Climate change and technology: perceptions from India

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The Global Climate Network is a collaboration of independent, influential and progressive research and policy organisations in countries key to tackling climate change. Together, members of the Network are committed to addressing the constraints faced by sovereign governments in agreeing international action.

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The Network will:

- Address the political (economic, social and cultural) constraints barring the way to action by bridging the divide between domestic and international policy
- Promote equitable solutions that take into account the huge development, financial and energy challenges countries face
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Each Network member has significant credibility and influence. By producing joint research, staging events together and seeking to influence policy, the Global Climate Network can help bridge the dangerous divide that exists and is currently widening between international negotiations and national politics.

The Network’s members are:

- **Institute of Public Policy for Research**, London, also acting as the secretariat for the Network: The UK’s leading progressive think tank with a strong track record on research and policy.
- **Center for American Progress**, USA: Founded by John Podesta, former Chief of Staff to President Clinton.
- **The Energy and Resources Institute**, India: Its Director-General is Dr Rajendra K Pachauri, Chairman of the UN’s Intergovernmental Panel on Climate Change (IPCC) and an adviser to the Indian government.
- **Research Centre for Sustainable Development**, China: An institute of the Chinese Academy of Social Sciences. Dr Jiahua Pan, its director, is one of 12 members of the Chinese Experts Committee for Climate Change.
- **Wuppertal Institute for Climate, Environment and Energy**, Germany. Wuppertal Institute’s ground-breaking climate change work is led by Dr Hermann Ott.
- **Vitae Civilis**, Brazil. Dr Rubens Born, Vitae Civilis’s Director, has had significant input into the government’s recent climate change plan.
- **International Centre for Energy, Environment and Development**, Nigeria. ICEED has expertise in climate change and energy policy.
- **The Climate Institute**, Australia. Set up in 2005, the Institute is a leading voice in climate research and advocacy, pioneering clean technology and investment solutions with government and business.
- **IMBEWU**, South Africa. An influential Johannesburg based legal consultancy specialising in climate change law, whose director is Andrew Gilder.

Dr Rajendra K Pachauri, Chairman of the Intergovernmental Panel on Climate Change, and Lord Chris Patten of Barnes, former European Commissioner for External Affairs, are the Network’s first patrons.
Executive Summary

This study attempts to understand the perception of different actors about clean/low carbon technology needs and barriers to their deployment and transfer in India. Technology transfer in the broad context of technological change is an extremely integrated process having a blend of science, policy, economics, etc., and hence it cannot be viewed in isolation. Therefore, in order to understand the intricacies involved in the process, we interviewed people with different area of expertise and experience. The study addresses three major themes: important technologies up to 2020; barriers to their development, transfer and diffusion; and lastly the kind of policy changes required to encourage transfer of low carbon technologies.

The study concludes that on the technological front the primary focus is on the energy sector. On the supply side of energy, clean coal technologies like supercritical and ultra-supercritical technology, integrated gasification combined cycle (IGCC) are important technologies till 2020. Regarding CCS (Carbon Capture and Sequestration) technology most of the respondents had reservations, similarly for nuclear, although it is an important technology for energy security but has a long way to go in terms of infrastructure, raw materials, safety, economics and other political issues. On the demand side, energy efficiency (EE) in the carbon intensive sectors emerged as the key at present. There is a need to invest in R&D and make current technologies more energy efficient. On the demand side of the energy, transport sector emerged as the primary sector that requires a specific policy intervention for technological change as it is suspected that this sector will show the highest energy demand amongst all the sectors over the next 30 years.

The study also suggests that the three most important barriers in transfer of environmentally sound technologies (ESTs) are (a) protection of intellectual property rights (IPRs); (b) high cost of technologies (transaction and implementation) and lack of financial resources; and (c) the lack of commercial viability of technologies given fluctuating market dynamics. Views about IPRs are, however, contrasting. While people in the private sector argue that strong IPR regimes tend to encourage innovative R&D, technology licensing and joint ventures, interviewees from the government consider that IPRs should not be given in principle as they prevent access to knowledge and information dissemination. Overall, the role of IPRs is contextual and it varies from one situation to another, therefore it needs to be thoroughly analysed, its influence and impacts need to be empirically studied and possible solutions need to be negotiated at the international platform, such that there are no losers in the technology transfer process.

Many key technologies have not yet penetrated the market and are susceptible to market fluctuations; hence, it is essential to have demonstration of these technologies to assess their commercial and technical viability. One of the significant findings of the study was that most of the interviewees noted that in India the technical capacity or expertise is at par with any other developed country in the world; however it is the institutional mechanisms for adoption and diffusion of these technologies and finance for innovative RD&D that are the basic limitations.

It is important to highlight that the technologies will not be automatically deployed. It will require a dedicated and effective policy and regulatory measures along with public finance. Technology financing is crucial for the whole paradigm of technological change. Financial assistance from the government, multilateral agencies, etc., has not been adequate. Hence the international negotiations must promote development of low carbon technologies in developing countries, by channelling finance, incentives and supporting R&D activities. Initiatives like a
focussed technology oriented agreement or global renewable energy target have to be discussed at the international platform, in case the mitigation goals cannot assist technology development and deployment. For development of ESTs, a global R&D initiative could be undertaken where technologies emerging from it can be disseminated without IPR protection and are treated as public goods.

Any technology we adopt today, the absolute emissions for a developing country like India will increase but with technological and policy intervention the emissions can be kept under control. However, there is no ‘one policy fits all’ approach for achieving this. Rather there is a need for integrated approach at international, national and local level, each of which should address the full range of key considerations.

