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TECHNOLOGY TRANSFER AND GLOBAL MARKETS

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Introduction

A key element of climate change mitigation and adaptation is the transfer of more effective and efficient low-carbon technologies between developed and developing countries. Although several policy mechanisms for technology transfer are in place, most observers agree that these have not been very effective in accelerating the rate of diffusion of energy-efficient and renewable-based technologies. There is a need for market-oriented approaches in order to diffuse efficient technologies more rapidly and to reduce high transaction costs, which are a major factor explaining the low effectiveness of existing mechanisms (Michaelowa and Jotzo, 2005; Jung, 2006; Hofman et al, 2008; Lovett et al, 2009; Byigero et al, 2010; Timilsina et al, 2010).

At the 2007 G8 Summit in Heiligendamm, it was recognized that an 'expanded approach to collaboratively accelerate the widespread adoption of clean energy and climate friendly technology' was needed (G8, 2007). In successive outputs from the United Nations Framework Convention on Climate Change (UNFCCC) negotiations, such as the 2007 *Bali Action Plan*, the 2008 Poznan Strategic Programme on Technology Transfer, the 2009 Copenhagen Accord and the 2010 Cancun Technology Mechanism, the requirement for scaling up technology transfer features prominently. The problem is that project-based funding mechanisms, such as those under the Global Environment Facility (GEF) and Clean Development Mechanism (CDM), can never do more than provide a fraction of the resources needed to transfer sufficient environmentally sound technologies to permit economic advancement of developing countries while minimizing greenhouse gas emissions;

for example, at the Poznan meeting, the G77 and China proposed funding in the range of 1 per cent of gross domestic product (GDP) from developed countries (Lovett et al, 2009). The often repeated call is for greater access to technologies through open intellectual property rights (IPRs) and more financial support for technology transfer. In practice, the only viable answer is to meaningfully engage the private sector and associated global markets that transfer technology. The challenge then becomes how to put in place the appropriate institutions and regulatory environment in order to gear markets towards rapid delivery of a range of technologies that have proven to be efficient and affordable for several uses but yet have limited market shares.

A further key element of the transfer process is the build-up of capacity in the recipient countries, such as the knowledge, skills and organization necessary for effective implementation of clean technologies and, ultimately, the emergence of domestic production. Although enhanced environmental regulation, such as that envisaged under the UNFCCC agreements, can promote innovation and competitiveness in line with the 'Porter Hypothesis' (Porter and van der Linde, 1995), and to some extent financing can be provided through UNFCCC agreements; the transfer and uptake of the technology requires something more. The cases outlined here are from a range of sectors, including energy-efficient lighting, solar panels, energy-efficient cement production and high-efficiency electric motors. These cases are chosen because the uses they represent make up a significant share of global energy production and because some of these technologies, such as efficient motors, have as yet limited penetration. Effective technology transfer mechanisms need to take into account the specific nature of the selected technologies, the various forms of distribution and delivery relevant for their diffusion, and the local context for successful adoption and implementation of these technologies by users. This chapter reviews existing mechanisms and develops ideas for more effective technology transfer mechanisms for these selected technologies. Key elements of such mechanisms need to take into account effective global access to environmentally sound and energy-efficient technologies, while also ensuring that appropriate technological capabilities are developed at the local level. In conclusion we demonstrate that neither access to technologies nor financing are the real limiting factors, but rather it is creation of the appropriate enabling environment to allow technology markets to work. We suggest multi-stakeholder partnerships as one possible way forward (Morsink et al, 2011).

Technology transfer mechanisms

The role of technology transfer (TT) has been part of the UNFCCC and its negotiations since its creation in 1992 and it continues to play a central role. For developing countries, in particular, the transfer of environmentally sound technologies (ESTs) from 'North to South' has been an important component for their commitment to climate agreements in recognition of the principle that mitigation efforts do not impair economic growth. In other words, the view is that deployment of new clean technology will enable countries to decouple greenhouse gas emissions (GHG) from development. There are some clear barriers to EST transfer: they are usually more expensive than conventional technologies and many developing countries do not have the installed manufacturing capacity for ESTs. More hidden are the lack of regulatory frameworks that would encourage private-sector engagement with developing country markets to promote ESTs and the incentives in place for retaining inefficient or high greenhouse gas-emitting technologies.

