRU

This case study was conducted and written by the SPRU team and is based principally on interviews conducted between September 2008 and January 2009.

233 India, G. o. (2008). National Action Plan on Climate Change (NAPCC). New Delhi, Government of India: 22.

4.1.1 Technology Overview

Relevance to reducing carbon emissions

Globally car ownership is growing and some studies suggest that it could increase by almost a factor of three, and that passenger travel will increase by 3.5-fold by 2030[234]. The transport sector is a critical sector to target to reduce carbon emissions. However, this will be costly due to the high unit costs of emissions reductions measures and the growing sales of transport vehicles globally[235]. About one third of consumption of petroleum products in India is by road transportation[236]. Moreover, India's transport sector is predicted to show the highest rate of growth in energy demand of any sector over the next 30 years[237].

According to Moriarty and Honnery[238] switching to full hybrid vehicles can increase fuel efficiency by up to 60% (especially in urban settings) compared to a conventional petrol-engine vehicle. They argue that full hybrid vehicles would be the largest contributor for fuel efficiency improvements, bringing a 2 to 2.5-fold increase in fuel efficiency in the global vehicle fleet by 2030. They also suggest that this increase in electricity use should come from renewables because these gains could be offset by an increase in electricity consumption. The fuel savings in micro hybrids, with start – stop capacity, are 3-10% of fuel savings but up to 20% in heavy traffic.[239] These fuel savings are less than those for full hybrids, but when examined on a large scale the potential for carbon reductions through these savings can be significant.

Current stage of development

Hybrid vehicles are vehicles that utilize a combination of internal combustion engine (ICE) and battery-drive electric motors. This is distinct from a purely electric vehicle (EV), or plug-in vehicle. The fuel used by the ICE can vary and includes petrol, diesel, biofuels, natural gas, among others. Phase I of the project described in detail the degrees of hybridisation[240]. In India, industry experts indicated the range of hybrids that were being used and / or considered in that country from micro hybrids, which have start – stop capacity, to full hybrids which include the ability to drive by electricity alone, although they still

234 Moriarty, P. a. D. H. (2008). "The prospects for global green car mobility." Journal of Cleaner Production 16(16): 1717-1726: 1724.

235 Tomlinson, S., Pelin Zorlu and Claire Langley (2008). Innovation and Technology Transfer – Framework for a Global Climate Deal. E. G. a. C. House. London E3G and Chatham House: 1-127: 48.

236 (IPC), I. P. C. (2007). *Eleventh Five Year Plan – Chapter 10 – Energy*. New Delhi: 383.

237 TERI (2006). Energy for the future: making development sustainable. Report for the Ministry of Environment and Forests, Government of India. New Delhi, TERI: 2.

238 Moriarty, P. a. D. H. (2008). "The prospects for global green car mobility." *Journal of Cleaner Production* **16**(16): 1717-1726: 1720.

239 Jackson, N. (2007). An Overview of Hybrid Technologies. Ricardo. United Kingdom, Ricardo.

240 Ockwell, D., J. Watson, et al. (2006). UK-India Collaboration to Identify the Barriers to the Transfer of Low Carbon Energy Technology. London, Report by the Sussex Energy Group (SPRU, University of Sussex), TERI and IDS for the UK Department for Environment, Food and Rural Affairs: 85-87.

have some form of an ICE.[241] Phase I also discussed the types of drivetrains -- series (only the electric motor is connected to the transmission, often better for stop and go situations), parallel (both the ICE and the electric motor are connected directly to the wheels, often better for open road driving) and series / parallel (a vehicle with both capacities).[242] The cost of a hybrid vehicle drivetrain can be up to four times more expensive than an equivalent conventional gasoline engine.[243]

The number of players involved in hybrids is steadily increasing. Phase I noted key players such as Toyota, with their hybrid synergy drive, a series / parallel drivetrain, the collaboration between GM, DaimlerChrysler and BMW (GM Allison Transmission's EP System), and Peuget Citroen's 'Efficient-C' diesel hybrid. Other players include Honda (focusing on smaller cars), Azure Dynamics (their BalanceTM Hybrid Electric system for commercial vehicles and their and Citibus Hybrid Electric systems), BAE Systems (their HybriDrive (TM) propulsion system using an electric motor and a diesel engine for commercial vehicles and buses), UQM Technologies, Torvec, Enova Systems, and Eaton Corporation (diesel-electric hybrid truck technology)[244].

In addition to the above firms which possess proprietary information on hybrid drivetrains, an increasing number of companies involved in various components are becoming engaged in this sector. Advances in various areas of automotive design (e.g. a lighter chassis to make up for the weight of the battery) are relevant to hybrid vehicles. However, the main components of the technologies particular to hybrid vehicles warrant further examination to effectively address the objective of Phase II of this study. These areas include electric motors and power electronics, battery systems and system integration.

Electric Motors / Power Electronics

As vehicles increasingly rely on electronics, engineers and technicians involved in vehicles must also incorporate expertise from electrical engineering and electronics. A number of industry experts indicated that as vehicles use more electronics, there is more potential for patents and Intellectual Property Rights (IPRs) to play a role in technology acquisition[245]. Electric motors are advantageous at times when lower speeds and throttle are required, such as in reversing, the stop and go situations common to urban driving.

241 Discussions, industry experts, October and November 2008; Discussions, NHPP workshop, November 2008

242 Ockwell, D., J. Watson, et al. (2006). UK-India Collaboration to Identify the Barriers to the Transfer of Low Carbon Energy Technology. London, Report by the Sussex Energy Group (SPRU, University of Sussex), TERI and IDS for the UK Department for Environment, Food and Rural Affairs: 85-87.

243 Jackson, N. (2007). An Overview of Hybrid Technologies. Ricardo. United Kingdom, Ricardo.

244 Dynamics, A. (2008). "Corporate Information." Retrieved January 16, 2009, from www.azuredynamics.com. Markets, R. a. (2008). "Global and China Hybrid Electric Vehicle Industry Report, 2007-08 (Overview only)." Retrieved September 23, 2008, from www.researchandmarkets.com/reportinfo.asp?report_id=612544, Toyota. (2009). "Hybrid Synergy Drive." Retrieved January 15, 2009, from www.hybridsynergydrive.com.

245 Discussions, NHPP Workshop, November 2008.

Power electronics, including a traction inverter and a battery charger are becoming increasingly important. Further efficiencies, lower costs and improved reliability of these technologies are required to better diffuse hybrid vehicles. According to Steve Schulz of General Motors (GM), while the battery adds the most cost to a hybrid vehicle, power electronics can raise the costs of a vehicle up by 20 percent or more. In addition, the prices of power electronics, stemming from the semiconductor industry, are also related to the price of silicon, which has increased dramatically in recent years (further details on silicon are provided in the PV case study above).[246]

Batteries & Battery Management Systems

The most important technologies for hybrid vehicles are those related to batteries. The cost of batteries remains high and their capacities allow only short driving ranges. Improvements are needed to reduce the cost and weight of batteries while also increasing their capacity and life.[247]

The batteries that have been used in vehicles in the past are lead acid (Pb-acid); a technology that has been around for over 100 years. These have been popular due to their low cost (US$300-600 / kWh) and the fact that they are reliable and efficient (around 70-90%).[248] However, due to various factors including a lower battery life, a lower power density and environmental considerations, other materials are increasingly being used. Many vehicles are moving towards lithium ion (Li-ion) batteries due to their higher power density, their excellent efficiency (almost 100%), as well as their maturity and availability (they are the battery of choice worth US$6 billion / year in a number of common consumer products including mobile phones, cameras and computers).[249]

The main attraction with lithium ion batteries is that they require less battery weight to produce the same amount of energy and power as lead acid batteries. Li-ion batteries represent the strongest potential among battery technologies currently available. According to Hall and Bain[250] "A10m by 10m by 10m lithium battery installation can store 400 MWh. This is comparable to a wind farm."

246 David, M. (2008, February 27, 2008). "Speaker Explores Impact of Hybrid Vehicles on Power Electronics." Retrieved January 16, 2009, from http://powerelectronics.com/power_semiconductors/news/hybrid-vehicles-steven-schulz-0227/.

247 Lipman, T. a. R. H. (2003). *Hybrid Electric and Fuel Cell Vehicle Technological Innovation: Hybrid and Zero-Emission Vehicle Technology Links.* 20th International Electric Vehicle Symposium and Exposition, Long Beach, California, University of California – Berkeley and Natural Resources Defense Council., Discussions, NHPP Workshop, November 2008

248 Chen, H., Thang Ngoc Cong, Wei Yang, Chunqing Tan, Yongliang Li, Yulong Ding (2009). "Progress in Electrical Energy Storage System: a Critical Review." *Progress in Natural Science* **in press:** 7.

249 Baker, J. (2008). "New Technology and Possible Advances in Energy Storage." Energy Policy 36: 4368-4373, Chen, H., Thang Ngoc Cong, Wei Yang, Chunqing Tan, Yongliang Li, Yulong Ding (2009). "Progress in Electrical Energy Storage System: a Critical Review." *Progress in Natural Science* **in press:** 8.

250 Hall, P. a. E. B. (2008). "Energy-storage Technologies and Electricity Generation." *Energy Policy* **36**: 4352-4355: 4354.

However, the cost of these batteries remains high (>$600/kWh) and the charging process does have a 'wear and tear' effect on the batteries.[251] Key firms involved in battery technology for hybrid vehicles that have indicated an interest in India include Texas Instruments and Logitech. As newer battery technologies become more common and battery management systems become increasingly and battery management systems become increasingly sophisticated, there is more potential for patents and IPRs to play a role in accessing technology.

Systems Integration

Hybrid vehicles require integration of electrical, mechanical, chemical and software technologies. Putting all of these components together and ensuring they function properly has led some to indicate, "because of this integration requirement, hybrid vehicles are one of the most complex systems to design, manufacture and maintain".[252] Integration also includes improving efficiency and reliability and reducing costs in other aspects of the vehicle, common to conventional vehicles, including cooling systems and the chassis or body structure.[253] Simulation technologies and testing technologies also exist for each component or for the system as a whole. Informants noted that this reliance on software and complex systems integration could mean that patents and IPRs could play an increasing role in technology acquisition in the future.[254]

Current level of deployment in India

The Phase I report highlighted that future policies with respect to hybrid vehicles must be viewed within the Indian context. Important issues for policy makers to consider are the need for an integrated transport system; the fact that many passenger journeys are made by two wheel vehicles; and hybrid vehicles are only one of several low carbon vehicle options.[255]

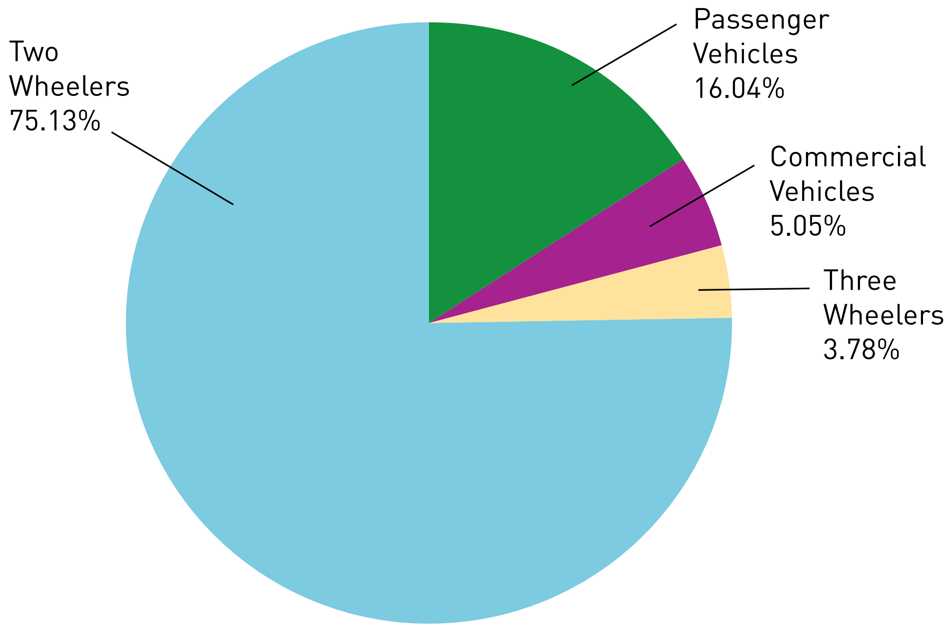
This section provides a snapshot of the vehicles market in India, then moves on to specific efforts underway with respect to hybrid vehicles. In addition, because hybrid vehicles rely on a combination of electricity and an ICE to operate a vehicle, this section will also examine developments in related to electric vehicles (EV).

In many developing countries, including India, increasing levels of personal wealth mean that private car ownership is steadily growing. For example, while

251 Chen, H., Thang Ngoc Cong, Wei Yang, Chunqing Tan, Yongliang Li, Yulong Ding (2009). "Progress in Electrical Energy Storage System: a Critical Review." *Progress in Natural Science* **in press:** 8.
252 Jensen, M. (2006). Simulation-based Design Integration Improves Hybrid Vehicle Reliability. *Automotive Design Line*: 1-3.
253 Discussions, NHPP Workshop, November 2008
254 Discussions, NHPP Workshop, November 2008
255 See Ockwell, D., J. Watson, et al. (2006). UK-India Collaboration to Identify the Barriers to the Transfer of Low Carbon Energy Technology. London, Report by the Sussex Energy Group (SPRU, University of Sussex), TERI and IDS for the UK Department for Environment, Food and Rural Affairs: 82-85 for specifics.

passenger vehicles constituted a little less than 12 percent of market share in India in 2002-2003, by 2007-08, they had increased to a little over 16 percent.

Figure 4.3: Market Share of Vehicles in India 2007-08[256]



At the same time, India is a key market for vehicles (the fourth largest car market in Asia, with a little more than 1.5 million sold in 2006/07 and cars only constitute 16% of the vehicles used) and is nearly one of the world's top 10 producers of vehicles – in 2007 India produced 1.9 million vehicles. The sector has grown around 17 percent in recent years.[257] As India is both a large vehicle user and producer, opportunities exist for India to take a leadership role in the area of hybrid vehicles. Moreover, India possesses many auto components companies – around 500 manufacturers in the organized sector and about 10,000 small and medium enterprises, allowing some Indian OEMs to produce products completely in India.[258]

In recent years, India has become a priority location for manufacturing and also increasingly sales for global vehicle and / or vehicle parts manufacturers such as Eaton, Ford and Honda.[259] However, private car ownership is only about 16 percent of transportation demand, and so important opportunities exist with respect to other vehicles, including those used for public transit (e.g. municipal

256 (SIAM), S. o. I. A. M. (2009, February 10, 2009). "Market Share." Industry Statistics Retrieved January 16 and February 10, 2009, from www.siamindia.com/scripts/market-share.aspx.
257 (IPC), I. P. C. (2007). *Eleventh Five Year Plan – Chapter 10 – Energy*. New Delhi, Jaura, A. (2007). *A Cleaner and Greener India: an Overview of Environmentally Friendly Vehicles (EFV) Initiatives*. 3rd International Environmentally Friendly Vehicles Conference, Dresden, Renner, M. (2008, Ma21, 2008). "Vehicle Production Rises But Few Cars Are 'Green'." Retrieved January 14, 2009.
258 (IPC), I. P. C. (2007). *Eleventh Five Year Plan – Chapter 10 – Energy*. New Delhi: 165.
259 InvestSmart, I. L. a. F. S. I. F. L. (2006). MSCI India ETF iShares. Mumbai, India: 1-37. , News, T. (2008). Eaton Calls for Government Subsidy for Hybrid Vehicles. *Thaindian News*.

buses), other alternatives for private transportation (e.g. two- and three-wheelers) and commercial vehicles.

With respect to the possibility for hybrid vehicles in India (both the use and manufacturing of), the general consensus amongst industry experts is that in the short term, micro and mild hybrid solutions made the most sense for India, due to the cost differential between micro / mild hybrid options and full hybrid options.[260]

Passenger Vehicles

In the case of passenger hybrid vehicles, Mahindra and Mahindra and Tata Motors are the most active at present, although Ashok Leyland and TVS have also developed concept vehicles. In January 2006, Mahindra and Mahindra developed a concept car. The Indian Ministry of Science and Technology (MS&T) expressed an interest in late 2006 and they, working with Tata Motors, produced a paper with respect to hybrids in India. The MS&T agreed to the National Hybrid Propulsion Platform (NHPP), based on the paper's recommendations, in their 11th Five Year Plan (2007-2012), with the aim of creating an indigenous demonstration fleet. The Planning Commission proposed the creation of a National Energy Fund to support research and development in this area. The Working Group on Energy R&D involved in this Five Year Plan suggested that 175 crores Rupees, or a little over US$ 36 million be spent on hybrid vehicles. Mahindra and Mahindra developed a demonstration vehicle in January 2008.[261]

Some foreign companies (e.g. Piaggio) have suggested that their future plans include the introduction of a hybrid vehicle to the Indian market. Having said this, at present only Honda offers the hybrid Civic (a mild hybrid) which was launched in June 2008.

Although this report focuses on hybrid vehicles, advances in electric vehicles (EV) are also examined, as hybrid vehicles rely on some of these technologies. One Indian firm focusing on electric passenger vehicles is REVA Electric Car Company, of Bangalore. This company began in 1994 as a joint venture between Maini India Group and AEV of California. REVA has seen increasing sales of its REVA car, first commercialised in India in July 2001, which is well suited for urban environments. It has a range of 80 kms when fully charged (7 hours), and 65 kms when 80% charged (2 hours), and can reach speeds of 80 km / hour.[262]

260 Jaura, A. (2007). *A Cleaner and Greener India: an Overview of Environmentally Friendly Vehicles (EFV) Initiatives*. 3rd International Environmentally Friendly Vehicles Conference, Dresden, SIAM (2008). SIAM Interview. New Delhi.

261 (IPC), I. P. C. (2007). *Eleventh Five Year Plan – Chapter 10 – Energy*. New Delhi, Jaura, A. (2008). Mahindra and Mahindra (M&M). Mumbai.

262 Company, R. E. C. (2004). "Corporate Information." Retrieved January 8, 2009, from www.revaindia.com.

Two-Wheelers

With respect to two-wheelers, at present, there are no hybrid options available. However, electric two-wheeler vehicles have been developed by a number of firms in India including Hero Honda, a joint venture between India's Hero Group and Honda Motor Company, Mahindra and Mahindra, and TVS, an electric scooter (Scooty Teenz EV – aimed at women travelling short distances), among others. In autumn 2008, spearheaded by Hero Honda's CEO, Sohinder Gill, the Society for Indian Electric Vehicle Manufacturers (SIEVMs) – consisting of representatives manufacturing vehicles, supplying components, providing energy and customers, was incorporated in New Delhi.[263] As two-wheelers have the largest market share of vehicles in India (over 75%), future developments in this area will be particularly important.