**Recommendations**

- There is a need for undertaking a technology needs assessment (TNA) for every sector, and making available a compendium or a publicly accessible database of clean technologies.
- Demonstration of technologies along with R&D is very crucial to assess technological and commercial viability.
- The role of IPRs in prohibiting technology transfer needs to be thoroughly analysed and empirically studied as there is a lot of uncertainty about the impact of intellectual property protection on technology transfer. As the role of IPRs is contextual and varies from one technology to another.
- Technology financing is crucial for the whole paradigm of technological change. Financial assistance from the government, multilateral agencies, etc., has not been adequate. Hence, the international negotiations must look to support development of low carbon technologies in developing countries, by channelling finance, incentives and supporting R&D activities. Developed countries have to take the lead and make the technologies along with the finance available to the developing countries for development, deployment and diffusion of technologies.
- A global R&D regime could be fostered for development of ESTs, where technologies emerging from it can be disseminated without protection of IPRs.
- There is a need for global comparative analysis to understand the country specific barriers to technology transfer as opposed to generic.
- Initiatives such as a focussed technology oriented agreement or global renewable energy target have to be discussed on the international platform, in case the mitigation goals cannot assist technology development and deployment.
- Domestic policies for promoting low carbon technologies have to be strengthened in the form of more publicly funded research, having low carbon technology procurement targets, creating markets for clean technologies, etc. These initiatives must further be complimented and supported by the international policy regime.
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1 Introduction

A wide range of literature has been produced since the UNFCCC became operational highlighting the need for development, deployment and transfer of environment friendly technologies in order to address climate change. For mitigating and adapting to climate change and achieving sustainable development, energy efficient and clean technologies are considered by all actors, including government, industry, NGOs and researchers, to hold the key. Despite such a wide agreement and efforts to promote efficient and clean technologies at national and international levels, inadequate progress has also been recognized by many. In addition, technology also remains one of the most contentious issues between developed and developing countries in the climate change negotiations.

The Energy and Resources Institute (TERI) undertook this study to understand the perception of different actors about clean/low carbon technology needs and barriers to their deployment and transfer in India as a part of the Global Climate Network (GCN) study ‘Breaking through technology: overcoming the barriers to the development and deployment of low carbon technology’ funded by DFID and GTZ. Similar studies have been carried out by other member organizations of GCN in China, South Africa, Brazil, the United States of America, the United Kingdom, Australia, Nigeria, Malaysia and Germany.

Overall, this study aims to:
- Identify the low carbon technologies and sectors that policy and decision-makers in India believe should be prioritized along with the purpose behind such a prioritization,
- Identify the barriers that exist to the development, transfer and wide diffusion of these/comparable technologies,
- Set out the perception of policy makers about the barriers to the development and ‘transfer’ of technology, and
- Identify possible developments of national and international policies and approaches that might help illuminate the technology development and transfer negotiations.

2 Methodology

For this study, semi-structured questionnaire based interviews with policy-makers, industry, researchers and civil society were conducted. In order to determine the scope of interview with each interviewee focused literature review was done.

2.1 Literature Review and Questionnaire Formulation

In order to make these interviews more tangible for policy considerations, a literature survey was carried out to (a) identify the important sectors and technologies which are considered important for addressing climate change in India, (b) existing barriers to deployment and transfer of these technologies, and (c) the domestic policy response to promote efficient and clean technologies. After conducting literature review a check list of questions for each interviewee was prepared. In addition, the discussions among the colleagues from the GCN member institutes were also taken into consideration. The interviews were built around technology
needs, availability and accessibility of technology, status of technology transfer, types of barriers in transfer and deployment of these technologies, role of different stakeholders in policy making, adequacy of domestic policies and institutional framework, market for ESTs, and role of carbon markets.

2.2 Interviews
On the basis of findings from the literature survey, a set of interviewees from different ministries and industries were identified to ensure that most of the issues raised in the literature are adequately covered. All interviewees were asked a set of similar questions along with the particular questions pertaining to their concerned sector/technology. Average duration of the interview was approximately 45–50 minutes. However, this varied from person to person.

Besides interviews of different actors and literature review, the opinions expressed by representatives from the Indian government and industry during various sessions of the Delhi Sustainable Development Summit 2009 (organized by TERI from 5–7 February 2009, at the Ashoka Hotel, New Delhi) have also been used for the analysis presented in this study.

After taking into consideration the views expressed by those interviewed, TERI decided against quoting any interviewed individual, for some of them had expressed reservations in this regard.

3. Review of literature on India

3.1 Key sectors for addressing Climate Change
India is the second most populous country in the world, and one of the fastest developing economies. Expanding population and gradual transition in the economic and social setting has led to increased energy consumption and carbon emissions (Jung, Srinivasan, Tamura, et al. 2005; Tamura 2006). A large part of the growth in future global energy demand, and consequently the GHGs emissions, is expected to originate in the developing countries (Chandler, Schaeffer, Dadi, et al. 2002; IEA 2008). After increasing steadily for at least two decades, India’s carbon intensities(from power and energy sector) began to decline rapidly after 1995, due to increased share of service sector in the GDP and energy efficiency improvements (Jung, Srinivasan, Tamura, et al. 2005). Although this looks like a positive start, there is still a huge potential for improvement.

Power sector receives top priority in literature when it comes to climate strategies in India. GHGs emissions in power generation have grown at 5.6% per year during 1994 and 2006, increasing from little over 300 MT CO\textsubscript{2} in 1994 to over 600 MT CO\textsubscript{2} in 2006, while other industries like iron steel and refinery are still below 100 MT CO\textsubscript{2} emissions.\footnote{http://moef.nic.in/downloads/others/Preparing%20GHG_Sumana%20Bhattacharya1.pdf} Keeping the CO\textsubscript{2} emissions low, while meeting growing demand for power has been identified as a major challenge for India. In this context, coal is extremely important for Indian economy for its dependence on coal to meet its power requirements, is substantial. India is the third largest producer of coal and can meet 52% of its coal demand. This dependence on coal is likely to continue in the future with an estimated doubling of domestic coal production and increasing coal imports in the next 30 years (Murthy, Panda and Parikh 2000; Jung, Srinivasan, Tamura, et al. 2005; TERI 2006). Given that India has just 0.8% of the world’s known oil and natural gas resources (Jung, Srinivasan, Tamura, et
al. 2005) and the World Energy Outlook projects that India’s dependence on oil imports will grow to 91.6% by the year 2020 (IEA, 2004), coal is even more likely to remain the mainstay in India from energy security point of view.