As noted above, a number of financial mechanisms are in place to encourage EST transfer and to help overcome the higher cost of clean technology, most notably the CDM and GEF. However, it is generally agreed that much more technology transfer is needed for climate change mitigation and adaptation. At COP13 in Bali (December 2007), it was decided 'to elaborate a strategic programme to scale up the level of investment for technology transfer to help developing countries address their needs for environmentally sound technologies, specifically considering how such a strategic programme might be implemented along with its relationship to existing and emerging activities and initiatives regarding technology transfer and to report on its findings to the twenty-eighth session of the Subsidiary Body for Implementation for consideration by Parties (Decision 4/CP.13)' (UNFCCC, 2008a). Developing countries take the position that any commitment to specific GHG reduction goals can only happen if accompanied by very significant expansion of technology transfer and support facilities. Consequently, in September 2008 China and the G77 put forward a proposal for a technology mechanism to accelerate the 'development, deployment, adoption, diffusion and transfer of environmentally sound technologies among all Parties, particularly from Annex II parties to non-annex I Parties, in order to avoid the lock-in effects of non-environmentally sound technologies on developing country Parties, and to promote their shift to sustainable development paths' (UNFCCC, 2008b). At the 2008 UNFCCC COP14 in Poznan, one of the few major decisions made was the Poznan Strategic Programme on Technology Transfer, which recognized limitations in the Global Environment Facility approach and the need for major private-sector involvement to cover the shortfall in funding needed (UNFCCC, 2008c; Lovett et al, 2009). Development of a Technology Mechanism was initiated at the 2009 COP15 in Article 11 of the Copenhagen Accord: 'In order to enhance action on development and transfer of technology we decide to establish a Technology Mechanism to accelerate technology development and transfer in support of action on adaptation and mitigation that will be guided by a country-driven approach and be based on national circumstances and priorities' (UNFCCC, 2009). IPRs continued to be a stumbling block, overcome to some extent by the proposed formation of a network of 'Climate Innovation Centres' to 'develop and deploy appropriate technologies to mitigate and adapt to climate change' (Sagar, 2010). The Technology Mechanism was agreed at COP16 in Cancun in 2010, to become operational in 2012 (UNFCCC, 2010). However, developing effective clean technology transfer is not straightforward. Existing mechanisms are often said to have high transaction costs and lack effectiveness as they are unable to mobilize the investment potential of the private sector and widespread adoption beyond the initial projects selected for support (Egenhofer et al, 2007; Forsyth, 2007). For example, the necessary institutional, technical and economic capability may be lacking for CDM projects in Africa (Jung, 2006; Timilsina et al, 2010), and an absence of the necessary regulatory frameworks can further prevent private-sector involvement (Michaelowa and Jotzo, 2005). Indeed, sub-Saharan Africa is perceived as a high risk for foreign direct investment (FDI) (linked, for example, to poor energy infrastructure, political instability and corruption) which is considered to have an influence on CDM investment (Byigero et al, 2010). Moreover, in most of Africa the relative lack of industrialization means that greenhouse gas baselines are low, so there is limited opportunity to mitigate emissions through CDM projects. On the other hand, any acquisition to the most modern technology enables technological leapfrogging.

The elements of more effective technology transfer lie in creating in-country capacity to manufacture and market the EST products. The intergovernmental Panel on Climate Change (IPCC) defines technology transfer as 'a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, NGOs and research/education institutions. It comprises the process of learning to understand, utilize and replicate the technology, including the capacity to choose and adapt to local conditions and integrate it with indigenous technologies' (IPCC, 2001, p101). This definition has also been adopted by the GEF (GEF, 2010). Transfer can take many forms, but one of the most dominant forms has been through FDI. The importance of FDI in the successful development strategies of Asian newly industrializing countries is often stressed. Key elements of this success were the strategy and ability to imitate and replicate technology indigenously and the parallel development of local skills and knowledge. Others forms are transfer through the provision of products incorporating the technology (e.g. energy-efficient lighting or photovoltaic panels for off-grid electrical supply, or licensing the capability to produce such products, perhaps to an indigenous firm, through co-development of domestic and foreign firms or through a joint venture) (Barton, 2007). A further form is the support of national capability to research and produce the products independent of a foreign company. A final form is technology transfer through official development assistance (ODA). Especially for low-income developing countries, this is the dominant form of technology transfer, while technology transfer to low-income developing countries through FDI is rather limited.