Three-Wheelers

Bajaj auto (Eco-Rick), Mahindra and Mahindra, Scooter India and TVS have developed prototypes of three-wheeler hybrid vehicles.[264]

Buses and Vans

As noted in Phase I, Ashok Leyland has developed a prototype hybrid bus chassis. In addition, BHEL have developed hybrid vans and buses.[265]

Commercial Vehicles

At present, no hybrid commercial vehicles are being produced in India, although there have been calls by some vehicle and vehicle component manufacturers located in India (e.g. Eaton India, located in Chennai) for a government subsidy to help them produce hybrid vehicles using diesel-electric technology for trucks.[266]

4.1.2 Intellectual Property Rights

Regarding Intellectual Property Rights (IPRs) and hybrid vehicles, there are three important considerations. First, ***IPRs are dominated by a concentrated set***

263 TVS. (2007). "Corporate Information – Scooty Gals." Retrieved January 8, 2009, 2009, from www.scootygals.com/teenelectric.aspx, Anand (2008). Society of Indian Electric Vehicle Manufacturers (SIEVM) constituted *Machinist*.

264 (USAID), U. S. A. f. I. D. (2007, June 29, 2007). "Zero Pollution Vehicles Travel the Streets of India." Retrieved January 9, 2009, from www.usaid.gov/locations/asia_near_east/features/zeropollution_india.html, Jaura, A. (2007). *A Cleaner and Greener India: an Overview of Environmentally Friendly Vehicles (EFV) Initiatives*. 3rd International Environmentally Friendly Vehicles Conference, Dresden.

265 Ockwell, D., J. Watson, et al. (2006). UK-India Collaboration to Identify the Barriers to the Transfer of Low Carbon Energy Technology. London, Report by the Sussex Energy Group (SPRU, University of Sussex), TERI and IDS for the UK Department for Environment, Food and Rural Affairs, Jaura, A. (2007). *A Cleaner and Greener India: an Overview of Environmentally Friendly Vehicles (EFV) Initiatives.* 3rd International Environmentally Friendly Vehicles Conference, Dresden.

266 News, T. (2008). Eaton Calls for Government Subsidy for Hybrid Vehicles. *Thaindian News*.

of foreign companies rather than domestic players in India. All industry experts – whether Indian or foreign – noted that Toyota, with their hybrid synergy drive, is the global leader in this area, pointing out that they have been working on this technology for at least 17 years, and so they have numerous patents in this area. Toyota's Prius has been commercially available since 1997, and when accounting for the R&D that had to have occurred before then, the Japanese firm has built up a wealth of expertise – and patents – with respect to this technology.

Another important aspect to understand with respect to IPRs and hybrid vehicles is that ***patents exist in a number of areas***, including batteries, electric motors and power electronics, engines and system integration. For example, just in the area of engines, "hundreds of patents exist today".[267] In addition, patents exist for both products and processes. Thirdly, ***there is a general consensus by firms and other players (e.g. academic institutions) that they must work together to make advances in this area***. This is because the technology is so complex and requires expertise from numerous disciplines – ranging from automotive, mechanical and electrical engineering to computer science. Moreover, firms are joining up to gain more market access, serving as a counterbalance to industry leaders. Finally, there are ***strong domestic efforts to develop indigenous hybrid vehicle technology in India***.

Do firms consider IPRs to be an issue in terms of working with this technology in India?

The general consensus among interviewees was that ***IPRs are an issue but that they are not perceived to be prohibitive***. The main view was that although numerous patents existed, there was still "enough room to manoeuvre". In fact a number of industry experts suggested that because the technology required complex and intricate knowledge of numerous areas, possessing many patents, experts are able to tweak their products and processes enough to make their changes distinct. At the same time however, experts agreed that the fact that ownership of these IPRs is concentrated played a role in slowing diffusion of the technology.[268]

The firms with the most active interest in hybrid vehicle technologies in India are domestic, however informal discussions with industry experts and foreign firms suggested that the main reason for a lack of technology transfer in this area is the lack of a potential market for hybrid vehicles rather than IPRs.

The domestic firms most actively doing research and development on hybrid vehicles are Tata Motors and Mahindra and Mahindra, although all firms operating in India, whether domestic or foreign, have expressed an interest in this area. When questioned about specifics on how much of the total cost of a product and / or process could be attributed to R&D, firms were not willing to

267 Jaura, NHPP Presentation, November 2008
268 Interviews, Industry experts, October and November 2008

disclose that information, or indicated that they could not pinpoint a specific figure.

Many experts recognized that as vehicle systems are increasingly drawing from the software, electronics and chemical industries, there is **a strong potential for IPRs to become more of an issue in the future**.

How have Indian firms and / or Indians been able to address access to IPRs?

Indian firms have adopted four strategies to access hybrid vehicle technologies. These strategies include:

1. in-house research and development

2. acquisition of firms working in this area

3. collaboration between players under the National Hybrid Propulsion Program (NHPP); and

4. licensing the technology from international and domestic second-tier[269] firms

In-house research and development

The first way in which Indian Original Equipment Manufacturers (OEMs) and other firms access hybrid technology is through in-house R&D efforts. Technical experts have worked and / or studied elsewhere (often overseas including Ford and the University of Minnesota) and brought their 'brain power' to the company. It was knowledge acquired through such experience that allowed Mahindra and Mahindra to develop a hybrid concept car in 2006 and a demonstration car in 2008. Advancements in hybrid vehicles demand intricate knowledge by those working in this area so these experts are able to adapt technologies to make their efforts unique, ensuring not to infringe on patents previously established by others.

In addition, some Indians acquire knowledge of hybrid vehicle technology by working for a subsidiary of a foreign company or a joint venture between an Indian and foreign firm. For example, General Motors has research teams in India, such as those providing support for their Detroit R&D office, including testing and simulation programs. However, this approach may not lead to an

269 Although the distinction between first tier and second tier firms can be considered arbitrary, generally first tier refers to those firms which have significant differentiation of their products and / or services in the market. These distinctive attributes can include brand name, global reach, quality, etc. Second tier firms refer to those companies that offer little differentiation of their products and / or services in the market

improvement in technological capacity[270], or developing these skills may take longer. As has been argued in Phase I, Key Message 6, technological capacity in recipient countries can be improved through less integrated forms of technology transfer.[271] Other joint domestic and foreign firms such as Maruti Suzuki, are conducting research on hybrids and engaging in national initiatives.

Acquisition of firms

The second way in which Indian firms and / or Indians gain expertise in hybrid vehicle technology is through the acquisition of other firms working in this area. One interviewee noted, "Tata Motors has been acquiring firms left, right and centre".[272] On hybrid vehicle technology, Tata Motors, through its United Kingdom subsidiary, bought a majority ownership in a Norwegian electric vehicle manufacturing company, Miljo Grenland / Innovasjon in autumn 2008 with the view of launching an EV in Norway (called India EV) in 2009.[273] Speaking more broadly than hybrids, Mahindra and Mahindra have also been pursuing an active acquisition strategy.[274]

Collaboration between firms and other organizations

The third way Indian companies address IPRs is through collaboration. The main mechanism through which this is being done is India's NHPP. Indians are aware that 90% of hybrid vehicle technologies are overseas and so an important opportunity exists to localize it. This cost shared program between government and industry was approved in the 11th Five Year Plan in early 2007. The NHPP under the leadership of SIAM constituted a panel chaired by Dr. Arun Jaura of Mahindra and Mahindra, and formed three groups. One group is focusing on passenger vehicles (Dr. Jaura from M&M), another on commercial vehicles (Mr. Govindrajan from Tata Motors), and a third on two and three-wheelers (Capt. Mohanram from TVS Motors). Each group is responsible for a plan and deliverables with the following three prongs:

a) Technology Demonstration

b) Technology Capability Development and

270 Phase I looked at technological capacity in further detail (e.g. Ockwell, D., J. Watson, et al. (2006). UK-India Collaboration to Identify the Barriers to the Transfer of Low Carbon Energy Technology. London, Report by the Sussex Energy Group (SPRU, University of Sussex), TERI and IDS for the UK Department for Environment, Food and Rural Affairs: 10-11). For a discussion of technological capacity from the point of view of developing country (DC) firms, examining the endogenous and exogenous factors that influence technological capacity, please see Marcelle, G. (2004). *Technological Learning: a Strategic Imperative for Firms in the Developing World* Cheltenham, UK and Northampton, MA, US, Edward Elgar.

271 Ockwell, D., J. Watson, et al. (2006). UK-India Collaboration to Identify the Barriers to the Transfer of Low Carbon Energy Technology. London, Report by the Sussex Energy Group (SPRU, University of Sussex), TERI and IDS for the UK Department for Environment, Food and Rural Affairs.

272 Interview, one industry expert, October 2008

273 Times, I. B. (2008). Tata Motors buys 50.3 percent stake in Norwegian electric vehicle maker for Rs.9.4 crore. *International Business Times*.

274 Jaura, A. (2008). Mahindra and Mahindra (M&M). Mumbai.

c) Workforce development through university competitions[275]

The OEMs have agreed to share IP with partners working on these areas on things they have developed together, but will keep the IP on those aspects they have developed on their own. As this initiative has received government funding (70% of US$140 million), the OEMs will share the IP with the government and release this knowledge into the public domain after two or three years. The Indian OEMs are working with a number of foreign and domestic technology suppliers including engineering firms, battery providers and system integrators (e.g. Texas Instruments, Ricardo, FEV, Hybridtronics) on the NHPP.[276]

Licensing from second tier and / or technology supplier firms

The final way in which Indian firms address IPRs is through the purchase of technology licenses from other firms. For example, Mahindra and Mahindra worked with Bosch, Siemens and FEV to transform their concept car, developed internally, into a demonstration vehicle. Many of these second tier or smaller companies recognized the potential growth for hybrid vehicle technology in the Indian market, and so wanted to be an active participant in this area.

In summary, industry experts indicated that firms in India are taking a round-about approach to address IPRs. Rather than approaching the global leaders like Toyota directly, a number of firms are pursuing ingenious ways (explained above) to acquire and develop the necessary knowledge. Improvements are being made. Indian firms, governments and academic institutions are actively engaged in this area and are finding ways to address IPRs to access technology. A number of experts saw this complexity, requiring intricate details of the technology, as an opportunity to create unique patents.

At the same time, some IP experts questioned the ability of Indian firms (with often less resources available for legal expertise and proceedings) to ensure the "distinctiveness" of their IP should a conflict arise between them and an international player.[277] However, IPRs are affecting the rate of diffusion and, as noted earlier, may play an increasing role in the future as these systems become increasingly complex.[278]

4.1.3 Collaborative research, development, demonstration and diffusion (RDD&D)

This section of the case study examines the role for collaborative RDD&D initiatives in ensuring successful technology transfer. This section first

275 Discussions, NHPP Workshop, November 2008, Jaura, A. (2007). *A Cleaner and Greener India: an Overview of Environmentally Friendly Vehicles (EFV) Initiatives*. 3rd International Environmentally Friendly Vehicles Conference, Dresden.

276 Discussions, NHPP Workshop, November 2008.

277 Interview, Indian IPR expert, November 2008

278 Various interviews, Indian industry experts, October and November 2008; NHPP workshop discussions, November 2008

describes the prominent RDD&D actions being pursued by Indian firms, and then investigates the implications these actions have on facilitating or hindering technology transfer.

Like their international counterparts, the Indian government, along with Indian trade associations (e.g. SIAM), OEMs and technology suppliers recognize the need to work together to move hybrid vehicles forward.

There are two ways in which collaboration on hybrid vehicle technology by Indian firms occurs. The first is through independent actions taken by OEMs, through a series of bilateral discussions and arrangements. The second is through the NHPP. With respect to the first approach, Indian OEMs are actively researching and seeking out global and domestic partners that possess the expertise the Indian firms would like to acquire.

The advantage of this approach is that Indian firms are the most active 'driver' in the process, identifying appropriate partners with the necessary expertise that would be willing to share their expertise (whether through licensing of the technology, acquisition of the company and / or key personnel, and / or other collaborative arrangements including joint ventures, memorandums of understanding, personnel interchanges, etc.) As indicated earlier M&M was able to develop a demonstration hybrid vehicle working with FEV, Bosch and Siemens. In addition, Tata's acquisition of Miljo, through their UK subsidiary has led to its plans to launch an EV in Norway. The only EV on the market, REVA, began as a joint venture between an Indian and an American firm in 1994, which after seven years of R&D, launched an EV in India in 2001.[279]

The disadvantage of this approach is that it often takes a long time to identify the firms possessing the necessary knowledge, let alone the often lesser known names who possess the sought after technology and are willing to work with Indian firms.

Collaboration is occurring on a larger-scale via the NHPP. Lead by SIAM, and supported by key OEMs and the Government of India, the NHPP represents an excellent opportunity for successful technology transfer and development of hybrid vehicles in India. Key players working in the automotive industry have agreed to come together and consolidate their efforts to indigenise this technology in India. Some OEMs are taking a 'wait and see' approach; however all are interested in NHPP activities. Through this effort they have a common vision, seeking to improve:

- Emission Control systems
- Energy Management and systems

279 NHPP workshop discussions, November 2008, Company, R. E. C. (2004). "Corporate Information." Retrieved January 8, 2009, from www.revaindia.com, Jaura, A. (2008). Mahindra and Mahindra (M&M). Mumbai, Times, I. B. (2008). Tata Motors buys 50.3 percent stake in Norwegian electric vehicle maker for Rs.9.4 crore. *International Business Times*.

- Thermal management of components
- Lightweight and aerodynamics body/chassis
- Low rolling resistance (including body design and tires)
- Reduction of accessory loads[280]

The advantage of this approach is that by pooling this amount of human, financial and technical resources and ensuring constant communication increases the chances of improving the rate of technology diffusion and development.[281] On the other hand, others argue having more 'players under the tent' can hamper progress.[282]

It is too early to assess the effectiveness of the NHPP. However, the fact that the key trade association, the government, domestic and foreign firms and academic institutions have come together at the national-level under a common vision to create an "Indian hybrid vehicle technology" is positive. The NHPP's advances can be attributed to having SIAM, as the key trade association, take the lead and serve as a facilitator between industry and government, as well as the active engagement of the key Indian OEMs. Mahindra and Mahindra and Tata Motors have been the most active on this initiative although GM and Maruti Suzuki are also showing increasing interest.

In addition to these two approaches, *ad hoc* efforts also exist between companies, government organizations (e.g. the Collaborative Automotive R&D (CAR) section of Technology Information, Forecasting and Assessment Council (TIFAC), in the Department of Science and Technology – also engaged in the NHPP), and academic institutions (e.g. the IITs and IIC in Bangalore). When specifically asked about the potential to engage universities, many opined that in India, the disconnection between pursuits of the academic world (basic research) and industry (concerned with deliverables and practical applications) remained strong. Efforts to bridge the gap in India, such as incubators, have been increasing in the last five years, but they are not enough.[283]

Indian firms are aware of the frontier technology advances and global efforts working on hybrid vehicles. They noted that key regions conducting research in this area are Japan, the United States, Europe and increasingly China. In addition, firms are abreast of specific global initiatives such as:

- BMW, Daimler-Chrysler and GM partnership, on their Allison Transmission's EP System;

280 Discussions, NHPP Workshop, November 2008

281 Mallett, A. (2007). "Social Acceptance of Renewable Energy Innovations: the Role of Technology Cooperation in Urban Mexico." *Energy Policy*(35): 2790-2798.

282 Pietrobelli, C. (2000). Technology Transfer in Developing Countries. *Technology Transfer*. D. A. M. Schroeer. Hants, UK and Burlington, VT, US, Aldershot and Ashgate.

283 Jaura, A. (2008). Mahindra and Mahindra (M&M). Mumbai, Interviews with various industry experts, October and November 2008.

- Challenge X: Crossover to Sustainable Mobility, sponsored by GM and the United States' Department of Energy where engineering teams from North American universities compete on sustainable automotive options;
- the Freedom Car and Fuel Partnership funded by the United States government on research for hybrids and other alternative transportation systems
- Future Car and Future Truck competitions, where academia and industry work together to improve education and public awareness of these technologies; and
- AUTomotive Open System Architecture, or AUTOSAR, which is a standardized automotive software system, particularly focused on electronics for vehicles, developed by automotive manufacturers, suppliers and equipment developers. The aim is to "cooperate on standards and compete on implementation" [284]

These global initiatives represent important opportunities for Indian firms to be active players and to develop expertise in this increasingly complex field. In the past, Indian firms have largely adopted an independent, bilateral approach, although the NHPP represents an important step in which India can position itself to become a global leader in this area.

4.1.4 Policy implications

With respect to present policy efforts and their impact on hybrid vehicles in India, all interviewees noted that in the past little was done by the Government of India to promote collaboration between firms and others on hybrid vehicles, or to promote patents specifically for hybrid vehicles by domestic (or any) firms; the onus (including money, time and personnel) was on Indian OEMs. All cited the NHPP as being a key policy to promote hybrid vehicles, noting that the government was becoming increasing interested and aware of this issue.

A number of respondents noted that it is standard policy of the Government of India to have incentives such as tax breaks to encourage R&D actions by Indian firms (none wanted to mention specifics). However, this does not necessarily equate to developing technological capacity, or developing firms' capacity to work with and develop new technologies. Furthermore, tax breaks for R&D are often general, and not for specific technologies.

The Government of India also recently reduced the excise duty (taxes on goods produced in India) on hybrid cars from 24 % to 14 % for consumers. In addition, the GoI reduced the countervailing duty (or taxes on imported goods where the importing country deems that the exporting company has subsidized its

284 Discussions, NHPP Workshop, November 2008, X, C. (2008). "Information About *Challenge X*." Challenge X, Retrieved January 23, 2009.

exports)[285] on hybrid vehicles from 114% to 104%. Electric vehicles are currently exempted from all excise duties but are subject to a 16% customs duty in India. Moreover, the Ministry of New and Renewable Energy provides a 33% or 75 000 rupees subsidy for those purchasing the REVA for public transport.[286]

All interviewees agreed that the NHPP, where the Ministries of Science and Technology and New and Renewable Energy are active players, would help to facilitate the transfer and development of hybrid vehicle technologies in India. All also felt that the government's approach through providing incentives for R&D has and would continue to play a positive role in encouraging the transfer and development of these technologies.

However, none indicated that the government was playing an active role in encouraging collaboration with others – Indian firms were the dominant player in fostering links with other partners, whether international or domestic. This has important implications for the potential for technological capacity development, which often occurs as a result of acquisition of new knowledge and expertise, usually via interactions with others. The general consensus was that these were positive steps but that more actions, such as increased monetary subsidies for purchasers and producers of hybrid vehicles are needed.

As noted in the solar PV case study, discussions with officers working at the India Patent Office (IPO) indicated that the GoI has numerous incentives in place to encourage Indian firms and individuals to file patents, such as a relaxation of fees. In addition, the GoI has actively pursued an awareness campaign and is undertaking major training initiatives, including the opening up of the National Intellectual Property Training Institute on IPRs in Nagpur. However it is not clear that auto industry experts were aware of these policies as none made specific reference to them.[287]

With respect to IPRs, although some OEMs and other automotive firms have submitted patents in India, none noted special treatment or other incentives from the government to domestic producers (even though they exist).

Opinions are mixed regarding the potential role for environmental legislation. Some representatives mentioned the importance of environmental legislation in driving demand for hybrid vehicles in India – highlighting Delhi's experience with Compressed Natural Gas (CNG) vehicles in that city as well as the requirement that only non-fossil fuel vehicles (including electric vehicles, horse / oxen-drawn and bicycles) be permitted within a certain radius of the Taj Mahal. Others indicated that efforts should be directed at making the technology more affordable to the average Indian (i.e. reducing costs).[288]

285 (WTO), W. T. O. (2008). "Subsidies and Countervailing Measures." Retrieved January 23, 2009, from http://www.wto.org/english/tratop_e/scm_e/scm_e.htm.