Transport sector has been identified in many studies as another key sector for intervention in India in order to address climate change. According to a TERI study India’s transport sector is predicted to show the highest growth in energy demand amongst any sector over the next 30 years (TERI 2006). With a developing economy and increased standards of living, there has been a rapid increase in the vehicles on road and hence the carbon emissions. Thus transport sector represents one of the key sectors for climate change mitigation.

As access to commercial energy is low, the country depends heavily on biomass for its energy needs. The inefficient use of biomass is both an energy security issue and a climate change concern (Jung, Srinivasan, Tamura, et al. 2005; and TERI 2006). According to UNDP’s World Energy Assessment 2000, the biomass technical potential in ‘developing Asia’ in 2000 was between 311 and 502 MTOE, which is 5%–6% of the world’s total. This figure is likely to be much higher as the availability of agriculture residue in India alone is 539 MT, as estimated by the Ministry of New and Renewable Energy. Forestry wastes such as twigs and bark have not been counted in this estimate. (UNDP 2000). It is likely therefore that the rural India will use biomass for its energy needs due to its easy and cheap availability. According to Lovett, Quinn, Ockwell, et al. (2006) the traditional indigenous practices have been eroded which ensured that the biomass, once released during burning, may subsequently be sequestered by other woody biomass. Therefore, access to modern energy in rural India as well as efficient ways of utilizing biomass energy receive a considerable attention in literature.

Other sectors that find regular mention in literature on India are buildings and industry. It is argued that enhancement of energy efficiency measures in these sectors offer a substantial potential for mitigating climate change.

3.2 Key technologies

One of the most effective means of mitigating carbon emissions from these key sectors identified in literature is to facilitate, development, deployment and transfer of low carbon technologies (Tamura 2006; Ockwell, Watson, MacKerron, et al. 2008; Luken, Rompaey and Zigova 2008; Luken & Rompaey 2008; Worrell, Berkel, Menkem et al. 2001)). It has been argued that development is key priority for India and clean technologies can help it in climbing the development ladder in clean and sustainable manner. Thus, it is imperative to understand the key factors influencing technology development, transfer and diffusion in the context of development and its effect on climate change. According to Ockwell, Watson, MacKerron, et al. 2008, one of the most important approaches to technology paradigm is the adoption and adaptation of low carbon technologies, which has two important aspects: the development of new innovative capacity and the diffusion of new technologies in the market (Ockwell, Watson, MacKerron, et al. 2007; Ockwell, Watson, MacKerron, et al. 2008). A World Bank study reports that most developing countries lack the ability to generate innovations at the technological frontier, and consequently, technological progress in developing country like India occurs through the adoption and adaptation of pre-existing but new-to-the-market or new-to-the-firm technologies (World Bank 2008). In other words, technology transfer has been a key solution suggested in the literature. However, Ockwell, Watson, MacKerron, et al. 2008, also argue that effective technology transfer must
facilitate a broader process of technological change and capacity building within developing countries (Ockwell, Watson, MacKerron, et al. 2008).

In terms of key technologies, there is an explicit emphasis in literature on clean coal technologies such as supercritical, ultra-supercritical technologies and IGCC, as far as building domestic technological capability is concerned. On the demand side of energy efficiency, transport and building sectors have been singled out as having the substantial potential for energy savings, and thus avoided emissions.

Among the renewable energy sources, solar power has been seen as one of the most important sources of clean power generation in the country. Its significance is manifested by the fact that the National Action Plan on Climate Change has ‘solar mission’ as one of the eight missions to address climate change in India. Among the domestically available technologies, a clear preference emerges in favour of small hydro power plants. India is fast becoming one of the pioneers in manufacture of technology used for exploiting wind as a source of electricity, e.g., Suzlon is the fifth largest company in the wind sector worldwide. India has a huge potential of becoming the leader in use of wind as source of power.

Among other options bio-fuels and hydrogen energy are also being explored as the potential clean energy source to substitute liquid fossil fuels, especially in the automobile sector as this can also help reduce the dependence of the country on imported liquid fossil fuels (MNRE 2008). However, the current technologies for bio-fuels are subject to controversy due to food vs. fuel debate and the second generation technologies which offer substantial potential for fossil-fuel substitution are not yet mature and commercially viable. The technologies for use of hydrogen as a source of power generation or in automobiles are still under research and are yet to undergo demonstration and commercialization (MNRE 2008). Besides, nuclear energy is also seen as a potential source of clean energy in the future. But at present there are some reservation regarding nuclear. It is an important technology for the future energy security but has a long way to go in terms of infrastructure, raw materials, safety, economics and other political issues.

3.3 Policy measures

The Planning Commission, Government of India has proposed through its ‘Vision 2020’, the strategic goal of transforming India into a developed nation and a knowledge economy by the year 2020 (Planning Commission 2007a, b). However, it has a bent towards defence, space, atomic energy, etc. Thus, there is little finance available for other important sectors and there is a need to mobilize more funds for other sectors to achieve the overall goal of ‘Vision 2020’. The Government of India, in its Tenth Five-year Plan (2002–07) has emphasized the strengthening of application-oriented research and development (R&D) for technology generation; technology commercialization; and technology transfer from academic and research organizations to industry (Planning Commission 2002). This is complimented by indirect incentives to promote industrial R&D by private sector, particularly investment in R&D in the renewable energy and energy efficiency. Many policies and regulations have been introduced towards this end. However, it is important to note that the emphasis on development and deployment of energy efficient and renewable energy technologies is primarily driven by the concerns relating to energy security (energy conservation and diversification of energy sources to protect against the depleting fossil fuel resources and higher dependence on import of oil) rather than climate change. A cleaner environment is seen as a co-benefit instead of main objective of these policies. Overall, power, transport, buildings, and manufacturing are the key sectors that have been identified to promote
energy efficiency and renewable energy. As far as technologies are concerned, IGCC, supercritical and ultra-supercritical technology, fuel-cells, energy efficient buildings and building components, electric vehicles (EVs), hybrid electric vehicles (HEVs), mass transport systems, solar thermal and solar PV, bio-fuel technologies (particularly the second generation biofuel technologies), small hydro power and wind power along with nuclear power are among the most discussed technology.