Experiences with technology transfer have led to understanding the concept of technology transfer as a process that includes a flow of knowledge, as well as goods and which has to be paralleled by processes for learning and capacity-building in developing countries. It is therefore necessary to see technology transfer as part of a broader process of sustained low-carbon technology capacity development in recipient countries (Ockwell et al, 2008). Others have in a similar vein stressed the importance of adequate absorptive capacity and technological capabilities in recipient countries (Mytelka, 2007). Key constraints for effective technology transfer of low-carbon technologies to developing countries are therefore often related to the lack of transfer of capital goods, equipment and knowledge in combination with the lack of an appropriate host environment for technology transfer.

In the next section we present four case studies to illustrate the diversity of enabling environments, incentives and barriers for the transfer of ESTs. In some cases, such as energy-efficient lighting and solar photovoltaics (PV), new regulations, the availability of funding and other incentives such as tax concessions are promoting their spread. In other cases, such as cement manufacture and efficient motors, the diffusion of ESTs is somewhat slower.

Four case studies

We have selected four technologies – lighting, solar panels, cement production and electric motors – for further analysis of technology transfer through global technology markets. Widespread uptake of these technologies would lead to significant reduction in global carbon emissions as the end-uses and industrial uses they represent take up a significant share of global energy and electricity use. Each section briefly reviews the current situation and efforts being made to encourage transfer of the technology.

Lighting

Lighting is an important element in the daily life of the majority of the world population. It is also a major contributor to the climate change problem as it represents around 19 per cent of the world's electricity consumption and emits 1900 million tonnes of CO_2 on an annual basis, which is equivalent to around 8 per cent of world emissions (IEA, 2006, p25). During the past few decades, energy-efficient lighting has become available, with energy savings of between 70 and 80 per cent relative to incandescent lamps, most notably by compact fluorescent lighting (CFL), which is now commercially available, while light-emitting diode (LED) technologies are expected to deliver light even more efficiently than CFL.

The global market in lighting has long been dominated by three leading multinational lamp manufacturers: Philips (based in The Netherlands), Osram (Germany) and General Electric (US). These three companies have a presence in almost all global markets and have a significant share in global trade in lighting products, facilitated by a high degree of standardization between international lighting markets (IEA, 2006, p251). Although the 'Big Three' all have manufacturing facilities in China, they account for only a small proportion of the large Chinese market (IEA, 2006, p251).

In terms of the technology involved, energy-efficient lighting is more than substituting traditional light bulbs for CFLs. 'Lighting energy can be saved in many ways, including (i) improving the efficiency of the light source; (ii) improving the efficiency of the specific component of lighting system, typically the ballast; (iii) improving the efficiency of the luminaries; (iv) improving the efficiency of the control gear deployed; and (v) making better use of daylight inside built environment' (Figueres and Bosi, 2006, p2). In terms of the process of technology transfer, this implies that effective TT involves also the build-up of knowledge and skills to facilitate the appropriate use and implementation of energy-efficient lighting within the specific local user contexts.

A number of developing countries have implemented relatively successful energy-efficient lighting programmes. Major CFL substitution programmes have been implemented in Brazil, Mexico, Peru, South Africa, Guadeloupe and Martinique. China has implemented an ambitious Green Lights Programme and has become the world's largest CFL market. The Green Lights Programme was originally initiated by the Chinese government in 1996; yet its successor (2001 to 2005), in which UNEP and the GEF have an active role as supervisors and funding partners, was significantly more far reaching and ambitious. The project had as its main objective to 'reduce lighting energy use in China in 2010 by 10 per cent relative to a constant efficiency scenario' and as a secondary goal 'to increase exports of efficient quality lighting products, aiding the Chinese economy and helping to reduce energy use and GHG emissions worldwide' (UNDP, 2000, in Lefevre et al, 2006). However, creation and operation of successful efficient lighting initiatives is more dependent upon organization and political priority than direct economic advantages (IEA, 2006). Key factors for successful programmes have included the following: the price differential of CFLs compared to incandescent lamps has been minimized by direct subsidy or soft-financing; there has been a proactive promotional campaign; the quality of CFLs has been ensured; and there has been pressure on the energy system, such as a power crisis.