286 Arun, L. P. (2008, May 8, 2008). "Indian Budget 2008-2009 Implies Huge Sops for Small Cars in the Automotive Industry." Retrieved January 19, 2009, from http://www.frost.com/prod/servlet/cif-econ-insight.pag?docid=129432737.

287 Interviews, IPO officers and industry experts, October and November 2008

288 Interviews, industry experts, October and November 2008, NHPP discussions, November 2008

4.1.5 Conclusion

The majority of IPRs relevant for hybrid vehicles are held by a few foreign players. The majority of firms indicated that IPRs are not prohibitive, but that the strategies they are adopting to acquire the necessary knowledge and hardware to conduct RDD&D in this area are having an impact on the rate of diffusion.

In addition, the technologies involved in hybrid vehicles are becoming increasingly complex, draw from various disciplines, and are already covered by numerous patents. Those with intricate knowledge of this industry saw the complexity as providing an opportunity to create unique IPRs, without infringing on existing IPRs. Others noted that Indian firms may be challenged by foreign firms with respect to the "uniqueness" of Indian firms' IPRs.

Moreover, many recognized that IPRs could play a greater role in the future as automotive systems become increasingly complex and engage more with other disciplines including chemistry and electronics. Indian firms and Indians working for foreign firms are actively engaged in RDD&D on hybrid vehicle technology. International collaboration is occurring within a number of firms as a result of actions undertaken by the private sector; however, none mentioned government incentives to encourage these linkages. To increase the rate of diffusion of hybrid vehicle technologies and to further develop firms' ability to acquire knowledge and expertise, government policies need to explicitly focus on encouraging technological capacity within firms.

4.2 SME case study – TERI

This case study was conducted and written by TERI and is based on previous in depth work in this area.

4.2.1 Background

The SME (small and medium enterprises) sector plays a vital role in the Indian economy, contributing around 45% of manufacturing output and 40% of exports, and employing more than 40 million people. However, having functioned for five decades within an overly protective economic and industrial framework, a large proportion of Indian SMEs remain isolated from modern technological developments. They use obsolete, inefficient technologies to burn commercial fuels like coal, oil, and gas, leading to wastage of fuel as well as release of high volumes of greenhouse gases and particulate emissions that are harmful to health and damage the atmosphere. Many SME sub-sectors are energy-intensive, with fuel costs making up 20%–50% of the total cost of production. While individual SME units are relatively small in size, their sheer numbers, coupled with the fact that they depend on low-efficiency fuel burning technologies, make the SME sector a sizeable source of carbon emissions. Hence, there is a clear and urgent need for SMEs to adopt EE (energy-efficient) technologies that will help them reduce both fuel consumption and carbon emissions.

This case study summarizes two successful TT (technology transfer) projects undertaken by TERI with the support of SDC (Swiss Agency for Development and Cooperation), to promote EE technologies in two energy-intensive SME sub-sectors: small-scale foundries, and small-scale glass industries.

It is important to note that TERI played two roles during this project:

As primary recipient of the improved technological know-how, through ongoing capacity building of the TERI team by its overseas partners.

As facilitator and technology service provider for the development, adaptation, demonstration and promotion of the improved technologies in the concerned SME sectors, through direct field-level interactions with entrepreneurs and other industry stakeholders.

Small-scale foundries

Profile

Foundries make iron castings from molten iron. Castings find diverse applications such as in the manufacture of sanitary pipes and fittings, automotive parts, and engineering equipment like pumps, compressors, and electric motors. There are about 5000 small-scale foundry units in India, with a collective annual output of about six million tonnes of castings. While their output predominantly caters to domestic markets, a small percentage is exported. The foundry sub-sector is growing at 8%–9% annually and provides direct employment to an estimated half-a-million people.

The Indian foundry industry had its roots in the 19th century, when industrialization and rapid expansion of railways provided an assured and growing market for castings. After independence, the steel and coal-mining sectors largely remained under government control, and hence the foundry industry was assured about both the availability and prices of its primary raw materials, pig iron and coke. In this scenario, energy efficiency was not a major concern for foundries. However, the situation changed following the opening up of the Indian economy in the early 1990s. With the removal of licenses and permits to obtain coke, small-scale foundries are no longer assured of coke supplies at steady prices. Hence, energy efficiency has become of vital concern for small-scale foundries—as a means to reduce fuel consumption and costs and thereby increase profitability and competitiveness.

Foundries are mainly located in clusters across the country. The clusters vary in size: some have less than 50 units, while others have over 500 units. Typically, each cluster specializes in producing castings for specific end-use markets. For instance, the Howrah cluster in eastern India has around 300 foundries that mainly produce low-value-added castings such as manhole covers and pipes; while the Rajkot cluster in western India has around 500 foundries that mainly produce grey iron castings for the local diesel engine industry.

Mirroring the different products they make and the diverse markets to which they cater, foundry clusters differ from one another in terms of technology, operating practices, and commercial dealings. Within a cluster, foundry units usually operate in isolation; there is little sharing among them of information related to technology, operating practices, and so on. The units may form loose associations; but these are primarily for the purpose of obtaining fuel (coke) at favourable prices from suppliers and for other trade-related issues.

Technology

A foundry makes iron castings by melting a variety of iron-containing materials such as pig iron and cast iron scrap in a furnace called cupola. The molten iron so obtained is then poured into moulds to make castings of desired shapes. Usually, cupolas burn coke as fuel. Melting is by far the most energy-intensive stage of foundry's operations.

Till the early 1990s most Indian foundries were using the conventional 'cold blast' cupola. As described later, TERI partnered with the UK-based BCIRA (now known as BCIRA Cast Metals Technology Centre)[289] to identify, transfer and adapt a more energy-efficient melting technology for small-scale Indian foundries—the DBC (divided blast cupola). A Swiss consulting firm, Sorane SA, played a major role in facilitating this technology transfer process.

Scope for reducing carbon emissions

The total coke consumption by the foundry sub-sector is estimated to be around 600,000 tonnes per year (equivalent to around 1,640,000 tonnes CO2). There is considerable scope for saving 20%–40% fuel and reducing carbon emissions in this sector by switching to the energy-efficient DBC technology.

Small-scale glass industries

Profile

Almost the entire small-scale glass industry in India is located in a single cluster in Firozabad, about 40 km from Agra. According to a TERI estimate, each day glass units in Firozabad produce around 2000 tonnes of glass products including 50 million bangles, and provide direct employment to an estimated 150,000 people. Besides having a near-monopoly in the production of bangles, the Firozabad glass cluster also produces popular low-value glass products

289 BCIRA is Britain's leading organization involved in research and development within the field of cast metals.

(bowls, tumblers, lamp shades and so on). There is a steady demand for such products all across India. However, with very little to distinguish the glass products made by one unit from another, and in the absence of direct linkages with consumers or retail markets, units sell their products at prices dictated by dealers and middlemen. As a result, competition is vicious among units, and profit margins are thin and unpredictable.

In the early 1990s, glass entrepreneurs had very few options to increase returns. There was no room to reduce manpower or wages. Fuel (coal) costs were beyond their control. The only way to reduce fuel costs was by increasing the energy efficiency of the glass melting furnace; but this task required technical knowledge and skills that neither the entrepreneur nor the traditional furnace builders (*mistrys*) possessed.

Technology

Glass is made by melting silica sand (which contains about 96% by weight of silicon dioxide or SiO2) together with chemicals that reduce melting temperature and give strength and colour to the end-product. The molten glass is drawn from the furnace, blown or formed into desired shapes, and then annealed (heated and cooled in a controlled manner) to impart hardness to the glass. Depending on their nature, the products are then subjected to various cutting and finishing operations. The glass industry is highly energy-intensive, with fuel cost in many cases accounting for over 40% of product cost.

In Firozabad, three basic kinds of melting furnaces are used to make glass: tank furnaces, open-pot furnaces, and closed-pot furnaces. Glass for making bangles is melted almost exclusively in open-pot furnaces. Till the early 1990s, almost all these furnaces operated on coal. By 1996, most tank furnaces had switched from coal firing to oil firing, but pot furnaces were still being fired by coal. As described later, TERI worked with British Glass and other partners from UK and Switzerland to transfer know-how for the development and promotion of a more energy-efficient melting technology for small-scale glass melting units in Firozabad—the gas-fired recuperative pot furnace.

Scope for reducing carbon emissions

According to a study by TERI in1995, the pot furnace units in the Firozabad glass cluster consumed around 100,000 tonnes of coal annually. Hence, there was considerable potential to reduce coal consumption and decrease carbon emissions in this sector by shifting to more energy-efficient technologies for producing molten glass.

4.2.2 Intellectual property rights

The technologies that are used within the small-scale foundry and glass industry sectors in India have evolved over centuries, and are quite unique in terms of the designs of furnaces, sizes of units and operating practices. Extensive local adaptation is required (in terms of design, scale of operations, and operating practices), to develop improved technologies for these sectors, and the improved technologies are themselves quite unique—at the sector, cluster, and (often) unit levels. Hence, existing/prior intellectual property rights (IPRs) were not an issue in these two cases, and did not pose a barrier with regard to the introduction of low-carbon technologies.

However, as elaborated in the next section, the collaborative RDD&D (research, development, demonstration and diffusion) approach followed in both these cases was instrumental in ensuring that the best know-how available in the respective fields internationally (specifically, with the British and Swiss partners) was transferred to the Indian firms through TERI. SDC designed its bilateral assistance programme in such a way that in both cases, the technology development efforts were initiated at a very early stage of the technology development cycle, enabling smooth transfer of the 'softer' (know-how) components of the technology.

The agreement between SDC and TERI specifically provided for both parties to mutually decide on whether or not to patent innovations resulting from their collaborative work. Following demonstration of the improved EE technologies, TERI and its partners promoted their replication by further adapting the technology designs to suit local conditions and individual unit requirements. These derivative technology designs were unique. However, SDC and TERI made no attempt to patent them, in view of the broader goal of benefiting the SME sector and reducing carbon emissions through replication of the technologies.

4.2.3 Collaborative research, development, demonstration and diffusion (RDD&D)

In 1992, SDC initiated a macro-level study by TERI of energy consumption patterns in the Indian SME sector. Based on this study, SDC partnered with Indian NGOs/research institutions and international consultants to initiate a programme aimed at introducing clean, EE technologies in four energy-intensive SME sub-sectors. Two of these sub-sectors—namely, the foundry and glass industries—are discussed in this case study. The other two sub-sectors identified were the small-scale brick industry, and small/micro enterprises that burn biomass fuels. The long-term purposes of the SDC programme were:

- To help SMEs achieve energy savings and thereby improve profitability of operations
- To bring about reduction in CO2 and other emissions and thereby address environmental concerns at both local and global levels.

Technology transfer process

In the case of both small-scale foundries and small-scale glass industries, EE technologies were identified, transferred and adapted to local conditions and requirements in the following broad stages:

- Conducting energy audits to identify areas in which to improve energy efficiency (needs assessment)
- Identification, design, development and adaptation of EE technological solutions in collaboration with
  - International experts
  - Industry associations
  - Local experts
- Demonstration and fine-tuning of the improved technologies through unit-level demonstration/pilot projects
- Strengthening the knowledge and skills of local entrepreneurs and building their confidence and capabilities in the new/improved EE technologies, through ongoing capacity building programmes (thus preparing the ground for dissemination and mainstreaming of the demonstrated technologies)

During the TT processes, TERI obtained strategic support and inputs from Sorane SA, Switzerland. Sorane SA provided advice in energy management and systems integration, helped identify and coordinate activities with international energy and environmental consultants, and assisted by way of backstopping.

Energy audits

In 1993–94, TERI conducted detailed energy audits of representative units in the Agra foundry cluster. The audits revealed that the 'coke feed ratio' or CFR[290] (a measure of cupola efficiency) ranged between 31% and 19% in the existing cupolas, compared with the best CFR levels achieved within India and abroad of about 10%. This indicated large potential for improving energy efficiency by introducing optimally designed cupolas and adopting BOP (best operating practices). TERI also conducted energy audits of representative glass units in the Firozabad glass cluster in 1994. These audits revealed that the energy efficiency of the coal-fired open pot furnace was very low, with flue gases escaping from the furnace at a temperature of around 950 °C. These findings indicated considerable potential to increase energy efficiency in pot furnaces through heat recovery from flue gases.

290 The energy efficiency of a cupola is measured in terms of the amount of coke consumed per tonne of metal charged. Known as CFR or coke feed ratio, this is usually denoted as a ratio or as a percentage. The lower the CFR, the more efficient is the cupola.

Identifying technologies for transfer

Having identified the areas in which to introduce EE technologies—namely, cupola furnace in foundry units and coal-fired open pot furnace in glass units—TERI teamed up with international partners to select appropriate technologies which could be transferred and adapted to the local industry needs.

In each case, the first step was to evaluate existing technologies to identify those that could be adapted or modified to meet the standards set for better energy efficiency and environmental performance. Thereafter, from among the available options, the most appropriate one—that is, the one most suited to adaptation to meet local needs and conditions—was selected and transferred for further development to meet the needs of the industry concerned.

DIVIDED-BLAST CUPOLA

In the case of foundries, the results of the Agra cluster energy audits were discussed and validated by experts from Cast Metals Development Limited, UK—a group company of BCIRA. The discussions also focused on finding ways to improve the efficiency of the melting furnace. Based on its consultations with the British partners, TERI chose the divided-blast cupola or DBC as the best option to improve energy efficiency in small-scale foundries at a modest investment. The DBC offered the following advantages over the conventional cupola:

- coke consumption reduced by about 25%;
- tapping temperature increased by about 50º C; and
- melting rate increased.

GAS-FIRED RECUPERATIVE POT FURNACE

The identification of EE technology options for the open pot furnace in Firozabad presented a unique challenge, primarily because a pot furnace is intrinsically inefficient in design. Pot furnaces were being used in countries such as Britain and Germany; but these burned better-quality coal or coke to make very high-value products such as crystal ware, as a result of which the proportion of fuel cost in the product cost (that is, the energy intensity) remained low, making operations profitable. In contrast, the pot furnaces in Firozabad burned medium-grade coal to make relatively low-value items, and hence the fuel cost made up a substantial portion of the product cost. The result: low profitability of operations.

Following extensive consultations between TERI, its British partners and Sorane SA, a new pot furnace design was evolved through research, development and demonstration in the Firozabad glass cluster: a gas-fired pot furnace with its burner mounted on the crown, and with a recuperator to recover and reuse waste heat from flue gases.

Technology development and demonstration

DIVIDED BLAST CUPOLA

TERI developed and demonstrated the DBC at a foundry unit in the Howrah cluster. In setting up the demonstration plant, the project brought together local and international experts in many disciplines project management, foundry technology, energy management, cupola operations, and environmental technology.

In particular, Cast Metals Development Limited, U.K., provided crucial support and expertise in transferring technical know-how related to the DBC, and at every stage during the design and commissioning the demonstration plant. The British partner assisted the TERI team in conducting an energy audit of the existing cupola in the demonstration unit; analysing the results of the audit so as to evolve design parameters for the new DBC; ensuring that quality and design norms were adhered to during the fabrication of various components of the DBC; and fine-tuning various sub-systems during the trial runs. The TERI team received extensive training in the UK in designing the energy-efficient DBC, and also benefited from its interactions with experts during field visits.

The demonstration DBC was successfully commissioned in mid-July 1998. The DBC showed a marked improvement in energy efficiency (CFR 8%) compared with the existing cupola (CFR 13.3%). In effect, the new plant yielded an energy saving of about 40% compared to the earlier cupola. The DBC also yielded additional benefits in terms of an increase in metal temperature and a substantial reduction in silicon and manganese losses. On an average monthly melting of 430 tonnes, the demonstration DBC yielded an annual saving in coke of 270 tonnes. The payback period worked out to less than two years on the investment in the DBC alone.

Although the new DBC had proved itself to be far more energy-efficient than the existing cupola, proper operating practices had to be followed to reap the full benefits of its improved design. Hence, following the demonstration, TERI and its British partners worked for several weeks in training the furnace operators and maintenance personnel to follow BOP (best operating practices) in the day-to-day running of the plant.

RECUPERATIVE POT FURNACE

In designing, developing and demonstrating the new gas-fired pot furnace, TERI worked closely with a number of British partners whose key roles are summarized below.

- British Glass, U.K., provided expertise in glass technology. Along with other partners, British Glass also finalized the conceptual and detailed designs of the new pot furnace.
- AIC (Abbeville Instrument Control Ltd), U.K., helped in developing the concept and design of the new furnace, including its heat recovery unit (recuperator).
- Chapman and Brack, U.K., provided guidance in constructing the crown of the furnace.
- TECO (Toledo Engineering Co. Inc.), U.K., provided expertise in commissioning the recuperator for the furnace.
- NU-WAY, U.K., supplied the burners for the furnace.

The gas-fired recuperative pot furnace was successfully commissioned in February 2000. Following the demonstration, TERI and its British partners trained furnace operators and other workers in monitoring and operating the new system. The British partners continued to provide support in trouble-shooting the furnace system and in fine-tuning its performance parameters.

The energy consumption of the gas-fired recuperative furnace was measured at 16.5 Gcal/day, as against 39.4 Gcal/day in the traditional coal-fired pot furnace. This represented a 58% reduction in energy consumption, of which around 28% came from heat recovery alone. Estimates by the project team indicated that the recuperative furnace was also 34–38% more energy efficient than the retrofitted gas-fired furnaces being used by other pot furnace units in the Firozabad cluster.[291] Because of its increased fuel efficiency, the recuperative furnace promised a payback within two years.

Technology dissemination and results

Following the successful demonstration of the two EE technologies—the DBC and the recuperative pot furnace—TERI focused its efforts on disseminating these technologies through:

- providing customized design solutions and installation/commissioning support to other entrepreneurs on the new EE technologies

291 By December 2001, almost all pot furnace units in Firozabad had adopted a 'retrofitted' gas-fired furnace design, which provided some improvement in energy efficiency compared to coal firing. However, the recuperative furnace designed by TERI and its partners proved far superior in terms of energy efficiency, as described.

- awareness generation among industry stakeholders at both policy and cluster levels

- capacity building programmes involving entrepreneurs, fabricators, local consultants, masons and other stakeholders

The Swiss and British partners continued to provide technical support to the project so as to facilitate replication of the EE technologies.

By December 2008, around 60 DBCs of the TERI design were in operation in various foundry clusters across the country. These DBCs have brought about an estimated cumulative energy savings of 17,000 TOE (tonnes of oil equivalent) during the period 1994–2008. This is equivalent to a cumulative reduction in carbon emissions of 64,000 tonnes CO2. At a conservative estimate, adoption of the TERI-designed DBC by all the 5000-odd small-scale foundry units in India will make it possible to save about 25% of the coke consumed by the foundry industry per annum (that is, an annual saving of 410,000 tonnes CO2).[292]

Similarly, the TERI-designed recuperative pot furnace has been adopted by over half of the 80-odd pot furnace units in the Firozabad glass cluster, with most of the remaining pot furnace units expected to follow suit in the next few years. These replications have brought about a cumulative reduction in carbon emissions of 121,000 tonnes CO2 during the period 1994–2008. In addition to these 40-odd 'direct' replications of the TERI-designed furnace, there are reportedly around 30 pot furnace units that have adopted the *concept* of heat recuperation from the TERI-designed furnace. This in itself indicates that the TT process has succeeded; that the entrepreneurs have shed their traditional reluctance to consider changes in their technology, and are becoming increasingly confident in learning from the improved EE technologies and adapting them to suit their individual needs.