**Relevant policies, programmes and institutions**

The following are some of the policy initiatives taken by Government of India which have positive implications for environment friendly technologies.

- **National Action Plan for Climate Change** has a focus on eight missions, of which national Solar Mission aims to have a substantial increase in the share of solar energy in the energy mix. Enhancing energy efficiency has also been identified as a key component of the national strategy to combat climate change.(GOI 2008)

- Regulatory measures such as Energy Conservation Act (2001), Electricity Act (2003) and the establishment of the Bureau of Energy Efficiency (BEE) which has introduced energy standards, labelling of equipment/appliances, energy codes for buildings and energy audits.

- **Science and Technology Policy 2003.** One of the most important mandates of the policy is technology development, transfer and diffusion (DST 2003)

- **National Electricity Policy 2005** emphasizes on decentralized power generation and distribution and subsequently identifies renewable energy and energy efficient distribution systems as the key interventions.

- **National electricity Act 2003** encourages and stimulates the market of non-conventional energy resources/renewable and promotes cogeneration. This Act provided a huge boost to the renewable industry.

- **Energy Conservation Act 2001 (52 of 2001)** provides for the legal framework, institutional arrangement and a regulatory mechanism at the Central and State level to embark upon energy efficiency drive in the country.


- **National Research Development Corporation** has the objective of developing, promoting and transferring technologies originating from various national R&D institutions (DSIR 2007).

- **Technology Promotion Development and Utilization Programme (TPDU)** is an initiative of Ministry of Science and Technology (MoST) to promote development, deployment and diffusion of efficient and ESTs (DSIR 2009)

- **Technology Development Board** aims at accelerating the development and commercialisation of indigenous technology or adapting imported technology to wider domestic application. The board provides financial assistance in the form of equity, soft loans, or grants.

- **Technology Information, Forecasting and Assessment Council (TIFAC)** was set up in 1988 under the Department of Science and Technology. It is an autonomous organisation with a mandate to look into the future of technologies, assess the technology trajectories, and support technology innovation by network actions in select technology areas of national importance.

- **Solar photovoltaic Programme and Solar Energy Programme** to promote solar energy (MNRE 2008).
- The Biomass Power Programme aims at utilization of a variety of biomass materials through adoption of conversion technologies like combustion, pyrolysis, gasification, etc. The country now has more than 700 MW of capacity based on these technologies.
- The Biomass Energy and Co-generation (Non-Bagasse) in Industry promotes utilization of biomass (non-bagasse) for the generation of heat energy/power, to be used for captive requirement of industries.
- Under the Biomass Gasifier Programme, installation of latest versions of biomass gasification technology has lead to increased biogas generation and energy efficiency. (MNRE 2008)
- The Accelerated program for promotion of projects for Energy Recovery from Urban Wastes proposes attractive incentives in the form of capital subsidy to make urban waste-to-energy projects financially viable and remunerative to promote the adoption of state-of-the-art technologies higher financial assistance available for setting up of demonstration projects.
- The Indian renewable energy development agency (IREDA) has been established to promote, develop and extend financial assistance for renewable energy and energy efficiency/conservation projects with the motto: ‘Energy Forever’. (IREDA1987)
- The Bureau of Energy Efficiency (BEE) was established in 2005 under the Energy Conservation Act, 2001. Its objective is to promote energy efficiency practices among end-users, particularly in the manufacturing and building sectors. The BEE (Bureau of Energy Efficiency) is developing various standards such as building codes, incentive, training and awareness programmes to promote and facilitate deeper penetration of energy efficient technologies and practices. (BEE 2008)
- Through the Ultra Mega Power Plant Project, for all coal fired ultra-mega power plants (more than 4000 MW capacity) in India, use of supercritical technology has been made mandatory.

4 Summary of the key findings

Among the major themes that emerged from the interviews in the context of climate change and development, deployment and transfer of technology are the significance of energy sector, end-use energy efficiency, limitations of market, costs and availability of finance, IPR related issues, public behaviour, and role of national government and importance of international support. Major findings are summarized below.

4.1 Key sectors

In what key sectors are clean/low carbon innovation and technology development and deployment envisaged?
- All the interviewees consider the energy sector as the single largest sector which has immense need and potential for technological transformation in order to address climate change. This is not only in the context of need for development of new and advanced technologies, including renewable energy option, but also in terms of deployment and transfer of existing technologies domestically as well as internationally.
- Other sectors that are considered important, also have a clear link and bearing upon energy sector. These include power, transport, buildings, and manufacturing sectors. Some investors suggested that making these sectors energy efficient will reduce the actual demand for energy and subsequently the reduced need for capacity enhancement might allow the investors to opt for more efficient supply side technologies despite their high upfront costs.

- The power sector emerged as the foremost sector with the potential for technological change. Interviewee from the government suggested that use of technologies like Smart Grid which delivers electricity from suppliers to consumers using digital technology to save energy; reduces cost and increase reliability; helps in energy accounting, and thereby tailors production to the consumption process can be an important step in increasing the efficiency of the power transmission and distribution. Further, it was suggested that demand side management can help in reducing the pressure on the power plants.