Especially with regard to the quality of CFL, there is a need to ensure that good quality is guaranteed. According to a recent study 'analysis shows that one out of two compact florescent light-bulbs (CFLs) available in many areas of the world is of shoddy quality. Unless this issue is addressed in the near term, we will fall far short of energy saving goals, turning consumers against CFLs in the process' (USAID, 2007). A key component in China's relatively successful CFL programme has been the set-up of a national standardization organization that is responsible for the quality of the CFL products and for which all producers are obliged to test their products against a number of minimum quality standards developed by the organization. An innovative approach to improving product quality is the Lighting Africa Quality Assurance Product Awards Ceremony, where businesses are recognized for their efforts to improve quality (Lighting Africa, 2011).

The Global Environment Facility has played a major role in the efforts to support a global phase out of incandescent light bulbs and develop a lighting market transformation strategy benefiting all economies, including the developing world. This initiative was triggered by an increasing number of countries announcing their intention to phase out incandescent lighting. One of the first countries was Cuba, which banned the sale of incandescent lighting in 2005 and started a programme of replacing traditional light bulbs with CFL, a process said to be finalized in 2008, making Cuba effectively the first country where incandescent lighting is phased out. Since early 2007, almost all Organisation for Economic Co-operation and Development (OECD) governments began to develop policies aimed at phasing out inefficient incandescent lighting. Australia was among the first to pronounce a time schedule and regulations for phasing out incandescent lighting by 2012; other OECD countries (the European Union, the US and Japan) followed with similar time paths. Industries have also expressed their willingness and readiness to phase out incandescent lighting, Philips being the first in December 2006, followed by other firms. The EU has legislative processes for phase-out, while various EU countries developed national measures for phasing out incandescent lighting ahead of the EU time schedule. For OECD countries, the process of phasing out has been set in motion and is likely to be finalized around 2012. A number of developing countries have already started a process of phasing out, China being the most well known. Another example is Ghana, where a policy was introduced by the government to ban imports of incandescent light bulbs and other high-energy consumption lamps. In Ghana the shift to low-energy lighting is driven by a power crisis. The government is providing 6 million CFL bulbs free of charge to replace incandescent bulbs, saving 430GWh of electricity a year and reducing peak demand by 124MW (Energy Foundation Ghana, 2011). This has the combined effect of stabilizing grid supply and avoiding the installation of additional generating capacity.

In addition to CFL, light-emitting diodes (LEDs) and electron-stimulated luminescence (ESL) lamps are alternative lighting ESTs. Technical advances in LEDs have resulted in a doubling of efficiency and light output every three years since their introduction in the 1960s, giving rise to a wide range of applications; and they are increasingly being considered as a lighting solution in developing countries (Pode, 2010). In their assessment of LED technology transfer to India, Ockwell et al (2006) found four key barriers to TT:

1. Financial: manufacturing of LED chips is capital intensive and requires large investments beyond the scale of the relatively small Indian manufacturers.
2. IPRs: LED technology is highly protected with patents and Indian companies have been unable to obtain licences, choosing instead to import LED chips.
3. Market barriers: large lighting and LED manufacturers have not invested in India due to the small domestic market, and no joint ventures are established.
4. Human capital: although India has highly skilled engineers, expertise (and academic education) in LED technology is scarce (Ockwell et al, 2006).

Solar panels

A crucial component in mitigating climate change is a transition to a more renewable-based electricity system. Solar energy, captured through photovoltaic panels and/or thin-film solar technologies is expected to be a key component of such a transition. While the installed base of solar PV is predominantly in the industrialized world, particularly Germany and Japan, solar panels form a clean and renewable source of energy that can contribute to improving energy access and health conditions in low-income areas of developing countries. For example, solar PV is widely used in Kenya, particularly by the rural middle class of small business owners, school teachers, civil servants and cash-crop farmers who use it to power televisions, radios, mobile phones and to help with children's education and evening work, such as marking and accounting (Jacobson, 2007). In its June 2011 budget, the Kenyan government granted duty remission on raw materials for the production of solar panels in order to encourage local production and to help meet demand driven by policies to increase household use of solar PV and water heating, thereby reducing grid load. The International Finance Corporation and World Bank are also promoting commercial off-grid markets, including solar PV and other technologies, in sub-Saharan Africa through the Lighting Africa programme, with the aim of providing off-grid lighting to 2.5 million people by 2012 and 250 million people by 2030 (Lighting Africa, 2011).