4.2.4 Policy implications

- Small-scale industries in developing countries offer enormous potential to reduce CO_2 emissions at lower costs. This is important, considering the fact that SMEs in general do not have either the inherent financial capacity or the technical capacity to undertake research or adaptation activities that would help them improve their energy and environmental performance. It is therefore important to identify such SMEs in developing countries (preferably a group of enterprises with similar technological base and similar operating practices), and then develop tailor-made RDD&D programmes for them (which may be industry/cluster-specific) with support from multilateral/ bilateral organizations especially in the context of climate change.

292 Pal P, Sethi G. 2008. 'Implementing CDM projects among SMEs in India'. In *Economics and Management of Climate Change*, Bernd Hansjurgens and Ralf Antes (eds). New York: Springer.

- The RDD&D programmes should focus on cleaner production, which means conservation of resources and energy use in the production processes through improved technologies. The industry associations at the local/state levels can play an important role by identifying suitable locations for initiating such programmes, while multilateral agencies can help in facilitating inter-governmental partnerships and bringing international technical experts together in such programmes.

- The technology demonstrations could focus on 'incremental' technological improvements, which would be easily adopted by the SME sector. By their very nature, SME units find it hard to absorb rapid change; they are inhibited by factors such as lack of technical knowledge, resource constraints, low productivity, and so on. In many cases a step-wise, *incremental* approach in TT allows them to adopt and absorb better technology/operating practices, and based on their own unique (unit-specific) requirements; all that they require is the necessary technical back-up support to be able to do so. The incremental approach also imparts a growing confidence in the entrepreneurs to experiment with, evolve, and adopt their own cost-effective technological solutions.

- In order to ensure their sustainability in the long term, RDD&D programmes in the SME sector should have a strong partnership element and involve the local actors right from the initial stages. The local actors can take over once the consultants and expert R&D organizations have helped the SMEs in identifying and demonstrating the benefits of cleaner technologies.

- It is equally important for funding agencies to have a long-term commitment and a flexible approach in RDD&D programmes; for, change is invariably a slow process at the small-scale industry level. A prime factor that has contributed to the success of the TT project highlighted in this case study is the flexibility and long-term engagement with the project shown by SDC, and the unique partnership arrangement that exists among the project partners at different levels—between funding organization (SDC), implementing agency (TERI), local consultants, international consultants, industry associations at cluster level and grassroots-level agencies. There is a need to develop and replicate similar innovative partnership arrangements on a much larger scale for interventions in the SME sector.

- For a collaborative RDD&D venture to be effective in bringing about sustainable change in the small-scale sector, the improved technology(ies) must be disseminated on a large scale following demonstration. As an important component of RDD&D, the TT process can take place directly between technology supplier and end-user; but this may limit the extent to which local capacities are built in the new/improved technology. Instead, the TT process should involve intermediary institutions (such as R&D establishments, consultancy organizations) which can act as facilitators to build local delivery systems and capacities in the improved technology, and thereby help their dissemination on a large scale. An example is the TT project described above, in which TERI as an intermediary institution was able to absorb two improved EE technologies through collaboration with British partners, and then promote their dissemination among a large number of SMEs across India.

- One of the financial mechanisms available for promoting low-carbon technologies under international climate change protocol is CDM (Clean Development Mechanism). However, high transaction costs act as a barrier in initiating CDM projects in the SME sector. For CDM projects to be workable in the SME sector, there is a need to revisit the CDM implementation cycle, specifically the documentation and verification formalities. A simplified CDM project cycle for SMEs holds promise of reducing million of tonnes of GHG emissions in diverse SME sectors in developing countries.

4.3 IGCC case study – TERI

This case study was conducted and written by TERI and is based on interviews conducted between September 2008 and January 2009.

4.3.1 Background

Technology growth in India's thermal power sector

Electric power is the prime mover of economic development. India has increased its installed generation capacity from a mere 1330 MW at the time of independence in 1947 to 134,697 MW by March 2008. Coal-based power plants account for around 58% (77,729 MW) of this installed capacity. However, the present levels of power generation are insufficient to meet the demand for power. In order to bridge the existing power deficits and meet the rapidly growing demands for energy, India has set a generation capacity target of 215,804 MW by March 2012[293] Coal-based power plants will meet 114,490 MW of this capacity, which implies a considerable increase in overall CO2 emissions from the power sector.

293 Planning Commission. 2007. *Eleventh Five Year Plan for 2007-2012*. New Delhi: Planning Commission, Government of India

There are other challenges as well. Every power producer is under pressure to reduce the cost of electricity generation to remain competitive in the open market. Also, it has not been possible to meet the coal requirements of the thermal power sector through indigenous production of coal. Coal imports, which were 10.7 million tonnes in 2007-08 and are expected to be about 20 million tonnes in 2008-09, may go up to 40 million tonnes by 2012. Since the cost of imported coal is very high, the cost of power generation too will increase. Under these circumstances, there is a clear need to introduce energy efficient technologies for coal-based power plants, in order to cut down their CO2 emissions as well as reduce the costs of power generation.

Presently all coal-based power plants use pulverized coal (PC) combustion and generate power through the sub-critical steam cycle, with 90% of power generation contributed by units of 210/250/500 MW capacity ratings. The efficiency of these power plants has been increased over the years (33% to 38%)[294] with increase in unit size and adoption of higher steam parameters. In order to further increase generation efficiency (38% to 40%), super-critical and ultra-supercritical steam parameters are currently being adopted in a number of new coal-based power plants.

However, the only way to increase the efficiency of thermal power generation beyond the levels possible through ultra-supercritical (USC) steam cycle is through IGCC (integrated gasification combined cycle) technology. IGCC has the potential to yield gross generation efficiency in the range of 42–44%, compared to the maximum efficiency of 40% achievable through the USC steam cycle. By increasing generation efficiency, IGCC would bring about corresponding reductions in CO2 emissions as well.[295]

IGCC technology status – international

Several first-of-a-kind coal and petroleum coke-based IGCC plants have been built in a few countries (Table 4.2). However, these plants have demonstrated varying degrees of success; most require further development to be recognized as reliable operating plants. Improvements in operational reliability and process optimization can be brought about only when these technologies are commercially replicated.

294 Assuming boiler efficiency of 85%

295 An improvement of 1% in generation efficiency of a 500 MW power plant having PLF of 85 %, can reduce CO_2 emissions by approximately 0.1 million tonnes per year, as well as reduce the cost of generation.

Table 4.2 Coal-based IGCC plants built in the world [296]

Project-Location	Commissioning Year	Output (MW)	Feedstock	Product
Buggenum, Netherlands	1994	253	Coal/ biomass	Power
Wabash, Indiana, USA	1995	262	Coal/ petcoke	Power
Tempa Electric, Florida, USA	1996	250	Coal/ petcoke	Power
Frontier Oil, Kansas, USA	1996	45	Petcoke	Power and steam
SUV-Vresova,Czech Republic	1996	350	Coal/ petcoke	Power and steam
ELCOGAS, Puertollano, Spain	1998	320	Coal/ petcoke	Power
Valero, Delaware, USA	2000	240	Petcoke	Power
ICCT, Yankuang, China	2006	72	Coal	Power and methanol
Clean Coal Power, Nakoso, Japan	2007	220	Coal	Power

In addition to the IGCC plants listed in the table, a 100 MW IGCC demonstration plant based on PFBG (pressurized fluidized bed gasifier) technology from KRW, was set-up at Pinon Pine, Nevada, USA in 1998. However, it was operated only for a short time before it was shutdown because of technical and commercial reasons. The second PFBG technology, the 'U-gas'[297], has not been scaled-up beyond the pilot plant level.

IGCC technology development in India

A key technical barrier to using IGCC technology for power generation in India is posed by the high ash content of Indian coals as compared to low-ash, high-calorific value coals being used elsewhere in the world. Additional barriers are (a) the high capital cost of IGCC plants compared to pulverized coal (PC) plants; (b) the absence of successful commercial-scale IGCC plants that would evidence the reliable performance of IGCC technology at a level at least equal to the performance of existing PC plants; and (c) securing comprehensive performance guarantees for IGCC plants based on high ash Indian coals. As such, the IGCC technology is yet to be proven commercially.

296 *Gas Turbine World*, [vol 37/no. 1.54], Jan-Feb, 2007
297 The PFBG U-gas technology is patented by the Institute of Gas Technology, Illinois, USA

Following extensive feasibility studies[298] by the Council for Scientific and Industrial Research (CSIR), Government of India, it was determined that bubbling fluidized bed gasification is well suited for IGCC power generation using high ash coals[299]. Taking this into consideration, BHEL (Bharat Heavy Electricals Limited) developed a PFBG-based IGCC pilot plant of 6.2 MWe (4 MW gas turbine and 2.5 MW steam turbine) capacity at Trichy. BHEL also developed a pressurised moving bed gasifier for testing in this pilot plant. Based on these pilot-scale studies, BHEL designed a 125 MW PFBG-based IGCC demonstration plant, and then approached Government of India to fund the incremental cost of the project.

In order to assess the BHEL proposal and to ascertain the need for Government grants, the office of the Principal Scientific Advisor to Government of India set up an R&D committee in January 2003. The R&D committee validated that IGCC plants, based on the PFBG concept, are ideal for high-ash (35% to 45%) Indian coals[300]. Following further technology development research on the 6.2 MWe pilot plant, the R&D committee recommended in December 2005 that the incremental cost of the semi-commercial demonstration plant could be funded partly by the Planning Commission, Government of India, as grant-in-aid.

Based on this recommendation, in July 2008, BHEL & APGENCO commenced construction of a 125 MWe IGCC commercial demonstration plant at Vijayawada in Andhra Pradesh. Further engineering evaluation of the project has led to increasing the capacity of this plant to 180 MWe. It is understood from BHEL that a GE gas turbine Frame 9FA will be used for this demonstration project. It is well known that GE has good experience in operating gas turbines with low calorific value fuel gas, produced from air–steam gasification of coal. GE will transfer the technology for this gas turbine to BHEL, under the ongoing technology transfer agreement for gas turbines design and manufacture in India.

In 2005 and 2006, Nexant & NETL, USA also conducted a study with assistance from USAID & NTPC, India on IGCC technology selection for Indian coals[301]. This study concurred with the findings of the studies conducted by Government of India and BHEL—that PFBG technology (specifically, pressurised fluidised bed U-gas gasifier, with enriched air of 30% oxygen concentration by volume) is most suitable and economical for high-ash Indian coals. The study recommended setting up a 100 MW IGCC plant with this kind of gasifier and a GE 6FA gas turbine. During the stakeholders' interviews for the present study,

298 The primary objective of these studies was to rank the four gasification processes (Shell, Texaco, KRW, and the indigenously developed moving bed) for IGCC plants in India. It concluded that the KRW gasifier or similar fluidized bed gasification processes, such as U-gas, are most appropriate to use for high-ash Indian coals.

299 CSIR. 1992. Feasibility assessment of integrated gasification combined cycle (IGCC) power generation for high ash coals. New Delhi: Council of Scientific & Industrial Research, Government of India

300 GOI. 2005. *Development of integrated gasification combined cycle (IGCC) technology as suited to power generation using Indian coals*. Report no. PSA/2005/4, published by Office of the Principal Scientific Advisor to Government of India. New Delhi: Government of India.

301 USAID. 2007. *Feasibility study of coal-based IGCC power plants in India*. Topical Report for Phase B. New Delhi: United States Agency for International Development.

it was learnt that discussions for setting up this IGCC demonstration plant. are currently in progress between Government of India and USA Government under the 'Indo-US Energy Working Group', and a 'Technology Expert Group' has been formed to identify suitable Indian and US partners for the project. An RDD&D agreement between Indian and US partners may therefore lead to setting up a semi-commercial IGCC demonstration plant, and further diffusion of the technology for commercial power plants. However, it is clear that incremental cost funding would be needed for setting up the demonstration plant at an existing power plant site or a new site.

Potential areas for technology transfer for IGCC

The IGCC power plant consists of a number of sub-systems/products which have to operate in an integrated mode. Some of the IGCC system components, such as front-end coal handling, steam turbines, heat recovery steam generators, etc. are commercially available in India. However, the following may have to be obtained as a part of technology licensing and technology transfer with associated performance guarantees:

- Design and engineering of integrated system for IGCC power plant
- Coal drying system
- Pressurised coal feeding system
- PFBG technology (for high-ash Indian coals)
- Hot gas clean-up system
- Gas turbines for low calorific value fuel gas
- DeNOx & DeSOx systems for flue gases
- Control systems for IGCC plant

Many Indian companies are looking into the possibility of technology transfer from industrialized countries for these sub-systems. The technology transfer agreements (TTAs) will take place depending upon the future market. However, some systems for first few plants may be imported initially.

Feedback from stakeholders

The key players with an interest in development of IGCC technology in India through technology transfer and in-house development were identified as follows:

- Ministry of Power, Government of India
- National Thermal Power Corporation (NTPC)
- Reliance Power Limited (RPL)
- Bharat Heavy Electricals Limited (BHEL)
- USAID, New Delhi

This group represents the government, the power generators (public and private sector), the major power plant equipment designers and manufacturers, and an international agency that has also studied the possibilities of introduction of this technology in India.

A questionnaire was prepared for the senior officials of these organizations on IGCC technology development/transfer. The major questions asked were as follows:

- Present status of technology development/transfer in their respective organisations, and their future plans
- Administrative hurdles/barriers in technology transfer from industrialized countries
- IPR issues/barriers in transfer of technology
- Perceived risks in setting up commercial IGCC plants in India
- Besides gasification, the possibility of technology transfer for other sub-systems of IGCC
- Possibility of commercial IGCC plants for good quality imported coals
- IGCC technology for petroleum residues (petcoke, vistar) for India
- Predictions regarding IGCC technology introduction in India

In addition, discussions were also held with the US DOE (Department of Energy); NETL, USA; and GE, USA.

Based on the feedback from the above interviews and discussions, the following sections on technology transfer have been developed.

4.3.2 Intellectual Property Rights (IPR)

At the outset, it might be premature to comment on IPR issues related to IGCC, since this technology is not considered to be commercial globally. All the stakeholders interviewed under this study opine that IPRs might not pose a hurdle in the acquisition of IGCC technology. However, the fact is that given the high cost of developing reliable operating systems, it is evident that acquiring IPR for advanced system components and systems will add to the cost of licensing IGCC technology. A rough estimate suggests that in the initial stages of technology commercialization, an IGCC-based power plant may cost 25% to 30% more than a conventional state-of-the-art supercritical PC plant of comparable size. The additional cost reflects the fact that IGCC technology is particularly capital intensive as well the first of a kind costs that that are inevitably associated with any new technology. It will also include direct technology transfer fees if there is a need to license new components to local firms. The fact that there are only few technology suppliers is also likely to add to the cost.

As IGCC is a technology still in the final stages of development, a number of hurdles are associated with its acquisition:

- With the number of technology suppliers being very limited, there is limited access to knowledge/information about the long-term performance of various (competing) IGCC technologies, and hence buyers find it difficult to make an informed decision. [*NTPC official*: "The main risks are that technology for large capacity high pressure gasifier plants is not yet proven for Indian coals...Further, there is technology risk for other systems like hot gas clean-up, control and instrumentation, and integration of all systems of IGCC..."]

- The stakeholder interviews suggest that large-scale Indian manufacturers and suppliers of power equipment can overcome difficulties in obtaining key IGCC system components through the negotiation and establishment of mutually satisfactory agreements with overseas suppliers. [*BHEL official*: "BHEL has tied up with GE for supply of gas turbine, and identified manufacturers for supply of some of the sub-systems such as gas cleaning system and high pressure coal feeding system."] However, it is possible that the IGCC system and system component suppliers might be reluctant to transfer know-how to Indian companies who could become their potential competitors. Specifically, they might not be keen on sharing or providing technical knowledge and information to equipment manufacturers and suppliers in India, as this might create/strengthen potential competitors in the market for power generation equipment.

- The high cost of transferring IGCC technology is a direct consequence of the fact that there are only a few technology suppliers. As a result, competitive price negotiation with the technology supplier is very difficult. [*Interviewee*: "The cost of the first plant would be about Rs 80 million/MW, which is very high compared to the conventional plants which cost about Rs 50 Million/ MW…For large-scale implementation of this technology, policy changes are required such as stringent environmental norms, financial incentives in the form of soft loans, subsidies, interest waiver, tax exemptions etc."]

In general, the developers/suppliers of new, low-carbon technologies such as IGCC are cautious of exporting their technologies to developing nations, which are perceived to have 'weak' IPR protection measures. However, India is well-placed in this regard. The Government of India is a signatory to the International Regulation governing intellectual property, and is committed to protection of IPR. [*Government official*: "The IPR rights are fully protected in case of technology transfer…"] In the case of the high capital cost equipment/ sub-systems involved in IGCC plants, the suppliers would have to guarantee the reliability and quality of performance of the power plants. Also, the buyers will not accept the equipment/sub-systems unless their performance is backed by long duration trials runs with successful results. Under such circumstances— where both buyers and suppliers are equally concerned about issues of reliability and performance— the safety of IPRs is usually assured. In any case, the TTAs in respect of each component/sub-system of IGCC technology would cover and safeguard all related IPRs, as pointed out during the stakeholder interviews.

Given the fact that India already imports substantial quantities of coal, the possibility arises of acquiring 'proven' IGCC technology designs from abroad to set up IGCC power plants based on imported coal. Running of these plants would then provide Indian stakeholders with a base of IGCC-related knowledge and experience, from which they could modify designs etc. to accommodate high-ash Indian coals. In effect, this strategy would allow power generation in India using IGCC technology in two stages: (1) using imported IGCC technology and imported coal; (2) using suitably modified IGCC technology and Indian coals. While commercial-scale IGCC plants can be set up under this strategy, it would still require addressing IPR issues related to IGCC components/sub-systems. In particular, India does not have the know-how for the pressurized entrained bed gasifier[302] which is used for low-ash coals, and hence this system will have to be imported—entailing IPR costs. Furthermore, given the small number of operating coal-based IGCC plants abroad—that too, on semi-commercial scale—the Indian IGCC plants would have restricted choices in sourcing their coal, which would have to meet plant-specific quality parameters. This in turn would have both financial and policy implications in the long term.

To sum up, there are IPR issues related to the transfer of sub-systems/products associated with IGCC technology. These IPR issues have to be addressed and negotiated in order to transfer IGCC technology to India. The stakeholder

302 At present, only GE and Shell have the know-how for the pressurized entrained bed gasifier.

interviews suggest that while the IPR issues related to IGCC sub-systems/products can be tackled through the negotiation of appropriate TTAs (which will build in the IPR related costs), commercial development and deployment of IGCC technology on a large scale will happen only when both the suppliers and the recipients foresee sufficient business prospects in India for IGCC technology. [*Interviewee*: "Future collaborations will depend on the outcome of the BHEL–APGENCO demonstration plant (in progress) and the NTPC demonstration plant (being discussed by the Indo-US working group."]