- Transport sector, however, is considered to be given a special attention for any intervention. As it is likely to have serious implications not only for the energy supply sector (largely oil sector, a substantial part of it is met through imports) but also for manufacturing sector. For instance, if transport sector observes a shift away from oil driven vehicles to battery operated vehicles, it would put pressure on power sector as well as require adjustments in manufacturing of vehicles. Moreover, transport is a vital service for the overall developmental process.

- Most importantly, it was highlighted that the informal sector is largely inefficient and needs to be paid special attention. However, it was also noted that due to its scattered nature it is difficult to encourage and monitor energy efficient practices in this sector. The technological challenges in this sector are not related to transfer of technology or availability of finance, rather it is the lack of awareness and adequate policy and regulations which limits the scope of energy efficiency enhancement in this sector.

- The small and medium enterprises (SMEs) are identified as a key entry point for promoting energy efficiency measures. It was suggested that SMEs are relatively better organized and placed in the market as well as governance networks, therefore it will be easy to encourage them for taking up energy efficiency measures.

4.2 Important technologies
Which are the new and already developed technologies that are most important between now and 2020?

- Even though all interviewees noted the significance of renewable energy, it was stressed that for next 20–30 years their contribution to the energy supply might not be adequate. Although RET's have a significant potential in mitigating climate change but at present there are constraints associated with them like cost effectiveness, lack of commercial viability and relatively smaller scale of production as compared to energy demands.

- Subsequently, the deployment of energy efficient technologies, both, in energy supply sector as well as demand sector, is seen as the key in addressing climate change. Among the supply side technologies clean coal technologies (supercritical and ultra-supercritical technology; integrated gasification combined cycle or IGCC, fluidized combustion bed cycle) along with smart grid technology in power transmission and distribution are considered to be the most critical technologies. At present most of the power plants in India use sub-critical technology, however interviewees noted that there is a need
for using super critical and ultra-super critical technology, further IGCC is considered as a futuristic technology as it is still in demonstration phase in India. On the demand side energy efficient buildings, mass transport systems, efficient vehicles and home appliances are considered critical.

- Amongst the renewable energy options for immediate action hydro (small and mini hydro) power plants and first generation biofuels stand out as important technologies. From a futuristic point of view solar energy (PV and thermal) and second generation biofuels are considered among the most important sources of clean power generation in the country which have huge potential and are identified as key areas for intensive R&D. India is also fast becoming a leader in biomass and bagasse cogeneration technology, with the government having a target for addition of 1700 MW capacity, consisting of 500 MW of biomass power projects and 1200 MW of bagasse cogeneration projects up to 2012. Wind is also seen as a key source of energy particularly when India is fast becoming one of the pioneers in manufacture of wind technology.

- In this context the role of ‘soft technologies’ relating to organisation of production and consumption processes was also highlighted by a few interviewees. For instance, a mass consumption of transport services through mass-transport systems, or mass consumption of housing services through energy efficient buildings can save a lot of energy. The role of public behaviour, as soft technology, particularly in organisational set-up was also emphasised.

- From GHG mitigation point of view, on the CCS technology even though its immediate usefulness as an idea was recognised, some interviewees expressed security and cost concerns with CCS explaining the cautious approach adopted by the Indian government on CCS. One participant even questioned whether it would even serve as a barrier to the development of more efficient technologies.

4.3 Barriers

What are the barriers to innovation and deployment of existing and emerging new technologies?

Among the barriers to technology development, deployment and transfer in the context of climate change, market failure and inadequate efforts to correct the markets at national as well as international level, lack of financial resources and the absence of awareness and sense of urgency to address climate change have been almost unanimously identified as major hurdles. Other constraints, which saw differences in the opinion, include IPR, technological capability to develop and produce technologies domestically, bureaucratic hurdles, inadequate human and institutional capabilities, commercial viability of renewable energy, etc.

Market failure

Most of the interviewees were of the opinion that the inadequate level of development and deployment of environmentally sound technologies (ESTs) is due to market failure in the form of imperfect information about technologies, their actual long term costs, non-rational prices of environment un-friendly technologies. Most believed that if the users are well aware of the long term cost effectiveness of energy efficient technologies they would be willing to invest in these technologies. However, high initial costs can still function as barriers to their deployment. It was also pointed out that the high initial costs are not real barriers in some cases. Instead, they are the manifestations of the irrational prices of inefficient technologies and most often they do not incorporate the negative externality of these technologies. In this context, it was highlighted that most of the
fossil fuel based activities are highly subsidized which makes them economically attractive as compared to clean and efficient technologies. If the subsidies are rationalised, many of the efficient technologies would be more attractive. This of course requires that adequate information about these technologies is available freely to the end-users.

In general, limited size of the market for energy efficient products and renewable energy is seen as a result of market imperfection. The issue of IPR too is seen by few in this context. The fact that some of the technologies which offer great potential for energy saving as well as GHG reductions are protected by IPRs and ‘few multinational companies have created a monopolistic market in these technologies.’ This has, in fact raised not only the cost of deployment but also the cost of transfer to developing countries.

*Lack of financial resources*

On the issue of financial requirements and lack of adequate availability of finance for renewable energy and energy efficiency technologies, there is a firm consensus among all stakeholders in the country. High absolute costs of these projects make it necessary that adequate financial resources are available at a reasonable cost so that industry is willing to take the high investment risks.

The industry representatives expect more support from government in the form of soft loans and infrastructure provisions along with other concessions such as tax holidays/incentives, procurement policies to create a definite market, minimum purchase prices, etc. In the context of renewable energy projects, some of the respondents from industry side pointed out that the Indian government provided support only in the form of subsidies and marginal grants, but there are no appropriate provisions for project financing. The policy makers, even though agree with the demands of industry, point out that there are limitations on the capability of governments to provide financial assistance to industry. The major constraints for governments are the other developmental concerns which largely depend on public expenditure. It was also highlighted that even though the multilateral funding agencies have provided credit lines, they are not adequate.