Production of solar panels is concentrated in a limited number of countries and dominated by a select number of multinational companies. The production of PV panels is expensive and requires large-scale precision manufacturing capability. It is a moderately concentrated industry; the four leading firms produce about 45 per cent of the market (Barton, 2007). From a value chain perspective, the number of companies involved becomes lower when travelling higher up the PV value chain. The upper level of the value chain involves the production of silicon, the main resource for the solar cell, and this requires substantial know-how and investment, as does the production of wafers (EPIA/Greenpeace, 2008). With regard to the intermediate level of cell and module producers, know-how and investment needs are smaller than for silicon and wafer production, and the number of firms in the market is higher. With regard to the installation of solar panels, at the end of the value chain, these installers are often found to be small locally based businesses (EPIA/Greenpeace, 2008).

By 2000 around 1.3 million solar home systems were installed in developing countries; but organizational, financial and technical problems created difficulties for effective implementation, and market transparency is limited, leading to a lack of knowledge and information for potential users about cost-effective systems (Nieuwenhout et al, 2001). More recently, the IFC (2007) evaluated various solar energy projects in developing countries and, while recognizing the large potential market, highlighted problems of identifying the market segment most likely to take up the technology – although as mentioned above, in Kenya this is the rural middle class (Jacobson, 2007). In Bangladesh and India, poor people are constrained from obtaining solar lighting through financial exclusion, weak governance and passive non-governmental organization (NGO) and customer participation (Wong, 2011).

Although it is generally recognized that costs of solar panels still form a barrier, there are also indications that with the help of proper domestic incentives it is possible to move the PV market forward where a sufficiently strong commercial supply chain network has been developed (van der Vleuten et al, 2007). Examples of successful commercial markets for Solar Home Systems (SHS) can be found in Kenya, Morocco, Sri Lanka, on the Tibetan plateau in western China and in

Zimbabwe. Estimates suggest that commercial markets in these locations have reached penetration of up to several megawatts of installed peak power per country or up to approximately 5 per cent of the rural population (van de Vleuten et al, 2007, p1439). Similarly, Otieno (2003) reports positive results in Kenya. Decentralized (off-grid) rural electrification based on the installation of standalone systems in rural households or the setting up of mini-grids – where PV can be combined with other renewable energy technologies or with LPG/diesel – enables the provision of key services such as lighting, refrigeration, education, communication and health. During 2007, around 100MW of PV solar energy was installed in rural areas in developing countries, enabling access to electricity for approximately 1 million families (EPIA/Greenpeace, 2008).

Key elements that need to be taken into account for effective technology transfer of solar panels are establishing effective platforms for interaction, facilitating standardization through appropriate organizations, and increasing awareness and access to information by building regional or local knowledge centres (Shum and Watanabe, 2008). Because developing countries play rather different roles in the current solar panel value chains, strategies need to be differentiated. For some of the more advanced Asian countries that have gained access to the solar panel production value chain, the focus can be on facilitating access to technology in the form of co-development programmes (such as for multi-crystalline panels, but also for the emerging thin-film technologies) and sharing IPRs. The focus can also be on expanding global silicon production for PV (silicon, of course, is a major input for several industries, such as semiconductors and metallic alloys) with the participation of developing countries. Another type of approach should focus on supporting the build-up of regional platforms for the interaction of key stakeholders – knowledge centres that apply lessons learned from the many solar home systems that have been installed in relatively poor rural areas in developing countries and that act as catalyst for standardization processes.

Energy efficiency in the cement industry

The cement industry holds a key position in contemporary society as it creates the raw material for bridges, buildings, dams and other infrastructure. But the cement industry is also a major contributor to the climate change problem as cement production is roughly responsible for 5 to 8 per cent of global GHG emissions (Batelle, 2002; Müller and Harnisch, 2008; Worrell et al, 2009). Cement production occurs all over the globe, but production is now predominantly located in developing countries with 74 per cent of world production (Roy, 2008; Worrell et al, 2009). Production has expanded rapidly by 60 per cent in past decade, particularly in developing countries, with China responsible for 44 per cent of world production in 2004 (Price et al, 2006; Roy, 2008).

Cement is among the industries with the largest mitigation potential, together with steel, and pulp and paper industries (Roy, 2008). With 1930 million tonnes of CO_2, the cement industry emits 4.6 per cent of global anthropogenic GHG emissions (Watson et al, 2005), though estimates range up to 8 per cent (Müller and Harnisch, 2008). Around 50 per cent of cement emissions arise from the chemical process of converting limestone to lime in order to produce clinker, which accounts for around 90 per cent of cement emissions if powered by fossil fuels. Offsite electricity and transport emissions account for the remaining 10 per cent of emissions. Developing countries account for 70 per cent of global cement emissions, a figure which is set to rise as developing countries continue to have higher demand for their construction and infrastructure sectors.