4.3.3 Collaborative research, development, demonstration, and diffusion (RDD&D)

From section 1.3, it is apparent that PFBG technology would be required for IGCC power plants using the high-ash Indian coals. Thus, for development of IGCC technology in India, a first-of-a-kind commercial demonstration plant will have to be set up in order to prove the viability and reliability of the technology. Thus, there is a great potential for launching international collaborative RDD&D IGCC projects in India. An international team of specialists is required for such collaborative projects. The project team must consist of experts drawn from international IGCC technology suppliers/developers, power plant manufacturers, utilities in India and relevant research organizations/technical institutions. The collaborative experience and data collected from operation of the demonstration plants would be useful for scale-up to commercial-scale plants. The RDD&D project would thus help in developing the know-how and tacit knowledge of the partners. This will go a long way in accelerating diffusion of the clean technology in the future.

An arrangement for sharing of IPRs arising from the collaboration could be worked out between partners. Such IPR-sharing arrangements could act as incentives for international players to collaborate in developing IGCC technologies based on high-ash coals, which are likely to find a major market in India and other developing countries.

Alternately, the IPRs could be placed in the public domain, depending on the funding pattern of the RDD&D project and other related resources. If the major cost of the collaborative RDD&D project is met through international funds available for climate change, it may be possible to make these IPRs accessible to organizations in the developing countries for developing products/systems at affordable costs. Such a large collaborative RDD&D project will have substantial positive spin-off in terms of furthering the knowledge and building capacities of all stakeholders.

4.3.4 Policy implications

Sections 2.0 and 3.0 make it clear that IGCC technology development/transfer and deployment in India would require setting up of semi-commercial demonstration plants with coal gasification technologies applicable for high ash Indian coals. These plants would require national/international funding.

Various feasibility studies for IGCC technology development and diffusion (refer section 1.3) in India, and those for commercial IGCC plants[303], show that the capital cost and cost of electricity generation per kWh for commercial plants would be higher for initial IGCC plants, as compared to the PC combustion technology presently in vogue. Even if the project is registered as a CDM project, the funds flow through this mechanism will not be able to cover the additional funds required for IGCC plants. Thus, future IGCC plants would require incremental cost funding, till the technology becomes mature and cost-competitive.

This can be made possible only through policy interventions nationally and internationally. Nationally, incentives in the form of soft loans, subsidies, tax exemptions, etc. would have to be provided. The Government of India has already provided capital cost subsidy for the first IGCC demonstration plant. Once the technology is ready for commercial deployment, additional financial support will have to be provided to make the IGCC plants competitive with power plants based on supercritical technology.

In addition, financial support from developed to developing countries would be needed to provide for incremental costs and technology transfer fees, through international financing mechanism. This can be done from climate change funds for developing countries being negotiated through UNFCCC (United Nations Framework Convention on Climate Change). These funds can be used for the demonstration plants as well as for diffusion/deployment of IGCC technology at a fast pace. The technology transfer costs may be reimbursed directly from such funds to the companies in the industrialized countries which have the technology and make effective technology transfer.

303 Stephen Ansolabehere, et al 2007. *The future of coal- Options for a carbon constrained world.* Massachusetts Institute of Technology, Cambridge, Ma. (USA), 2007 (http://web.mit.edu/coal)

4.4 Wind case study – TERI

This case study was conducted and written by TERI and is based on interviews conducted between September 2008 and January 2009.

4.4.1 Background

India's potential for grid-connected wind power generation has been estimated at about 45,000 MW. As of September 30, 2008, India had a total installed capacity of 9521.80 MW grid-connected wind power[304], which places India fourth globally in terms of installed capacity after Germany, USA, and Spain.

The wind power development in India started in the mid 1980s with the establishment of demonstration projects in the states of Gujarat and Maharashtra. The wind power development in India is backed by a positive policy and regulatory framework (see Box 4.1).

Box 4.1: National Electricity Policy, 2005

The National Electricity Policy states that adequate promotional measures would have to be taken for development of non-conventional energy sources. Further, it states that "Progressively the share of electricity from non-conventional sources would need to be increased as prescribed by State Electricity Regulatory Commissions (SERCs). Such purchase by distribution companies shall be through competitive bidding process. Considering the fact that it will take some time before non-conventional technologies compete, in terms of cost, with conventional sources, the Commission may determine an appropriate differential in prices to promote these technologies".

The Policy also states that "SERCs may promote arrangements between the co-generator and the concerned distribution licensee for purchase of surplus power from such plants. Cogeneration system also needs to be encouraged in the overall interest of energy efficiency and also grid stability".

Electricity Act, 2003

The Electricity Act has several enabling provisions, with a view to promote accelerated development of non-conventional energy based power generation. As per Section 86(1) (e), "The State Commission shall promote co-generation and generation of electricity from renewable sources of energy by providing suitable measures for connectivity with the grid and sale of electricity to any person, and also specify, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the area of a distribution licence".

304 http://mnre.gov.in/ accessed on February 12, 2009

Broadly, the following incentives are provided by the government in order to encourage entrepreneurs to set up wind power projects.[305]

- Accelerated depreciation on initial investments.
- Income tax waivers on earnings for any 10 years during the first 15 years of operation.
- Regulations by many state governments that require electricity utilities to procure a certain percentage of their power from renewable energy sources such as wind energy. (In Maharashtra and Gujarat, for instance, the electricity utilities are required to procure 5% and 2% of power respectively from renewable energy sources.)
- Fixed tariff policies (or 'feed-in tariffs') that provide wind energy companies with a minimum guaranteed price per unit of electricity, and thereby encourage bankers to finance wind energy projects.

Besides being among the world's leading nations in installing wind energy capacity, India is now also in the major league in manufacturing 'hardware' for wind energy plants. Starting with 50kWe wind turbines in 1985, India is now in the major league with wind turbines of over 2 MWe being manufactured. The Indian wind companies also have state-of-the-art blade manufacturing facilities. Not only catering to the domestic markets, the Indian companies are also exporting these turbines to industrialized countries. Indian wind energy equipment manufacturers have created a niche for themselves by expanding their businesses in Europe, US, and Asia (including China). Indeed, Suzlon Energy Ltd. is the fifth largest player in the global wind energy market.

The major international wind turbine manufacturers include GE Wind Energy, Gamesa Eólica, REpower Systems, Siemens, Suzlon, and Vestas.

The key wind turbine manufactures in India include:

- Enercon India Ltd. (a subsidiary of Enercon GmbH, Germany)
- Suzlon Energy Ltd. (with its R&D centres in Europe)
- RRB Energy Ltd. (Technological cooperation with Vestas Wind Systems A/s, Denmark)
- Vestas Wind Technology India Pvt. Ltd. (Wholly owned subsidiary of Vestas Group, Denmark)

Leitner Shriram Manufacturing Ltd. is a new entrant in the Indian wind energy market and it has formed a joint venture with Leitwind BV of the Netherlands.

305 Somak Ghosh. 2008. 'Making wind a fail-safe lending option for banks'. *InWind Chronicle* **4** (5), October–November 2008. New Delhi: Indian Wind Energy Association.

Stakeholder interviews

In order to discuss IPRs and other issues related to wind energy, interviews were held with officials from four Indian companies related to wind energy sector. One of the companies does not want its name to be disclosed. The other three companies are:

- Suzlon Energy Ltd
- Senergy Global Ltd
- WinDForce Management Services Private Limited

The following sections have been developed based largely on these stakeholder interviews.

4.4.2 Intellectual property rights

The financial viability of a wind energy plant depends critically on the efficient performance and reliability of its equipment/components, in particular, the wind turbine. Indian wind turbine manufacturers must therefore be able to access and utilize the latest technological know-how related to wind turbines and associated components. This is especially important if they are to compete with foreign companies which offer state-of-the-art wind energy technologies. This brings to the forefront the issue of IPRs.

In the case of wind energy technology, IPRs are broadly categorized as:

- Hardware-related, e.g., blades and generators
- Software-related, e.g., aerodynamics and controls

Throughout the eighties and nineties, European wind turbine manufacturers like Vestas and Micon (Denmark) and Enercon (Germany) dominated the Indian wind energy market. By the early nineties, NEPC, a Chennai-based company having collaboration with Micon of Denmark, had emerged as a big company on the national scene. However, the primary role of the European companies in these joint/collaborative ventures was to market their (manufactured) products; that is, the transfer of technological know-how to Indian companies was restricted. In the mid-1990s Suzlon Energy Ltd entered the market with a new business model: one in which the Indian company had complete ownership of the manufacturing and technology (Box 4.2[306]). In fact, Suzlon has its own R&D centres in Europe and controls a majority stake in REpower Systems AG, Germany. The success of this strategy is evidenced by the fact that Suzlon Energy Ltd is now the fifth largest player in the global wind energy market.

306 IWEA. 2007. 'The hands that turn the windmill'. *InWind Chronicle* **3** (2,3), Oct–Dec 2006/Jan–Mar 2007. New Delhi: Indian Wind Energy Association.

Box 4.2: Suzlon strategy

In the joint ventures and collaborative ventures, it had been noticed that the [Indian] companies had to depend on their European counterparts for all technical aspects and even operation and maintenance issues, and hence, had serious limitations. The European companies were more interested in just manufacturing and marketing of wind turbines and not in complete integrated solutions…

Looking for complete ownership of the technology, Tulsi Tanti [of Suzlon] came across Sudwind, a small German company. Suzlon implemented its first windfarm of 3.5 MW for Vadodara-based IPCL using Sudwind wind turbines. Soon afterwards (1997) Sudwind went bankrupt and Suzlon had an opportunity to hire its engineers to create an R&D centre in Germany. Then onwards, there has been no looking back and interestingly, almost 10 years later, Tulsi Tanti reappears in Germany to gain ownership of RE-Power…

The Indian manufacturers address the issue of IPRs through three broad strategies:

1. Joint ventures;
2. Technology licensing; and
3. Acquisition or purchase of foreign firms.

During the stakeholder interviews, it was revealed that IPR is the main issue as far as transfer of advanced technology to India is concerned. Since necessarily these companies have to have the latest technology, the IPR becomes a greater challenge. This is so because (a) Indian wind market is very competitive where investors increasingly look for cost per unit of electricity generated and ask for minimum generation guarantees from the manufactures and (b) there are foreign companies like GE Wind Energy, and now Gamesa Eólica, which bring in the latest on-shore wind turbine technology. It often results in more expensive products and time delays in introducing state-of-the-art technologies in the country. It was also pointed out that sometimes technology owners use IPRs as a tool to create a barrier to new entrants to the market, whereby either the new entrant has to enter into a very expensive technology licensing agreement or is compelled to scout for an alternative – resulting in a long delay before it can launch its products in the new market. This was the case with a developing country entity trying to enter developed country markets where because of IPR of one of the common wind turbine components, which was held by another company in that country, the developing country entity had to face a lot of problems. It is evident that while technology transfer is taking place through usual commercial transactions, if the low-carbon energy technology like wind has to be propagated on a very large-scale to mitigate climate change, it would be essential to bring down the cost of IPR acquisition. This is also necessitated by the fact the developing countries have limited resources to be spent on climate change mitigation and adaptation while simultaneously maintaining the economic growth. This does not apply to those cases where some clean and efficient technologies are either already in public domain or not protected by patents.

Though the Indian wind energy sector is growing at an impressive pace for last few years, it is still dependent on the state specific preferential tariff. However, the National Tariff Policy 2006 makes it clear that in the long term, wind energy suppliers will have to compete with other energy suppliers in the power market.[307] In that scenario, more cost-effective and latest technological solutions would be required to be introduced. The high cost of IPR acquisition for such technologies or processes could become an impediment to bringing about this crucial change.

Moreover, in case of renewable energy technologies that already have a very small market (as opposed to conventional technologies), any burden on account of IPR makes their penetration even more difficult besides making the process of market development more dependent on policies and subsidies.

4.4.3 Collaborative research, development, demonstration and diffusion (RDD&D)

Apart from the technology transfer route, the Indian companies are also engaged in carrying out research and development jointly with their foreign counter-parts. Even in the case of technology transfer, R&D is often required to adapt a particular product to suit Indian conditions.

The main driving force for a company to go in for collaborative R&D is achieving better product quality or addressing a technical requirement. From the interviews, it emerged that, the expectations of the host company in such arrangements include:

- Proven technology
- Better performance compared to other alternatives
- Cost-effectiveness
- Transparent dealing

In return, the host company offers the foreign partner:

- Access to Indian as well as global markets
- Brand equity

307 Section 6.4 of the National Tariff Policy 2006 says: "Such procurement by Distribution Licensees for future requirements shall be done, as far as possible, through competitive bidding process under Section 63 of the Act within suppliers offering energy from same type of non-conventional sources. In the long-term, these technologies would need to compete with other sources in terms of full costs."

- State-of-the art production facilities
- Qualified technical team
- Absorptive capacity
- Back-up supply chain

As far as IPRs in relation to collaborative R&D are concerned, at times companies take the JV route. For instance, Suzlon has collaboration with an Austrian company to develop and manufacture large capacity induction generators (2.1 to 3.5 MW capacities). In order to maintain an edge, the Indian companies do look at collaborative R&D as a feasible option provided IPR is not an issue or it can be addressed in a simple fashion.

4.4.4 Policy implications

The stakeholder interviews suggest that the right kind of environment has to be created in India to encourage innovation and collaborative R&D in the wind energy sector, both nationally and globally. It is felt that the policy environment must facilitate indigenous technology development through collaboration between:

- Academic/research organizations
- Government laboratories
- Domestic Industry
- Global organizations/industries (if required). The level and timing of involvement of the global players, if at all, would be very case-specific.

As an example of such multi stakeholder collaborations, one may consider the ongoing research for the development of nano-technology for wind energy in Denmark in which the industry, academic institutions, and the government are collaborators.

The discussions with some of the Indian wind energy firms also indicate a need to look at these aspects from a national perspective, especially in the emerging areas like cutting edge technologies, manufacturing processes, and software. It was opined that it might be a good idea to set up "Task Force" to identify focus areas for intellectual property development, both for products and processes. The aim of the suggested Task Force is to have a broader national perspective rather than a narrow view, at times dictated purely by commercial interests. The rights and entitlements of different entities, in terms of sharing of intellectual property would have to be defined on the basis of their contribution to the developmental process. One of the possibilities of its funding could be through public-private partnerships. The incentive for the participants would be in terms of getting access to technologies, which in isolation might have been difficult to develop or access. There are instances when such arrangements had been tried successfully, e.g. in India's space programme (see Box 4.3)[308]. In any specific sector/field, the Task Force would analyze different ways of achieving the desired result and then based on the detailed analysis, suggest the most optimized route for the R&D efforts along with a time bound plan of action.

Box 4.3: Industry participation in the Indian space programme

Over the years considerable infrastructure and expertise is developed within the Indian hi-tech industries to provide support to space missions (satellite and launch vehicles).

The structural hardware of communication satellite is produced at Hindustan Aeronautics Ltd (HAL) which is one of the leading aerospace industry firms in the Asia pacific region.

The satellite propulsion systems are largely taken from production capability of BHEL, HAL and other private sector industrial giants like L&T, Godrej and MTAR.

In this context it is very important to develop the indigenous capacity for technology development and manufacturing. Equally important would be to incentivise innovations from the viewpoint of national priority. These innovations allude to `disruptive' technology or something that is not routine. This is of particular relevance in the realm of wind energy, where the scope for radical innovations appears to be limited and incremental innovations are likely to be more important.[309] An autonomous body established by the Government of India could be assigned the tasks of (a) protecting the intellectual property so developed and (b) marketing of the products/processes coming out of such collaborations. There are many autonomous bodies in the country where the members are either selected or nominated by the government (Box 4.4)[310]. This body may also buy IPRs relating to relevant low carbon energy technologies utilising the Climate Change Fund.

308 ISRO website www.isro.org; visited on 16 February 2009; and Shankara K N. 2002. 'Indian Space Program, with Special Reference to Satellite Communication'. Presentation at the AIAA Japan Forum–Satellite Communications Colloquim, 11 October 2002, Houston, Texas. Reston, VA: American Institute of Aeronautics and Astronautics: (http://www.aiaa.org/pdf/industry/presentations/japan02shankara.pdf)

309 "The basic technology is in the public domain, but there are relatively fewer players in this sector on a global scale. Patents seem to be more important in offshore applications. Given the nature of the technology, incremental innovation is likely to be important as the scope for radical invention in terms of breakthroughs or radical technologies is limited." [UNDESA. 2008. 'Climate change: technology development and technology transfer'. Background paper prepared for Beijing high-level conference on climate change: technology development and technology transfer, Beijing, 7–8 November 2008. New York: United Nations Department of Economic and Social Affairs]

310 National Institute of Ocean Technology website [www.niot.res.in] visited on 16 February 2009

Box 4.4

The National Institute of Ocean Technology (NIOT) was established in November 1993 as an autonomous society under the Ministry of Earth Sciences, Government of India. NIOT is managed by a Governing Council and the Director is the head of the Institute.

The major aim of starting NIOT under the Ministry of Earth Sciences, is to develop reliable indigenous technology to solve the various engineering problems associated with harvesting of non-living and living resources in the Indian Exclusive Economic Zone (EEZ), which is about two-thirds of the land area of India.

It also came out very clearly in the interviews that there was a need to create awareness among the industry players who do not have deeper understanding of implications of IPR rules and regulations, including those in the context of WTO regime. This is due to the fact that at times, the Indian companies are not well-versed with the interpretations of IPR regimes that exist in other countries.

5. Summary findings

Based on combined analysis of the findings of the literature review and the five case studies, this section presents the major findings of the study, focusing on two of the three areas of concentration – Intellectual Property Rights (IPRs), and collaborative Research, Development, Demonstration and Deployment (RDD&D) initiatives. Once the findings have been discussed, the final section of this report uses these summary findings to make policy recommendations, with a focus on international endeavors and will also discuss the framework for decision makers, the other area of concentration of the study.

5.1 IPRs

There are several factors that emerge from the case studies in relation to IPRs. These are summarized here and discussed in more detail under individual sub-headings below.

An important clarification in relation to IPRs and low carbon technologies is the difference between consumers, or users, of low carbon technologies, and producers of these technologies. Consumers of low carbon technologies are unlikely to experience any specific IPR related barriers to accessing low carbon technologies. The barriers consumers face are more likely to be related to costs (although a part of these higher costs can be due to IP), which are often higher for low carbon technologies than for conventional technologies. For example, it could be imagined that, once the technology becomes commercial, an IGCC power plant might cost 25-30% more than a supercritical coal-fired power plant. But it is difficult to say exactly how much of this extra cost would be related to patents, e.g. it may only be a small percent. For firms wishing to become producers of low carbon technologies on the other hand, the existence of and access to patents is likely to play a much more significant role in terms of the rate at which they are able to access the knowledge necessary to start manufacturing low carbon technologies. Such a situation, for example, seems to be slowing down the rate at which Indian firms are able to develop commercial hybrid vehicle technologies without infringing existing international patents owned by industry leaders like GM and Toyota.