All the interviewees also stressed the moral responsibility of developed countries to provide financial assistance either in the form of grant or technology at concessional prices, particularly to the effect that it compensates for the IPRs induced costs. On the market based mechanism, the interviewees had a positive opinion but also pointed out at its limited impact in the absence of other national or international support, particularly the Clean Development Mechanism (CDM). While for industry the market based mechanisms are important for their financial implications, for the policy makers the significance of market based mechanisms is much larger in that they encourage the private sector participation.

*Intellectual Property Rights*

The issue of IPRs (Intellectual Property Rights) is identified as a major barrier to Climate Change Technology Transfer (CCTT). However, its implications are perceived differently by the industry and policy makers. While for industry the IPRs induced costs are like any other costs associated with entrepreneurial activity, policy makers assign it much greater importance. For industry, IPRs have only cost implications and it does not make much difference if Indian government pays for the additional cost or the government of the country of the origin of technology. On the other hand, for policy makers IPRs constitute not only financial burden but also a hurdle in technological capability building process as IPRs prohibit flow and
access of necessary knowledge. Thus for industry, IPRs are a concern only in the context of commercial technology transfer while for policy makers and researchers alike, it is an issue relating to domestic technological capability building.

Some of the respondents were of the opinion that the IPRs are important to promote innovation in the field of clean technologies therefore doing away with IPRs may not be an appropriate solution. However, given the global importance of diffusion and deployment of technology transfer, the rich countries should make these technologies available for the developing and poor countries at reduced prices. Nonetheless, there was a broad consensus among the interviewees that few technologies, which have large potential for climate change mitigation, are owned by a very few number of foreign companies via IPRs, which is a cause of high costs as well as hindrance to domestic technological capability building.

**Domestic technological capability**

Domestic technological capability building is an issue on which the divergence between the industry and policymakers is most explicit. For industry, commercial technological transfer is most important while for government it is the overall technological advancement of the country that has a clear priority. While some of the industry representatives were of the opinion that barring few exceptions, many efficient technologies are domestically available which are at par with those owned by developed countries, e.g., wind and solar technologies. Therefore, in India the government policies have an important role to play. However, they also underlined the constraints that governments face in terms of financial resources and supported a larger amount of financial support from developed countries. On the issue of R&D, both industry as well as policy makers were of the opinion that there is a need to step up private sector R&D for climate friendly technologies with an adequate support from the public sector. Public–private partnership thus is a predominant solution.

However, in order to develop domestic technological capability, the respondents had a mixed opinion in terms of adequate infrastructure (institutional, educational, policy etc.) and human resources. While some thought that India has enough human resources as well as institutional capability to enhance its technological trajectory, others pointed out at the constraints particularly relating to the path dependent nature of technological learning curve along with financial constraints, e.g., smart grid in power distribution and transmission, which can save the power loss up to 30%–40% is likely to take some time for implementation in India due to same reasons. Some also pointed out poor and inadequate facilities for research and development and laboratories that are not well equipped with the necessary equipment and resources as a major constraint in technology innovation and diffusion.

**Commercial viability of renewable energy and issue of subsidies**

In India most of the money is invested in technology development is for fossil fuels, e.g., for exploring new extraction sites/new technologies/methods for extraction, etc. Fossil fuels or high carbon content fuel such as kerosene are heavily subsidised and most of the interviewees identified this as a negative subsidy and thus a huge constraint in promoting clean energy options like the renewables. It was argued, primarily by the industry and some of the researchers, that the absence of these negative subsidies along with marginal subsidies to renewable energy options would make renewable energy an attractive and commercially viable option. The
policy makers along with some researchers, however, pointed out that given the
time lag involved in potential exploitation of renewable energy options, removal of
subsidies on fossil fuels would have negative impacts on developmental objectives.
Thus the issue of subsidy acts as a huge dilemma for the government.

On the issue of commercial viability, all the respondents agreed on the long
term viability of ESTs. However, they underlined the fact that in the absence of
adequate demonstration of these technologies, the perceived risks associated with
these technologies, along with their high initial costs prevent the investors to come
forward. In this context, the role of government was considered to be important
for undertaking demonstration projects to boost confidence of the investors in new
technologies.

Bureaucratic hurdles
People from the private sector expressed that lengthy procedures for registration
and sanction of a project are the huge constraint in the renewable energy sector.
For example, in the wind energy sector, although India has a huge potential for
offshore electricity production, but getting ‘approval is a nightmare’. Second, there
is lack of political will, the issue of clean technologies and sustainable development
is not yet key into the decision making circle and is not given its due importance
considering climate change is no longer an impending reality. Bureaucratic hurdles
in allocation of resources such as land, water, providing for import duties, tariffs,
etc., and lack of infrastructure are recognised as two important constraints diffusion
and deployment of ESTs.

Lack of awareness
Many of the interviewees, particularly the policy makers, researchers and
industry association representatives felt that even though the commercially viable
technologies and adequate financial resources are available in certain cases, there is
a visible lack of knowledge about these options in the industry. This is particularly
true in the context of (SMEs). They attributed the unorganised nature of the SMEs
sector to be a major cause of lesser penetration of available technologies which
cannot only address the climate concerns but also productivity enhancement.

Role of private sector
There is a conflicting viewpoint on the role of private sector. Most of the low
carbon technologies are in the domain of the private sector and some argued that
the role of the private sector in propagating and diffusing these technologies is still
not clear, as they have not taken the necessary actions to promote and diffuse these
technologies. Although CDM has stimulated the private sector to venture into the
low carbon market, their contribution is still questioned by some. It was argued
that in such a scenario the role of public–private partnerships become important
as it can help overcome the barriers that hinder the diffusion and deployment of
clean technologies.

4.4 Policy suggestions
What are the domestic and international policy changes required to accelerate
development, diffusion and deployment of existing and new technologies?