Another important aspect to keep in mind is the distinction between the incremental cost of the low carbon technology and the potential cost of the IPR. In many cases, there will be virtually no demand for the low carbon technology in developing countries unless the incremental cost is covered by international mechanisms such as CDM, by domestic policies such as renewables targets, or energy efficiency standards (which can yield cost savings to the equipment users). This can also be related to different remedies – free IP will only make the low carbon technology competitive if the incremental cost is less than the IPR. In the case of IGCC for example, where IP may only be about 2% of the incremental costs of IGCC over conventional coal technologies, free IP would still make IGCC more expensive than conventional coal technologies. Compulsory licensing might be needed, but a way of funding the incremental cost would also be required.

The case studies made it clear that there are often complex numbers of IPRs relating to single low carbon technologies. Whilst IPRs have not prevented Indian companies being active, whether commercially or at the R&D stage, in production related activities across all five case studies analysed in this report, they do seem to slow the rate at which Indian companies can commercially produce low carbon technologies, particularly if they wish to produce at the cutting edge. This may have implications for the rate at which India can generate low carbon technological capacity, which in turn may negatively impact on the overall potential for, and speed at which a country could achieve a transition to a low carbon economic growth trajectory.

This position is well articulated by Sauter and Watson (2008) in relation to the potential for developing country firms to "leapfrog" towards producing technologies at the cutting edge, and the broader implications of this for developing countries' potential for leapfrogging over the high carbon industrial development pathways characteristic of developed economies:

> "...while intellectual property rights (IPRs) are generally considered as a necessary protection by leading firms (Goldemberg 1998), IPRs can at the same time constitute a major impediment for technological leapfrogging. While they do not necessarily prevent the diffusion of cutting edge technologies, they can be used by their owners to keep competitors away from their markets and prevent others to make useful experience for further developments and improvements of the technology (Steinmueller 2001). Such learning processes are fundamental for the creation of knowledge and skills – an important element of technological capabilities required for the leapfrogging of industrial development pathways."[311]

This situation suggests that there may be specific instances in specific countries where international policy intervention may be desirable to address situations where IPRs are slowing the rate at which developing country firms can start producing low carbon technologies. In the longer term, the results of this study suggest that international collaboration along the research, development, demonstration and deployment (RDD&D) spectrum represents an important opportunity to avoid situations where IPRs might become a barrier to technology transfer. It is also important to highlight the fact that enabling access for users of low carbon technologies, rather than producers of them, requires

311 Sauter, R. and Watson, J. (2008) Technological Leapfrogging: A Review of the Evidence Report for UK Department of International Development. SPRU, University of Sussex, December: 13. Available at http://www.sussex.ac.uk/sussexenergygroup/documents/dfid_leapfrogging_reportweb.pdf

carefully tailored financing mechanisms for assisting in meeting higher costs of low carbon technologies relative to conventional technologies. Finally, it must also be recognized that although many commentators stress patents as being the most relevant type of IPR for low carbon technologies, patents do not represent the whole picture. Trade secrets and other tacit knowledge are also very relevant in terms of understanding and acquiring knowledge relating to technologies. Here, once again, there is an important role for international collaborative RDD&D initiatives as a means for promoting knowledge sharing.

The remainder of this section picks out some headline findings from the case study analysis.

IPRs are often complex, and are relevant in terms of hardware (products) and software (processes and codified knowledge)

IPRs relating to low carbon technologies are far from simple. A vast array of relevant IPRs exist for a number of the technologies studied, including in relation to specific components, the integration of these components, as well as various processes and codified knowledge. In the hybrid vehicles case study, for example, patents exist across many areas – from specific components such as electric motors, batteries and battery management systems, to processes, computer software and systems integration.

Different strategies have been adopted by Indian companies to overcome IPR barriers

Indian firms use numerous strategies to acquire technology, including in-house R&D, licensing, partnerships and acquisition. In the solar PV, hybrid vehicles and wind energy case studies, Indian firms have acquired technology through creating joint ventures with foreign companies, through acquiring firms and / or personnel, and through purchasing technology licenses. In solar PV and hybrid vehicles, technology developments also occurred as a result of in-house RDD&D. Results indicate that those strategies that involve knowledge and expertise from international sources appear to have had more success in facilitating technology transfer and diffusion. However, it may be difficult for smaller firms – often with less resource available – to pursue these strategies.

IPRs are usually worked out on a commercial basis between technology suppliers and the firm receiving the technology through Technology Transfer Agreements (TTA)

In most of the case studies, the IPRs are held by a concentrated number of foreign firms. Interviewees indicated that IPRs are worked out between technology transfer participants through Technology Transfer Agreements (TTAs).

As noted in the IGCC case study, the TTA has various clauses covering the designs of products/systems to be transferred for commercial exploitation by the receiving party, IPRs, period of agreement, limits of market/countries for manufacture and sale of product/system, terms for termination, rights after expiry of agreement, arbitration procedures in case of any dispute, compensation to be paid to the company supplying the technology in terms of a technology disclosure fee as a lump sum or running royalty to be paid on sale price, etc. These TTAs are very meticulously negotiated to satisfy the commercial interests of both parties.

Results from the study about the implications of these TTAs were inconclusive. TTAs place restrictions on the user as to the number of systems/products, markets and so on. These features, along with the technology fees/royalty charges, are barriers to large-scale technology deployment. Some participants felt that TTA terms were fine, while others noted that the time required to research the technologies, identify potential partners, and negotiate the agreement delayed access to state of the art technologies. In the wind case study, for example, it was noted that technology owners use IPRs as a barrier to new entrants.

IPRs haven't prevented activity by Indian producers, but can slow the rate at which they can manufacture at the cutting edge

Indian technology producers are active, either commercially or at the R&D level, across all five technologies studied. However, IPRs seemed to be slowing the rate at which Indian companies were able to commercially produce certain technologies, such as hybrid vehicles. IPRs also seemed likely to become more significant in slowing the rate at which Indian producers that were already commercially active in an industry were able to move towards producing at the cutting edge (e.g. wind turbines that work at low wind intensities, or thin film PV), or move further along the value chain (e.g. producing PV grade silicon). This longer lead time for Indian companies to access relevant knowledge and develop relevant skills to produce new low carbon technologies implies a slower rate of accumulation of low carbon technological capacity. As argued in the introductory part of this report, developing low carbon technological capacity is integral to creating the capacity for sustained, low carbon economic development in India.

Some Indian producers wanted to access the cutting edge, while others were making economic returns from producing earlier versions of technologies

It worth noting that some interviews during this study suggested that the technology producers were generally satisfied with their business models which involved "following on", focusing on established, mature technologies (e.g. PV firms working on First Generation silicon PV technologies). For these companies IPRs were of little concern. Other firms (e.g. Suzlon in wind energy) expressed a desire to access the state of the art and indicated that IPRs play a role in access to such technology, often causing delays as they pursue alternative mechanisms to acquire the technology they desire.

From the perspective of India's overall development strategy, and also from the perspective of avoiding lock-in to older, higher carbon technologies with long capital life times, this situation raises questions relating to the desirability of national or international policy interventions geared towards encouraging commercial production activity at the cutting edge of low carbon technologies. This might speed the development of low carbon technological capacities and is of direct relevance to the discussion above of whether developing countries might be able to leapfrog towards technological frontiers and avoid high carbon development pathways. It is also important to consider that generally speaking there are only a limited number of firms globally with state of then art technology in any area. Achieving and maintaining that status is costly; requiring more R&D etc. Moreover, the market for these products is often limited initially to early adopters who will pay a premium price for new technology. Thus a state of the art corporate strategy can be financially and technically riskier than a follow on strategy based on mature technology.

Tacit knowledge and trade secrets must also be considered

The above discussion focuses on the relevance of IPRs for existing or potential Indian producers of low carbon technologies. It is important to note, however, that although many commentators stress patents as being the most relevant type of IPR for low carbon technologies, patents do not represent the whole picture. Trade secrets and other tacit knowledge are also very relevant in terms of understanding and acquiring knowledge relating to technologies.[312] For example, a situation could be imagined where Indian producers were given access to all patents relevant to hybrid vehicles, but were still unable to commercially manufacture hybrids due, for example, to the codified nature of many patents, or a lack of clarity as to how the patented component technologies work together as a system. Such knowledge might only be possible to access via direct contact with experts from international companies that are already commercially producing these technologies. It is for this reason that knowledge sharing via international collaborative RDD&D initiatives is a priority area for policy efforts to focus.

5.2 RDD&D

Several insights can be drawn from the case studies with respect to collaborative RDD&D and technology transfer in the area of low carbon energy technologies. These summarized here and set out in more detail under individual headings below.

As noted above, international collaboration on RDD&D can play an important role in facilitating long term initiatives that avoid problems with IPRs slowing

312 Interview, one Indian IP expert, November 2008; Ji, Z., Ravi Srinivas, and Nagesh Kumar 2008. 'Climate Change: Technology Development and Technology Transfer – Chapter III' in (UNDESA), U.N.D.o.E.a.S.A. (ed.) *Beijing High-Level Conference on Climate Change: Technology Development and Technology* Transfer. Beijing, China: UNDESA: 55.

the rate at which developing country firms can commercially produce cutting edge low carbon technologies. It can also facilitate access to the tacit and other relevant knowledge necessary to manufacture some low carbon technologies, and hence play an important role in developing low carbon technological capacity amongst developing country technology producers, which is important for underpinning sustained, low carbon economic growth.

The case studies analysed in this report highlighted several other important aspects of collaborative RDD&D initiatives. In terms of the benefits of such initiatives, collaborations between Indian and international companies were important in the SME case studies where the relevant technologies needed to be adapted to India-specific conditions to make them appropriate for end users in India. At the technology producer end, international collaborations were observed to speed the rate at which Indian producers were able to move towards producing at the cutting edge. For example, an Indian PV company that collaborated with an international firm took much less time to develop the capabilities necessary to manufacture thin film solar PV than another Indian firm which relied on indigenous R&D.

In terms of how to develop effective collaborative RDD&D mechanisms, the results of this study emphasise the need for public-private engagement. India's National Hybrid Propulsion Platform (NHPP) is an excellent example of a public-private partnership, although it lacks involvement from international players. The findings of the SME case study also highlighted the need for a needs-based approach to developing RDD&D collaborations that directly involves local actors. This case study also emphasised the importance of making follow-on funding available to ensure that the benefits of collaborative initiatives diffuse amongst wider end users as opposed to ending with those actors involved in initial collaborations.

Although Indian companies were clearly aware of which international companies they would benefit from collaborating with, they rarely mentioned any existing intergovernmental initiatives that aim to foster such collaborations. This suggests a need to better communicate and target international initiatives towards relevant companies in developing countries.

The study suggested that the main incentive for international companies to collaborate with Indian companies was the promise of access to new markets in India. This highlights an important need for domestic policy incentives to boost demand for low carbon technologies, whether end use technologies like hybrid vehicles (e.g. via tax incentives for low carbon vehicles, or emissions limits on new vehicles), or energy generation technologies such as renewables or IGCC (e.g. via feed-in tariffs or incremental cost subsidies). Where companies at the cutting edge of technologies were unwilling to collaborate with Indian firms, some Indian firms tended to look to overcome this barrier by working with second tier companies. For example, a number of companies seeking to manufacture hybrid vehicles were entering into discussions with international firms other than market leaders Toyota.

Collaborative RDD&D is required to adapt foreign technology to Indian conditions

Stories of the failure of technology transfer in the developing world abound, and exist in all sectors. In one example, the Canadian International Development Agency (CIDA) helped to provide funds to build a semi-automated bakery in Tanzania, which operated well below capacity due to missing spare parts. Imported farm machinery was also plagued by a shortage of spare parts, increased dependence on diesel fuel, and put strains on foreign exchange. This project, in the 1970s, catered to 10% of Tanzanians living in cities who were increasingly consuming wheat, rather than 90% of the population in rural areas consuming other products (e.g. maize, beans).[313] As another example, Jasanoff (2002) recalls her experience at a regional environmental agency in India where she saw water-measuring equipment provided by the World Health Organization sitting on the shelf as parts were missing and too difficult to replace.[314]

In contrast to these experiences, lessons can be drawn from the case studies. One major reason for the introduction of the energy efficient technologies used in the SME glass and foundry industries in India is due to the collaborative efforts that took place involving both local and international partners, including a domestic NGO, foreign businesses, a foreign aid agency, and international and local experts. All of the other four case studies also have instances of foreign technologies being adapted to the Indian environment through collaborative RDD&D.

Strategies that involve knowledge and expertise from international sources appear to have resulted in more successful technology transfer and diffusion

Collaborative RDD&D mechanisms have shown clear potential for developing capacity in and access to new technologies, as well as increasing the rates of technology diffusion, all pivotal goals in addressing climate change. International collaborations on research, development, demonstration and deployment show the highest potential for facilitating the transfer of knowledge and hardware. Better engagement at the international level with such initiatives can therefore play a role in improving the effectiveness of these collaborations by sharing knowledge.

In both PV and hybrids, one of the strategies that Indian firms use to develop technologies is through in-house R&D. However, the experiences of individual firms differ. For example, in the PV case study, it has taken HHV, which is using mainly indigenous resources, 10 years to move from research to commercial production of thin film solar PV. By contrast, Moser Baer PV Ltd., by partnering with several American firms, announced plans to build a thin film production plant in three years.

313 Freeman, L. 1984. 'CIDA and Agriculture in Central and East Africa' in Barker, J. (ed.) the Politics of Agriculture in Tropical Countries. Beverly Hills, CA: Sage.

314 Jasanoff, S. 2002. 'New Modernities: Reimaging Science, Technology and Development'. *Environmental Values* 11: 253-276: 262.

On hybrid vehicles, Mahindra and Mahindra conducted its initial RDD&D in-house but some key personnel had extensive experience abroad in this area. To move from a concept hybrid vehicle to a demonstration hybrid vehicle, M&M formed partnerships with some key global technology suppliers to make further advances on the technology.

Market access generally drives international company and foreign government involvement in collaborative RDD&D

Collaborative RDD&D initiatives in India are generally driven by domestic industry. Indian firms conduct research and identify potential partners to work with based on numerous attributes including access to and knowledge of cutting edge technologies, willingness to work with Indian partners, etc. From there, the key driver for international company involvement is access to the Indian market. There are no stipulations in place by the Indian government regarding collaboration between foreign and domestic firms for many low carbon energy technologies. There are only a few industries, such as defence and aspects of nuclear, where the government has requirements on these initiatives (e.g. a certain percentage of the technology be controlled by Indians, using local manufacturing capabilities as in the case of Boeing, etc.). One suggestion was to place more stipulations on international collaboration to ensure more domestic involvement in technology transfer. Others noted the difficulty with this option when trying to correlate these policies with obligations under the World Trade Organization (WTO).[315]

Indians familiar with the climate negotiations are aware of industrialized countries' obligations to developing countries on technology transfer, but their view is that the current arrangements under the UNFCCC, including market mechanisms (finance), are not enough to help developing countries on this issue. They argue that different mechanisms are needed to make technology transfer more effective.[316]

The Government of India has proposed a Technology Transfer Mechanism which includes a Technology Action Plan. The Action Plan would define specific policies, actions and funding requirements for public domain technologies, patented technologies, and future technologies, where funds would be attached to support these endeavours, including through compulsory licensing. One Indian IPR expert pointed out that the United States also uses forms of compulsory licenses.[317] Representatives from industry, while supportive of

315 Discussions, stakeholder workshop, November 2008; Interview, one Indian IP expert, November 2008

316 Discussions, Stakeholder Workshop, November 2008, India, G.o. 2008. 'Submission to the UNFCCC on Technology Transfer Mechanism' in UNFCCC (ed.). New Delhi: Government of India.

317 Such as under the Clean Air Act (CAA) section 308, where a party is unable to comply with the CAA without the use of obtaining a patent, and that patent license has been denied by the patent holder. An example of where this has been applied is in a 2006 case where a U.S. Court granted Toyota a compulsory license on three Paice patents for hybrid transmissions. Discussions, Stakeholder Workshop, November 2008, Lee, B. 2008. 'Stream 5 IPRs and the Diffusion of Climate Technologies ' in House, C. (ed.) *Chatham House Project on Trade, Financing and Climate Change: Building a Positive Agenda for Developing Countries*. London: Chatham House.

the idea of the government or another public agency purchasing licenses, recognized that it might be difficult to implement.[318]

Stakeholders suggested that the formation of a patent pool, very common in the electronics industry, could be another way to address IPRs for low carbon energy technologies.[319] This is another option that could be explored further.

Some Indian firms have adopted a strategic approach towards second tier companies where they cannot access existing state of the art technologies

In the case of hybrid vehicles, industry experts indicated that firms in India are taking a round-about approach to access state of the art technologies. Rather than approach the global leaders, like Toyota, directly, a number of firms were acquiring technology through licenses and / or agreements with second tier firms, where the technologies are not necessarily inferior, and improving and adapting these technologies to Indian circumstances.

Improvements are being made. Indian firms, governments and academic institutions are actively engaged in this area and are finding ways to access technology, although as noted in the IPRs section, accessing technology using these methods may play a role on rate of diffusion of low carbon energy technologies.

Industry players have little awareness of and pay little attention to international intergovernmental mechanisms

Industry players only briefly mentioned (if at all) existing international intergovernmental initiatives to assist technology transfer. This is not to say that Indian firms are unaware of current frontier research trends and global efforts relating to these technologies. In all of the case studies Indian firms had identified the countries and / or companies and to a lesser extent the research institutes engaging in cutting edge RDD&D. However, Indian firms have largely adopted an independent, bilateral approach with foreign firms and / or institutes, rather than joining multilateral initiatives.

In fact, many industry players suggested that domestic government actions could encourage technology transfer for low carbon energy technologies. Those involved in IGCC noted the assistance that the GoI has given to this technology, through providing an incremental capital cost subsidy for demonstrating this technology in India. This is the same approach used by the United States government for this technology. In addition, an incremental capital cost subsidy was provided to those plants seeking to produce alternatives to Ozone Depleting Substances (ODS), through a multilateral fund, under the Montreal Protocol. At the same time, highlighting the Clean Air Act (CAA) in the U.S. and feed in tariff

318 Discussions, Stakeholder Workshop, November 2008., Interviews, Industry Experts, October and November 2008,

319 Discussions, Stakeholder Workshop, November 2008.

schemes in Germany and Spain, the consensus is that the government can do more to support the transfer and diffusion of low carbon energy technologies. Those involved in PV noted that although recent policies to support this technology in India were encouraging, the core of their business was outside of India. Others indicated that the GoI, including the MNRE and the DST, is undertaking various schemes and funding initiatives to support low carbon technologies but that few people know about them. Some stakeholders further suggested that the GoI could support certain technologies, creating targeted national champions.[320]

Private-public engagement is needed for RDD&D programs

Similar to the findings from the five case studies in Phase I, the current findings suggest that technology transfer activities must include cooperation between both the public and private sectors. The private sector is an integral actor in the transfer of low carbon energy technologies as this is where the majority of these actions take place.

The public sector also has an important role to play in encouraging collaborative RDD&D programs. This can be done through formal partnerships, or through initiatives driven by the private sector, but where the public sector provides some incentives. Actions can include a focus on a country's National Systems of Innovation (NSI), as India has done. This focuses on infrastructure and political stability, along with more direct efforts such as providing financial and human resources for RDD&D.

Interviews for this study indicated that India has developed a reputation for having a highly educated pool of talent due to investments in its NSI. This enables India to produce high quality products at lower cost.[321] Mittal (2003) in his study on the Indian automotive sector notes "the cost differential enjoyed by India ranges from 10 to 35 percent depending on value addition, engineering complexities, and level of assembly".[322] India's foreign direct investment has also increased substantially since it liberalized her economy from US$ 150 million per year in 1991 to US$ 52.5 billion in 2007.[323]

Technology selected for RDD&D must be needs-based & involve local actors

To ensure their sustainability in the long term, RDD&D programmes should have a strong partnership element and involve local actors from the outset. Local actors took over once the consultants and expert R&D organizations had

320 Discussions, Stakeholder Workshop, November 2008

321 Ockwell, D., Watson, J., MacKerron, G., Pal, P. and Yamin, F. 2006. 'UK-India Collaboration to Identify the Barriers to the Transfer of Low Carbon Energy Technology'. London: Report by the Sussex Energy Group (SPRU, University of Sussex), TERI and IDS for the UK Department for Environment, Food and Rural Affairs: 12 and 16; Discussions, industry experts, October and November 2008

322 Mittal, D. 2003. 'the Export Potential of the Indian Automobile Industry' in Award, C.Y.T.L. (ed.). Calcutta, India: IIM: 2

323 Times, E. 2008. 'Global Foreign Direct Investment Grows to Almost $1 Trillion in 2007, 20% Increase in FDI Capital Expenditure in US': |Earth Times.

helped the SMEs identify and demonstrate the benefits of cleaner technologies. The inclusion of intermediaries in such processes (trade associations, NGOs) can also help ensure success by providing on the ground knowledge, access to local contacts, and a local "go to" place should technology purchasers have challenges, etc.

Partnerships for RDD&D must target building of local technology capacities to deploy and develop technologies

Findings in Phase II echoed those in Phase I that technology transfer must take place as part of a wider process of technological capacity building in developing countries. For example, commentators on India's Light Emitting Diode (LED) industry avowed that India's ability to manufacture white LEDs would not be affected much if Indian firms were to acquire relevant IPRs without improvements in technological capacity in this area.[324] In Phase II, independent of whether a firm can access IPRs, the complex nature of the hybrid vehicle technologies calls for firms to have the ability to understand and 'master' the numerous intricate details for technology transfer and development to be successful. Firms' ability to do so often depends on their technological capacity.

International collaboration on RDD&D is more frequent amongst larger Indian firms

Linkages through efforts initiated by Indian companies occur more frequently amongst larger Indian firms. These larger firms have easier access to resources including capital, personnel and global networks. International policy can help to encourage collaboration between organizations involved in frontier technologies and smaller firms.

324 Ockwell, D., Watson, J., MacKerron, G., Pal, P. and Yamin, F. 2006. 'UK-India Collaboration to Identify the Barriers to the Transfer of Low Carbon Energy Technology'. London: Report by the Sussex Energy Group (SPRU, University of Sussex), TERI and IDS for the UK Department for Environment, Food and Rural Affairs.: 8 and 109.

6. Policy Recommendations

Significant contributions have recently been made in developing potential institutional architecture for facilitating technology transfer under the United Nations Framework Convention on Climate Change (UNFCCC). It is not our intention here to add to this literature. We would instead encourage interested readers to consult the work of E3G and Chatham House in this regard.[325] These policy recommendations concentrate instead on key criteria for successful international collaborative (Research, Development, Demonstration and Deployment) RDD&D initiatives, which is the focus of this report. There are two good reasons for this focus.

Firstly, based on this study's findings, ***it is likely that international collaborative RDD&D initiatives will have a significant impact on technological capacity development while offering creative ways around issues related to IPRs***. Whilst access to IP might sometimes present a barrier to technology transfer, or play a role in slowing the diffusion of technologies, it is not clear from the analysis in this report that an international fund to buy up IP will facilitate technology transfer on a large scale. Neither is it clear how such a fund would work, bearing in mind the complexity of patents relating to many low carbon technologies and the large role that tacit knowledge and trade secrets play in enabling companies to restrict access to low carbon technologies. Collaborative RDD&D offers a potential means of securing joint ownership of IPRs at the same time as exposing developing country firms to the necessary tacit knowledge to be able to work effectively with low carbon technologies.

Secondly, ***early engagement in international collaborative RDD&D initiatives might also address individual companies' and countries' concerns with maintaining comparative advantages***. It would be naive to ignore the existence of such concerns, which likely play a strong role in the deadlock observed in international negotiations on technology transfer. Indeed, informal discussions between the study team and international negotiators have often raised this issue. Similarly, conversations with international industry actors indicate that some are not interested in working in India based on their previous experiences – which include actual copying or the potential for copying of products and processes by Indian firms. Engagement in collaborative RDD&D initiatives at early stages of technology development, for example fuel cells, IGCC, and Third Generation PV, has the potential to overcome these concerns as international firms may not yet have identified specific market potential in these undeveloped areas and hence be more willing to work and share knowledge, with developing country partners.

325 Tomlinson, S., Zorlu, P. and Langley, C. (2008) Innovation and technology transfer. Framework for a global deal. E3G and Chatham House, London

We begin these policy recommendations by setting out key criteria that can guide the design of international collaborative RDD&D initiatives. We then set out a guide for decision makers to identify key issues that international and national policy must address in relation to specific technologies. Finally, we conclude by making some India-specific recommendations for potential areas, which might benefit from international collaborative RDD&D initiatives.

6.0 Key criteria to guide the design of international collaborative RDD&D initiatives

Policy designed to facilitate the establishment of collaborative RDD&D initiatives should be guided by the following criteria.

Identify appropriate participants

- Collaborations must involve both public and private actors and should be facilitated at the international level with the aim of bringing together technology leaders with interested companies in developing countries.

- Collaborations should also aim to strengthen links across different sectors of the domestic economy within developing countries, especially industry/academia/government connections. Each of these players can bring different skills and expertise to the table. This recommendation draws on the triple helix model in innovation studies where industry, the academic sector and governments at various levels (nation, region / state, and local) work together to innovate. The argument is that projects with more sources of leadership and support will be more likely to succeed.

- Industry associations at the local/state levels can play an important role in assisting with the identification of suitable locations for initiating collaborative programmes, while multilateral agencies can facilitate inter-governmental partnerships and bring international technical experts together.

Identify key sectors

- Efforts should focus on establishing initiatives that are specifically designed to address the differing levels of technological capacities that exist in relation to low carbon technologies within specific developing country contexts.

- Using Technology Needs Assessments as a starting point, a multilateral body should commission assessments of the existing technological capacity across specific priority sectors and technologies within a country. This should then be used to assess which sectors would benefit most from the establishment of international RDD&D collaborations. These assessments must also identify which stage of the RDD&D spectrum needs to be focused on. It is likely that this will differ according to the specific industry, technology and/or country context.

Secure engagement

- To facilitate engagement by international firms, clear articulation of the benefits (e.g. new market access, access to knowledge of local technological requirements) is required. Provision of such information could usefully be facilitated by investigations commissioned under the auspices of a multilateral body.

Address intellectual property rights

- Collaborative initiatives require specific, up front agreements as to how IP will be treated.

- Partners may be more likely to commit resources if IP is agreed to be shared.

- Consideration also needs to be given to whether governments or supporting multilateral organisations might want to specify time horizons for IPRs resulting from such collaborations being made publicly available so that wider society might benefit. These time horizons must be long enough to allow partners to initially capitalise to the extent that eventual public availability of IP does not deter actors from engaging.

- Collaborative initiatives should include a specific element aimed at increasing knowledge and awareness of the domestic and global IP system. The fieldwork that supported this study suggested that, although many of the low carbon energy industry experts consulted are aware that India has a domestic patent system (and some had submitted patents in India and elsewhere) and is undertaking major reforms in this area, they were not aware of all specific incentives that the patent office has put in place (e.g. a relaxation of fees for Indian submitters vs. foreign submitters).

Provide Finance

- Sustained financial support is required to ensure any insights or technological advances arising from such collaborations are transferred throughout the sector (as opposed to only benefiting those companies initially involved in the collaboration).

- It is essential that financial mechanisms offer support across the full RDD&D spectrum. All too often funding opportunities have tended to focus on initial R&D and/or commercialisation of fully developed new technologies, whilst failing to support the integral stages of demonstration and subsequent adaptation which occur prior to technologies being ready for commercial adoption. This lack of funding in the middle stages of technology development is often referred to as the "valley of death" as it contributes to promising new technologies never reaching commercialisation.

6.1 Decision making guide for design of transfer activities to maximise technological capacity development

6.1.1 Background

The decision making guide begins from the assumption that a specific technology has already been identified as desirable within the specific context of the country to which that technology is to be transferred. For the purposes of this report, decision making guide is meant as a system for classifying things, or a framework to assist in decision-making. This could be done on the basis of Technology Needs Assessments, or alternative suggestions that have been made as to how to go about identifying appropriate technologies.[326] What this decision making guide adds is an iterative approach to identifying the key considerations that will determine the impact of innovation and transfer activities around this specific technology on the level of low carbon technological capacity within the recipient country. Decision makers should remember that, due to the context specific nature of both technologies and the countries to which transfer is desired, this decision making guide is only able to form "… a partial synopsis; the entire analytic process in reality is of course highly iterative and interactive. In reality, the elements depicted here are typically addressed repeatedly and in a variety of sequences, when applied to a particular situation."[327]

Other organizations have also developed frameworks for low carbon energy technologies, including renewable energy sources, to assist policy makers and practitioners in their decision-making processes. This list, by no means exhaustive, provides some examples of taxonomies for low carbon energy technologies. These are particularly useful, especially the Carbon Trust's framework, since they emphasise how policy approaches need to vary with the stage of development.

326 See Tomlinson et al. (ibid.) and Brewer, T. The technology agenda for international climate change policy: a decision making guide for structure in analyses and negotiations. Background Paper for ECP Seminar Strategic Aspects of Technology for the UNFCCC and Climate Change Debate: The Post-Bali Technology Agenda Brussels, 3 October 2007

327 Ibid.: 7.

1. **The Carbon Trust** developed a **Renewable Policy Framework** for the United Kingdom's situation, where technologies were categorized into stages regarding technology development, starting with the early stages of research and development (R&D), and ending with those technologies that are near commercial. From there, common characteristics and policies amongst renewable energy technologies found within that particular stage of technology development were identified (see Figure 6.1 below).

Figure 6.1: Four Stages of Technology Evolution[328]

TECHNOLOGY EVOLUTION →

	Stage 1 Early Stage – R&D	**Stage 2** Early Stage – Demonstration Projects (eg. some marine technologies)	**Stage 3** Large Scale Growing (eg. offshore wind)	**Stage 4** Near Commercial (eg. onshore wind)
Characteristics	▶ Feasibility uncertain	▶ Several technologies becoming feaible ▶ Technology choices still to be made	▶ Fundmental technology or process selected ▶ Technology refinement and cost reduction underway	▶ Technolopgy prtoven – scale projects already operatioal ▶ Operating returns not yet attractive (without subsidy)
Current Policies	▶ DTI Technology Programme ▶ EU framework Programme for research and Technical Development ▶ Carbon Trust Applied Research programme ▶ Carbon Trust Technology Acceleration (eg. Marine Energy Challenge)	▶ Carbon Trust Technology Acceleration (eg. Marine Energy Challenge) ▶ Marine Renewables Deployment Fund ▶ Renewables Obligation ▶ Climate Change Levy exemption.	▶ Renewables Obligation ▶ Capital Grants ▶ Climate Change Levy exemption	▶ Renewables Obligation ▶ Climate Change Levy exemption.

2. REToolkit – the Renewable Energy Toolkit of the World Bank consists of two structures

   a) An Issues Note that examines relevant policy, economic and financial issues regarding renewable energy systems. The note also provides a comprehensive examination of various policy frameworks worldwide to encourage the use of renewables including feed in tariffs, renewable obligations, and tax credits, among others. The Note also includes a technology chapter that provides technical details regarding a number of renewable energy technologies, such as hydropower, wind, biomass, geothermal, and solar photovoltaic (PV).

328 Trust, L.E.K.C.a.t.C. 2006. 'Policy Frameworks for Renewables – Analysis on Policy Frameworks to Drive Future Investment in Near and Long-Term Renewable Power in the UK'. London: the Carbon Trust.: 7.

b) A website which contains electronic information related to renewable energy development including knowledge documents, case studies and a technology module (For details see http://go.worldbank.org/OWJW3JRYJ0)

The idea of the Toolkit is to assist World Bank staff members and others to design and implement renewable energy projects.[329]

3. **Climate Technology Initiative (CTI):** The CTI was established at the first Conference of the Parties (COP1) to the UNFCCC in Berlin in 1995. In 2003, the CTI became one of the IEA's implementing agreements. The CTI aims to be consistent with the objectives of the UNFCCC process, working with relevant actors including the UNFCCC Secretariat, member parties, the Expert Group on Technology Transfer (EGTT), the International Energy Agency (IEA), among others.

One of the activities of the CTI is to work with developing countries to produce technology needs assessments, based on methodologies developed by the CTI in 2002 and the United Nations Development Programme (UNDP) in 2004.[330]

6.1.2 The decision making guide

The decision making guide is set out in Figure 6.2. It begins with questions regarding the existing technological capacity within the recipient country. On the basis of answers to these questions, questions are then raised in relation to: transfer arrangements; temporal considerations; and, incentive structures. These questions should be answered within the context of an understanding of the theoretical discussion in the introduction to this report, and the summary of key findings and policy recommendations in the concluding section of this report.

329 Bank, W. 2008. 'REToolkit: A Resource for Renewable Energy Development' in Bank, W. (ed.). Washington, D.C.: World Bank.

330 , (CTI), C.T.I. 2002. 'Methods for Climate Change Technology Transfer Needs Assessments and Implementing Activities Developing and Transition Country Approaches and Experiences': CTIGross, R., Dougherty, W., and Kumarsingh, K 2004. 'Conducting Technology Needs Assessments for Climate Change' in UNDP (ed.). New York: UNDP.

Figure 6.21. Decision making guide for identifying optimal transfer arrangements for maximising technological capacity development

Existing technological capacity

Is this hardware or software related? Or both? Is the relevant knowledge explicit or tacit? Or both?
What is the nature of the skills required to implement this technology?
What sectors do these skills encompass?
What level of these skills currently exists in the recipient country?
Which sectors need to be targeted for development via the transfer arrangement?
Is there a need to increase connectivity between public, private and research sectors?

Transfer arrangements	Temporal considerations	Incentive structures
Which firms or other actors own the relevant technologies? Are they foreign or domestic? Do patents (or other IPRs e.g. copyrights for computer software) exist? Or have they expired? Have patents been issued at the national and international (triadic – EPO, Japan and US PTO) levels? How willing are these actors to transfer the technology? Are there any IPR issues that need to be negotiated? Are there alternative approaches that might overcome barriers relating to unwillingness of actors to share the technology? This could include approaching second tier firms, or considering domestic technology development. Which activities along the RDD&D spectrum would be most beneficial in plugging any identified skills gaps? Is it possible to negotiate less integrated transfer arrangements with maximum use of host country skills, labour and parts? Is it possible to negotiate specific knowledge transfer and training arrangements as part of the transfer process?	What overall development strategy is technology transfer playing a part in? Is the desire to leapfrog over high carbon development pathways and avoid lock-in to high carbon infrastructure, or is a slower, more iterative development pathway acceptable (with potentially higher opportunities for learning and capacity building)? If barriers are to be overcome via an indigenous development route, what are the implications of this for speed of technology diffusion and associated carbon emissions?	If activities at earlier stages of the RDD&D spectrum are desirable, what incentive structures are in place to bring international, private sector players to the table (e.g. promise of new market access)? And how are these incentives to be communicated to the relevant actors? Are there any policy related barriers, either national or international, that need to be addressed (e.g. tariffs and subsidies, IPR regimes)? Are there any market failures that need to be addressed? Are policies in place to encourage more domestic engagement in technology transfer (e.g. certain % of domestic ownership, products and services only sourced locally, etc.)?

6.1.3 Decision making guide – an applied example

Below we apply the decision making guide to the case study of hybrid vehicles analysed earlier in this report. This provides an example of the process decision makers might go through when designing policy interventions that maximise the contribution of technology transfer activities to technological capacity in the field of low carbon vehicles.

Existing technological capacity

Q: Is this hardware or software related? Or both? Is the relevant knowledge explicit or tacit? Or both?

- Both hardware and software issues are relevant to hybrid vehicles. The technology requires integration of electrical, mechanical, chemical and computer software technologies. This range of hardware and software components also makes systems integration key.

- Some of the relevant knowledge is explicit and will exist in the form of component and system designs, automated production processes, and so on. But a large amount of tacit knowledge is also likely involved which has been acquired by industry leaders such as Toyota by virtue of having applied experience of working with hybrid technologies for a number of years. Access to this tacit knowledge will require either direct engagement with firms with experience of working with hybrid technologies, or a process of acquiring this knowledge through learning by doing.

Q: What is the nature of the skills required to implement this technology? What sectors do these skills encompass?

- The various software and hardware related components of hybrid vehicles imply a need for a wide range of skills spanning a number of sectors. Relevant technologies and sectors include:

  - Electrical technologies: batteries, electric motors, power electronics and related semiconductors (e.g. traction inverters, battery chargers)

  - Mechanical technologies, including internal combustion engines, drive train mechanics and other mechanical components relevant to vehicle design and manufacture

  - Chemical technologies for the development of improved batteries

  - Computer software technologies to interface the electric and internal combustion engines

  - Systems integration knowledge for the integration of the component technologies

Q: What level of these skills currently exists in the recipient country?

- As one of the world's top 10 producers of vehicles, and with many auto components companies (consisting of around 500 manufacturers in the organized sector and about 10,000 small and medium enterprises), India has significant existing capacities within conventional vehicle technologies.

- Some companies, including Mahindra and Mahindra and Tata Motors, Ashok Leyland and TVS, are working to develop hybrid technologies and will therefore have some relevant expertise

- Several of the technologies involved in hybrid vehicles require bespoke adaptation and integration into hybrid systems. The lack of existing commercial production of hybrid vehicles in India implies that further skills development may be necessary within the sectors outlined above in the context of adapting and integrating these technologies for the production of hybrid drive trains.

Q: Which sectors need to be targeted for development via the transfer arrangement?

- As vehicle systems are increasingly drawing from the software, electronics and chemical industries, it may be necessary to target these industries to ensure the development of hybrid relevant expertise within India.

- Indian OEMs are already working with a number of foreign and domestic technology suppliers including engineering firms, battery providers and system integrators (e.g. Texas Instruments, Ricardo, FEV, Hybridtronics), suggesting an existing level of international engagement. Targeting these industries to better facilitate international knowledge transfer agreements would benefit the development of indigenous technological capacity in areas relevant to hybrid vehicles.

Q: Is there a need to increase connectivity between public, private and research sectors?

- Significant advances have been made in this respect in India via the National Hybrid Propulsion Platform (NHPP). Policy efforts should therefore be focused on nurturing this collaborative initiative, and encouraging engagement from relevant international companies to move this initiative beyond its current domestic focus.

Transfer arrangements

Q: Which firms or other actors own the relevant technologies? Are they foreign or domestic?