The interviews conducted reflected the need for the following kind of policy
initiatives.
4.4.1 Domestic policy changes

Market correction
Market based instruments play a very important role in determining the market behaviour. In India low carbon markets are on an upswing, and there is a huge potential that RE sector offers for GHGs emission reductions but a project should be commercially viable in order to be economically sustainable for a long period. For instance, CDM which is a market based instrument for reducing GHG emissions and mitigating climate change, has not been effective in facilitating transfer of technologies. Some identified CDM more as a market mechanism whose focus has been shifted from mitigating climate change. Although CDM has incentivized the industry to look at clean technology because of availability of carbon finance, the growing perception is that the current CDM needs to be reformed. It was suggested that CDM benefits can also be used for technology development.

Market based mechanisms have created a marked shift in the implementation of RE, EE and fuel switching technologies in different sectors. However, some of the interviewees reflected that market has failed to provide any answer to the climate crisis primarily due to frequent and unpredictable price fluctuations in the carbon market. Thus, expressing a need for an effective price signalling mechanism. If the price mechanisms are not effective then there is need to go for regulations. Thus a combination of price signalling and regulations can lead to an effective market regime.

Need for a renewable energy policy
Although India has an Energy Policy (2006), some interviewees expressed the need to have a policy that has an exclusive focus on renewable energy and is not a supplement to the already existing energy options. Similarly, policies concerning energy efficiency are enough, but to increase the use of renewable energy technologies there is a need for a shift in the policy framework. Considering the technology vision 2025, which has a strong emphasis of increasing the share of renewable in the energy mix it is imperative to have a focussed action on this front. However, there was a difference of opinion regarding this, where some interviewees argued that an integrated energy policy would be a better choice in terms of policy implementation as compared to formulating a separate renewable energy policy.

Enabling environment
Many interviewees expressed the need for policies that provide with enabling environment. For example, some state governments have introduced the policy of reimbursing the cost of power evacuation produced from wind, which is a huge incentive and has made the state of Maharashtra become the top choice of investors in the wind energy sector.

Second, some of the respondents suggested that government should provide the basic infrastructure for technology development like electricity, land, water, etc., for testing and demonstration of these technologies.

 Tradable Renewable Energy Certificates
It was suggested that transforming renewable energy certificates (RECs) to tradable RECs will make them more attractive in the carbon market. In India there are talks of introducing tradable RECs amongst the state governments, if such an initiative gathers momentum, the market will become more conducive for RE sector.
Fiscal incentives

It was strongly recommended, particularly by industry, that strengthening the current fiscal incentives like sales tax benefits, income tax benefits, depreciation benefits, tax holidays, etc., is vital for attracting more investment that can boost development, deployment and transfer of ESTs. One of the interviewees gave the example of production tax credit (PTC) which has acted as a critical tax incentive for promoting the development of renewable energy and energy efficiency in the US and hence suggested that if a variant of PTC is introduced in India, it may help in changing the market dynamics.

Levelized tariffs

The major hurdle in promoting renewable energy technologies is the higher cost of production which influences the energy prices and subsequently the commercial viability of renewable energy projects. It was recommended that if the tariffs for energy generated through renewable energy sources are brought to the level of non-renewable energy sources by means of feed-in-tariff or other subsidies, it would make renewable energy attractive to the consumers. For example, currently power generation from solar is expensive so until price equalling is done and producing power from solar is made equivalent to conventional power sources, the traditional power choices will be the mainstay. However, in the coming decades the economies of scale will kick in and gradually the conventional sources of power will become scarce and costly, while RE will become cheaper and will and more economically viable. Similarly, the technologies in the power sector like IGCC and super critical are still in the initial phase of demonstration and implementation in India and there is need for government initiatives that can make these technologies cheaper and conducive to the Indian economic conditions.

Technology needs assessment

Most of the interviewees identified conducting a technology needs assessment (TNA) as a crucial step in overall process of technological change and development. The government needs to come forward with a mandatory technology needs assessment and conduct mapping exercises regarding the kind of technologies that are available for every sector, the needs and technology best suited to these needs and thereby making a compendium or a database available in the public domain.

Government procurement

For promoting renewable energy, the industry strongly recommended government procurement policies to create a minimum secured market to encourage the investors. It was pointed out that even though the government of India has such policies in place, they are far from the required incentive and support.

Demonstration and diffusion of technologies

Many interviewees expressed that research in ESTs should be complemented with RDD&D (research, development, demonstration and diffusion). Technologies that develop should be robust to become commercial, hence it is crucial to provide necessary infrastructure for the demonstration and testing of the technologies before they come to the market. Further such research development and deployment activities should be publically funded, so that investors can test these technologies in the market without fear of market failure.
Increase training and knowledge sharing

Training and knowledge sharing is important for technology diffusion, thus technology transfer should not be limited to instrument transfer only but also include knowledge transfer. Some interviewees expressed a need for having international collaboration for knowledge sharing and capacity building. Further one of the respondents suggested that there is need for doing knowledge management, wherein all the available and required technologies are documented and made available in the public domain.

4.4.2 International policy changes

Specific funds at UNFCCC level

At the UNFCCC level there is need for technology development focused agreement. For funds there should be a board on the same lines as Adaptation Fund board and it should have all the legal authorities and power that other boards under the UNFCCC have. Further monitoring and issuing authority for this board should be same. Some of the interviews expressed a need for a global financing mechanism for funding innovative research and the product of that research should be actively disseminated.

Promotion of R&D and public-private partnerships

Many interviewees suggested that investment in clean technology research should be promoted by providing necessary grants and aids. There is a need to have extensive publically funded research, involving institutes like IITs (Indian Institutes of Technology) and providing them the required resources and infrastructure for they have the technical know-how. Some interviewees also argued that considering that private sector is not coming forward on its own at a required level, it is important that public sector support is provided to them. Therefore, there is a need to strengthen public-private partnerships to encourage technological innovation and development of technologies.

Intellectual Property Rights

Most of the interviewees identified IPRs as a major constraint in technology transfer, and thus suggested that IPRs should not be there in principle as they hinder dissemination of knowledge and technologies. Therefore, some flexibility in trade regime is required at the international level. In case that is not politically feasible then the developed countries should compensate for the IPR costs associated with technology transfer. At the commercial level IPRs are perceived largely as ‘a cost component’. Therefore, some of the interviewees mentioned that IPR related costs should be met by governments or through intergovernmental agreements or it may be done through an international technology fund.

Carbon tax

Some of the interviewees stressed on the introduction of a regulatory regime like a carbon tax, based on the polluter pays principle. This tax should be reflective of the negative externality from industrial or production processes.

 Tradable renewable energy production target

Few respondents also suggested that along the lines of emission reduction targets, renewable energy production targets should be assigned for countries. These
targets can be made tradable to introduce flexibility. This would ensure a certain global market size for renewable energy technologies and would enhance the R&D efforts to make them cost effective.

5. Conclusion

Technology transfer in the broad context of technological change is an extremely integrated process having a blend of science, policy, economics, etc., and hence it cannot be viewed in isolation. Therefore, in order to understand the intricacies involved in the process, the interviews conducted involved people with different area of expertise. The study addresses three major themes: important technologies up to 2020; barriers to their development, transfer and diffusion; lastly the kind of policy changes required to encourage transfer of low carbon technologies. Following are the conclusion and recommendations emerging from this study.

On the technological front the primary focus is on the energy sector. On the supply side of energy, clean coal technologies like supercritical and ultra-supercritical technology, IGCC are important technologies till 2020. Regarding CCS most of the respondents had reservations, similarly for nuclear, although it is an important technology for energy security but has a long way to go in terms of infrastructure, raw materials, safety, economics and other political issues. On the demand side, energy efficiency (EE) in the carbon intensive sectors emerged as the key at present. There is need to invest in R&D and make current technologies more energy efficient. On the demand side of the energy, transport sector emerged as the primary sector that requires a specific policy intervention for technological change as it is suspected that this sector will show the highest energy demand amongst all the sectors over the next 30 years.

It may be argued that the three most important barriers in transfer of environmentally sound techniques (ESTs) are (a) protection of IPRs; (b) high cost of technologies (transaction and implementation) and lack of financial resources; and (c) lack of commercial viability of the technology given fluctuating market dynamics. Views about IPRs are contrasting; people in the private sector argue that strong IPR regimes tend to encourage innovative R&D, technology licensing and joint ventures while those in the government consider that IPRs should not be given in principle as they prevent access to knowledge and information dissemination. However, the role of IPRs is contextual and it varies from one situation to another, therefore it needs to be thoroughly analysed, its influence and impacts need to be empirically studied and possible solutions need to be negotiated at the international platform, such that there are no losers in the technology transfer process. Similarly, the R&D cost of technologies is relatively low when compared to the total cost including the transaction, installation, implementation, operation and maintenance costs. Therefore it is not the cost of technologies which is a barrier but the cost associated with using these technologies that prevents their adoption and diffusion. Lastly, these technologies have not yet penetrated the market and are susceptible to market fluctuations; hence it is essential to have demonstration of these technologies to assess their commercial and technical viability. One of the significant findings of the study was that most of the interviewees noted that in India the technical capacity or expertise is at par with any other developed country in the world. However, it is the institutional mechanisms for adoption and diffusion of these technologies and finance for innovative RD&D that are the basic limitations.
It is important to highlight that the technologies will not be automatically deployed. It will require a dedicated and effective policy and regulatory measures along with public finance. Technology financing is crucial for the process of technological change. Financial assistance from the government, multilateral agencies, etc., has not been adequate. Hence the international negotiations should development of low carbon technologies in developing countries, by channelling finance, incentives and supporting R&D activities. Initiatives like a focussed technology oriented agreement or global renewable energy target have to be discussed at the international platform, in case the mitigation goals cannot assist technology development and deployment. For development of ESTs, a global R&D initiative could be undertaken where technologies emerging from it can be disseminated without IPR protection and are treated as public goods.

Any technology we adopt today, the absolute emissions for a developing country like India will increase but with technological and policy intervention the emissions can be kept under control. However, there is no ‘one policy fits all’ approach for achieving this. Rather there is a need for integrated approach at international, national and local level, each of which should address the full range of key considerations.

Recommendations

- There is a need for undertaking a technology needs assessment (TNA) for every sector, and making available a compendium or a publicly accessible database of clean technologies.
- Demonstration of technologies along with R&D is very crucial to assess technological and commercial viability.
- The role of IPRs in prohibiting technology transfer needs to be thoroughly analysed and empirically studied as there is a lot of uncertainty about the impact of intellectual property protection on technology transfer. As the role of IPRs is contextual and varies from one technology to another.
- Technology financing is crucial for the whole paradigm of technological change. Financial assistance from the government, multilateral agencies, etc., has not been adequate. Hence, the international negotiations must promote development of low carbon technologies in developing countries, by channelling finance, incentives and supporting R&D activities. Developed countries have to take the lead and make the technologies along with the finance available to the developing countries for development, deployment and diffusion of technologies.
- A global R&D regime could be fostered for development of ESTs, where technologies emerging from it can be disseminated without protection of IPRs.
- There is a need for global comparative analysis to understand the country specific barriers to technology transfer as opposed to generic.
- Initiatives such as a focussed technology oriented agreement or global renewable energy target have to be discussed on the international platform, in case the mitigation goals cannot assist technology development and deployment.
- Domestic policies for promoting low carbon technologies have to be strengthened in the form of more publicly funded research, having low carbon technology procurement targets, creating markets for clean technologies, etc. These initiatives must further be complimented and supported by the international policy regime.
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