- As outlined in detail in the hybrid case study, industry leaders tend to be large international companies, although significant developments are currently occurring within India.

Q: Do patents (or other IPRs e.g. copyrights for computer software) exist? Or have they expired? Have patents been issued at the national and international (triadic – EPO, Japan and US PTO) levels?

- Numerous patents exist in a number of areas, including batteries, electric motors and power electronics, engines and system integration.

- IPRs are dominated by a concentrated set of foreign companies rather than domestic players in India. Patents have been issued at both the national and international levels.

Q: How willing are these actors to transfer the technology?

- Indian companies are focussing their efforts on developing indigenous versions of hybrid technologies. This implies that existing patent owners are not willing to openly share this technology, or that Indian companies perceive little benefit in accessing existing commercial versions of the technology and prefer to own/work with their own versions.

Q: Are there any IPR issues that need to be negotiated?

- The general consensus among interviewees for this study was that IPRs are an issue but that they were not perceived to be prohibitive in that Indian firms had space to manoeuvre by developing slightly different versions of the technology which would not infringe patents. It is therefore possible that Indian companies might successfully move into working with hybrid technologies without needing to engage in significant negotiation in relation to IPRs. However, this does call into question whether the technology might more rapidly be put to widespread use in India if access to IPRs could be successfully negotiated with the international companies currently leading this industry.

- However, informal discussions with industry experts and foreign firms during this study suggested that the main reason for a lack of technology transfer in this area was the lack of a potential market for hybrid vehicles in India, rather than IPRs. This implies that domestic or international policy regulating vehicles emissions might be more effective in facilitating technology transfer than any focus on IP.

Q: Are there alternative approaches that might overcome barriers relating to unwillingness of actors to share the technology? This could include approaching second tier firms, or considering domestic technology development.

- The activities of the National Hybrid Propulsion Platform (NHPP) suggest that Indian companies are confident that they will be able to bypass IPR issues via indigenous technology development activities.

- Another possible strategy would be to approach firms other than Toyota, such as GM and Citroen, whose second tier status might render them more willing to share their own hybrid drive trains at more competitive prices.

Q: Which activities along the RDD&D spectrum would be most beneficial in plugging any identified skills gaps?

- The fact that several Indian companies have developed concept cars implies that an emphasis on technology demonstration would be most productive in terms of assisting with the development of hybrid relevant skills bases in India. This would require engagement from international firms in possession of existing commercially viable hybrid drive trains.

Q: Is it possible to negotiate less integrated transfer arrangements with maximum use of host country skills, labour and parts?

- An emphasis on the use of host country skills, labour and parts within any international transfer arrangement would be significant in contributing to developing relevant technological capacities within India. Less integrated transfer arrangements should therefore be a priority for any negotiations with international companies.

Q: Is it possible to negotiate specific knowledge transfer and training arrangements as part of the transfer process?

- Negotiations with international companies also need to focus on knowledge transfer and training arrangements. This should aim to avoid situations such as that observed in China where Toyota is, under a joint venture with a Chinese company, manufacturing hybrid vehicles. Here, whilst host country manufacturers are used, the hybrid drive train itself is manufactured in Japan before being shipped to China and used in the assembly process. This means that Chinese companies are not developing expertise in how to manufacture and work with the key part of the hybrid vehicle. Such an arrangement is unlikely to assist in the development of hybrid specific technological capacities amongst Chinese firms.

Temporal considerations

Q: What overall development strategy is technology transfer playing a part in? Is the desire to leapfrog over high carbon development pathways and avoid lock-in to high carbon infrastructure, or is a slower, more iterative development pathway acceptable (with potentially higher opportunities for learning and capacity building)?

- This is a pertinent question in relation to hybrid vehicles and low carbon transport options in general in India. Decisions need to be made as to whether Indian involvement within the hybrid vehicle industry is motivated by a desire to reduce carbon emissions in India, or a desire to develop an export-oriented industry. If it is the latter, then the existing iterative approach that is being adopted to developing capacity in India to manufacture hybrid vehicles is not problematic in any sense other than lost potential earnings. If it is the former, then an iterative approach could be argued to be too slow, thus raising the need for international technology transfer arrangements to speed up the transfer and diffusion of hybrid vehicle technologies in India. At present it would seem there is very little market for hybrid vehicles in India and significant domestic policy interventions would be required to create such a market – for example by introducing strict emissions restrictions for new vehicles.

Q: If barriers are to be overcome via an indigenous development route, what are the implications of this for speed of technology diffusion and associated carbon emissions?

- The current emphasis on indigenous development of hybrid technology in India implies that hybrid vehicle technologies are unlikely to diffuse rapidly in the near future. As noted in the case study and in Phase I, there are, at present, more urgent priorities in terms of sustainable transport options in India (e.g. sustainable mass transport systems) that would be likely to have a much greater impact on carbon emissions than efforts geared towards the development of indigenous capacities in hybrid vehicles. However, as personal mobility continues to exponentially increase in India domestic policy incentives to create a market for hybrid vehicles will be of increasing relevance in terms of reducing carbon emissions. As two-wheelers currently dominate the market share of vehicles in India (around 75%), more attention should be placed on this segment.

Incentive structures

Q: If activities at earlier stages of the RDD&D spectrum are desirable, what incentive structures are in place to bring international, private sector players to the table (e.g. promise of new market access)? And how are these incentives to be communicated to the relevant actors?

- As highlighted above, the lack of a domestic market for hybrid vehicles in India was cited by several individuals interviewed as a key reason for the lack of existing international engagement within India by current technology leaders. This implies that a central incentive for international engagement in demonstrating hybrid vehicle technologies in India would be domestic policy incentives to create a hybrid vehicle market in the country. This would then open up possibilities for engaging international companies in demonstration projects on the basis of accessing the resulting Indian market.

- In the face of a lack of political will to implement policy incentives such as strict vehicle emissions controls, another tack that India could consider to attract international company involvement would be to play along similar lines to the development of India's existing conventional vehicle industry, in particular access to more affordable manufacturing capacities.

Q: Are there any policy related barriers, either national or international, that need to be addressed (e.g. tariffs and subsidies, IPR regimes)?

- The key policy barrier that needs to be addressed in relation to hybrid vehicles is the introduction of policy incentives for the creation of a market for low emissions vehicles in India.

- Better communication of the design and enforcement of India's IPR regime might also be advantageous in encouraging hybrid technology leaders to engage with Indian companies.

Q: Are there any market failures that need to be addressed?

- As with any low carbon technology the lack of a regulation of CO2 emissions is an obvious market failure.

- This could be addressed this via international carbon trading initiatives, but it is far more likely to be more effectively addressed by the policies advocated above which aim to directly regulate emissions from new vehicles; the Clean Development Mechanism has virtually no transportation sector projects.

Q: Are policies in place to encourage more domestic engagement in technology transfer (e.g. certain % of domestic ownership, products and services only sourced locally, etc.)?

- Some existing incentives encourage buyers to purchase Indian cars (e.g. the Indian EV, the REVA) and the Government of India has decreased excise duties (or taxes on goods produced in India) for hybrid cars from 24% to 14%. The Government of India has also decreased taxes on imports of hybrid vehicles from 114% to 104%. Consideration might be given to the desirability of larger incentives for domestic production of hybrid technologies.

6.2 Promising areas for collaborative RDD&D on low carbon energy technologies in India

Based on this study's findings, all five of the case studies would benefit from international public and private collaborative efforts. More specifically:

i. Solar PV

Solar PV would benefit through all stages of the technology development. For example, the importance of developing the market through demonstrating and deploying this technology in India cannot be downplayed due to India's high insolation rates, opportunities for electrification through PV (small and large), and some suitable land areas for larger solar PV applications, particularly in Gujarat and Rajastan.

On the other hand, India has had a solid PV industry in place as well as research underway on PV for a number of decades. In addition, Indian firms and institutes are linked with global networks on PV including industry and research leaders in Germany, the United States and Japan. India would therefore benefit from expanding on this foundation, utilizing international collaboration on research and development in certain areas including upstream PV activities (producing PV-grade silicon and ingots and wafers), thin film technologies, as well as in energy storage systems. One potential way for international collaboration to occur is through utilizing links between Indians and the Indian diaspora community abroad. As noted in more detail in the PV case study, many of the PV researchers, especially in the U.S., are of Indian origin, so fostering these channels to provide expertise, exchanges, finances, etc. would be beneficial for the technology transfer and development of solar PV in India.

ii. Hybrid vehicles

For hybrid vehicles there are various reasons why the sector would benefit from collaborative RDD&D, including the fact that:

- Generally speaking, India's automotive sector – both manufacturing and consumption is growing;
- The government is actively supporting indigenous R&D on hybrids;
- Players working in the industry recognize the need for collaboration to make advances in this area;
- Key groups within India are organized around a common vision and national strategy; and
- Strong international links exist amongst many players in the industry, but there are still many areas requiring technological advancement.

Indian firms are undertaking various strategies to acquire the necessary technology expertise and hardware to make advances on hybrid vehicles. International collaboration on RDD&D efforts, such as acquiring foreign companies or personnel (Indians) who had lived and / or studied abroad, or licensing technologies, have played a key role in the successful transfer of technology and indigenous developments in this area to date. Acquiring new knowledge and expertise from abroad has also occurred in the domestic collaborative initiative, the National Hybrid Propulsion Platform (NHPP).

The NHPP consists of key players from various sectors in one industry, united under a common vision. Players involved in the NHPP have agreed to keep the IPRs on products and processes developed individually to themselves and to share IPRs developed together with the public after a certain amount of time (2-3 years). It can serve as a positive example for other countries (developing *and* developed) to adopt in the area of low carbon energy technologies (e.g. maybe each country can choose some 'national champion' technologies, based on their requirements, expertise and environment). However, this initiative is just beginning – collaborative RDD&D has helped this initiative, but it also has much potential to make further advancements, and so it could also benefit from further collaborative RDD&D in various ways. For example, governments or organizations can encourage further exchanges between experts from India and elsewhere, or augment the funds given to the NHPP from the Government of India. One of the goals of the NHPP is to have an Indian hybrid demonstration vehicle in time for the Commonwealth Games that New Delhi is hosting in 2010. Perhaps the Government of the United Kingdom could become more active in this process, either directly, or by providing incentives for British companies (e.g. Ricardo) to play a more active role. A promising area of international collaboration with respect to this technology would be particularly useful in demonstration and deployment phases, due to India's large market potential and with the country's carbon emissions from transport expected to grow substantially in the coming years.

iii. IGCC

Global efforts, including those in India, should turn to commercializing IGCC technology. Technology commercialization in developing countries is more likely when linked to technology developments occurring in industrialized nations. At the same time, research and development efforts remain crucial, especially when faced with the challenges of applying this technology using Indian high ash coal. One option would be for India to work with international partners to make the Pressurized Fluidized Bed Gasification (PFBG) system (e.g. KRW or U-gas), more suitable to their coal, based on the conclusions of studies done earlier by the Government of India, USAID, among others.

On the other hand, a more proven IGCC technology is the pressurized entrained bed gasifier (PEBG) system could be used in India, using imported coals that are better suited for that technology. The framework for decision makers we have proposed could be one manner in which policy makers could pursue a path forward – assessing the implications of pursuing either strategy, as well as the overall goal – trade offs between rapid deployment of the technology and building technological capacity. Finally, it is important to understand that policy makers charged with developing a strategy to address low carbon energy technology transfer must also take other factors into account, including energy security concerns. For instance, if India were to choose the PEBG route, would this imply that more coal would need to be imported? Or could they use coal that India was planning on importing anyway, originally to be used in sub-critical or supercritical power plants?

iv. Small and Medium Sized Enterprises (SMEs)

SMEs offer enormous potential to reduce CO2 emissions at low cost in India. SMEs in general do not have the financial or technical capacity to undertake research or adaptation activities to improve their energy and environmental performance. SMEs in developing countries therefore need to be identified (preferably a group of enterprises with a similar technological base and similar operating practices), before tailor-made RDD&D programmes are developed (which may be industry/cluster-specific) with support from multilateral/bilateral organizations.

One of the financial mechanisms available to promote low-carbon technologies under international climate change protocol is CDM (Clean Development Mechanism). However, high transaction costs act as a barrier in initiating small CDM projects in the SME sector. For CDM projects to be workable in the SME sector, there is a need to revisit the CDM implementation cycle, specifically the documentation and verification formalities. A simplified CDM project cycle for SMEs holds promise of reducing million of tonnes of GHG emissions in diverse SME sectors in developing countries.

v. Wind

In the wind sector, Indian companies, particularly those that have joint ventures with firms from industrialised countries, often engage in collaborative RDD&D with their overseas counterparts. Although most of these RDD&D collaborations focus on adapting a particular product to suit Indian conditions, there are a few examples where the collaborations have focused on development of new products (for example Suzlon's collaboration with an Austrian firm to develop large capacity induction generators given in the case-study).

Collaborative RDD&D is a win-win option for all partners. Through such collaborations Indian firms gain access to proven technology which is essential for maintaining their competitive edge in local markets, and the industrialised country partner gets access to Indian markets as well as the production facilities of their Indian counterpart. The issue of IPRs could also be addressed through such collaborative arrangements.

Annex 1

Case studies originally considered for the study

IPRs

These include those listed in the Steering Group and kick off meetings followed by those that were flagged up in the Bali workshop:

- LEDs
- Biomass
- Hybrid vehicles
- IGCC
- Underground coal gasification
- Wind turbines
- Biomass pellets
- Indian SMEs
- Industrial/power sector thermal technologies
- Building sector technologies e.g. insulators & advanced chillers
- Non-CFC / low global warming potential refrigerants
- Conversion of cellulose to glucose for fuel cells
- Solar PV

The following are Bali workshop outputs (together with contact details of people who suggested the case studies if provided – note that these are the views of participants and have not been corroborated by the project team):

Examples where IPRs HAVE been a barrier to technology transfer:

- GEF supported concentrated solar power plants have been very slow to develop in part because the price offered by the bidders was much higher than GEF expected. Maybe this is the cost of proprietary knowledge of the four manufacturers? Cedric.philibert@iea.org
- Possibly the transfer of catalytic converters
- Pharmaceuticals
- New advances in solar (recent activity in U. S. might incite change in the composition of solar capture)
- IT
- The Creative Commons licence used in the arts industry has been successful and may warrant investigation

Examples where IPRs HAVE NOT been a barrier to technology transfer:

- Free software
- Some life-saving drugs and HIV aids drugs have been exempted from IP protection
- Similarly some high yielding varieties of crops have been exempted from IP (Vivek Kumar, TERI).
- Solar powered LED products.
- Almost every technology that has been used in CDM projects
- The expansion of solar water heaters in China, often a model (evacuated tubes) originally developed by an Australian university. No patents were ever secured. cedric.philibert@iea.org
- Wide scale dissemination of PV home systems in many developing countries.
- The GEF projects for efficient industrial boilers (coal-fired) in China. The IP relative to manufacturing these boilers were bought by the GEF and given to three Chinese boilermakers. cedric.philibert@iea.org
- Waste water management.
- Renewable energy development.
- According to the ICTSD (John Barton) study they have not been a barrier to transfer of biomass, solar or wind to India, China and Brazil.

Other sectors worth looking at to understand IPRs and low carbon technology transfer:

- Agriculture, GM
- A recent World Bank study highlighted an initiative in the agriculture sector (CGIAR) that use local centres of expertise to develop and deploy improved strains of crops – deemed a success.
- Perhaps the multimedia industry and the problems it is facing.

RDD&D

The following are Bali workshop outputs where participants highlighted the sectors that they felt had potential to benefit from joint RDD&D:

- Halophytic biofuels.
- Distributed generation. There is a clear need for wider deployment (and probably developments) of technologies that allow power grids to support both large central and dispersed small-scale energy generation.
- Depends from where you come. Households (decentralised infrastructure) from a developing policy vein. Industry (production) coming from the other side of the economy.
- Second and third generation biofuels.
- CCS
- Agriculture.
- Water.
- Adaptation to climate change by engineering projects.
- IT sector has much to gain. Many firms operate in this sector without resources or know how to build effective IP portfolios.
- Sectors where very early emerging technologies, not well resourced, no clear pathway (Merylyn Hedger IDS)
- Public transportation.
- Remote sensing.
- Mixed fuel vehicles.
- Improvements on two-stroke engines.

Annex 2

Interview questions

General introductory questions

1. Can you tell us a little about your company (e.g. history, number of employees, nature of business)

2. Who are the key players in your industry? What is the market like in India and internationally?

3. What are the key policies/issues (international/national/regional/local) that affect your activities?

IPRs

Group 1: IP issues

1. In what way are IPRs relevant in the context of your business (e.g. do you own patents, do you license patents, or do you not use patents; what do patents relate to, hardware, software)?

2. How have you gained access to, or maintained protection of, relevant IP? Do you have concerns regarding the protection of your IP?

3. Have IPRs prohibited you from working with a certain technology / accessing certain hardware / software?

4. In what way have they been prohibitive and if not prohibitive, why?

5. If you have not had problems gaining access to IP, in what way have you benefited from the IP that you have been able to access?

6. Do you have access to cutting edge technology in your field?

Group 2: Policy

1. Is government doing anything to facilitate access to relevant IP?

2. What more could government do?

3. How does the Indian approach to IPRs work for you in relation to indigenous innovation?

4. How does the India patent office deal with access to foreign IP?

Group 3: Rounding up

1. Are there other barriers to you working with this technology (e.g. capacity/ technical ability to work with the technology).

Collaborative Research, Development, Demonstration & Deployment (RDD&D)

Group 1: Past and present

1. Are you, or have you been, involved in any collaborative initiatives? If so, in what way did you benefit? What challenges did you encounter?

2. What was the nature of your collaborative engagement with other parties (e.g. formal / informal [old college friend etc.], national/international)?

Group 2: Potential future

1. Are there any particular actors or organisations you would like to collaborate with and why?

2. What would you contribute to a collaboration (i.e. what would be the incentive for others to collaborate with you)? What would you expect others to contribute?

3. Are you aware of any other collaborations in your or other industries (even if you weren't involved)? Were they successful? Why / why not?

Group 3: Policy

1. How could government policy try to address any imbalance in Q4 in order to bring relevant actors to the table for a successful collaboration?

2. Is government doing anything to facilitate such collaborations? What more could government do?

RDD&D in relation to IP issues

1. Could collaborative RDD&D overcome IPR issues?

2. How would this be facilitated in relation to IP (type of arrangement, actors involved etc.)?

3. How would IP be shared under such an arrangement?

4. Do you think that technically advanced companies would collaborate under such an arrangement where IP was shared?

5. Should there be some way of making IP publicly owned via such collaborations?

6. Can you think of any other ways in which IP issues could be overcome (whether via RDD&D or some other means)?

Questions particularly for govt representatives, NGOs, trade associations

Group 1: Taxonomies or frameworks for decision making for low carbon technologies

1. Are you familiar with any decision making frameworks for low carbon technologies (international, national)?

2. If so, have you used any of them?

3. If not, why not?

4. If so, have they been useful or not?

Group 2: Other general questions

1. Are you aware of any initiatives that aim to increase technical capacity amongst Indian firms that are working with this specific technology (e.g. training, certification, university programs, etc.)?

Department of Energy and Climate Change. www.decc.gov.uk