China is by far the largest producer of cement, with its production more than the next 20 largest countries combined. Western Europe is the second largest producer at 11 per cent, followed by South and East Asia at 8 per cent. The industry has undergone significant consolidation over the past decade to the point where the five largest companies represent 42 per cent of global capacity and the ten largest 55 per cent. However, the cement sector also comprises a vast number of small firms. For example, estimates for the total number of firms in China are from 5000 to 8300, and the top five cement producers in Russia account for only 10 per cent of production capacity (Watson et al, 2005). Cement is primarily consumed close to where it is produced for two key reasons. The first is that raw materials for cement production are widely available. The second is that cement is a costly product to transport relative to its value, particularly over land. Only 5.8 per cent of production is traded, with 40 per cent of this traded between regions. The largest exporters are Western Europe, Japan and India, while the US is the largest net importer of cement, importing 8 per cent of its consumption (Watson et al, 2005), primarily from China, Canada, Columbia, Mexico and the Republic of Korea.

The set-up of an agreement in the cement industry will be a challenge because production is spread among many plants and companies across the globe, while the level of international trade is rather low. Furthermore, a process of increased consolidation of the traditionally fragmented cement industry is under way through mergers and acquisitions, and through growth of large national players in emerging economies such as China and India. This increasing consolidation process may be accompanied by the establishment of a global cement industry institution, and thus better enable the cement industry to become a strong partner in sectoral agreements (Watson et al, 2005). According to Watson et al (2005), an emissions intensity agreement could be a way for the cement industry to move forward, with efficiency gains potentially leading to 16 per cent lower emissions.

The cement sector has reasonably good conditions for international cooperation as portions of the cement industry have also organized themselves under the World Business Council for Sustainable Development's Cement Sustainability Initiative (CSI). The key challenge will be how to involve China as the CSI includes 16 companies representing about 50 per cent of global cement production outside of China. Key components of the initiative are 'climate protection and CO_2 management', where monitoring and reporting of CO_2 emission has been mainstreamed under members by setting up a common approach and monitoring and reporting protocol. The initiative also aims to develop public policy and market mechanisms for reducing CO_2 emissions, but this has not been specified yet and fixed emissions targets are unlikely to be popular given the central economic role of the industry (Bradley et al, 2007). A more likely approach is a focus on technology and financial assistance towards developing countries such as China and other countries where significant growth is expected.

Unlike lighting or solar PV, there is no simple technological entry point for reducing GHG emissions from the cement industry. Rather, it is a matter of simultaneously tackling a range of issues within an overall approach to reaching a consensus among producers. Key elements for cement agreements need to focus particularly on the options available to increase the amount of blended cement, replacing old plant with energy-efficient technology, and on diffusing best practices with regard to energy management, which also includes developing low-carbon or renewable biomass-based energy provision for this rather energy-intensive industry (de Coninck et al, 2007; Müller and Harnisch, 2008). Pilot projects for carbon capture and storage (CCS) could also be connected to the energy requirements of the cement industry, although CCS has yet to move beyond the demonstration stage (Russell et al, 2011) and has not gained much credibility in the UNFCCC negotiations as an effective tool for mitigation as there are few additional benefits compared to alternative carbon capture approaches. In particular, forestry offers a wide range of livelihood opportunities.

Energy-efficient electric motors

Electric motor systems are considered to be responsible for up to 40 per cent of industrial electricity demand worldwide (Brunner, 2007) – thus a major source of greenhouse gas emissions. It is estimated that uptake of high-efficiency motors (HEMs) could improve the efficiency of motor systems by 25 to 30 per cent on average. Motor system components are widely traded commodity goods that are currently subject to different testing standards and performance and labelling requirements (SEEEM, 2006). As a result, there are substantial variations in the market penetration of high-efficiency motors and motor systems around the globe. Countries that have implemented minimum energy performance standards at relatively high efficiency levels have market shares for high-efficiency motors of over 70 per cent, whereas the market share in countries without them hovers below 10 per cent, despite voluntary programmes (SEEEM, 2006). The International Energy Agency estimates that up to 7 per cent of global electricity demand could be saved by more energy-efficient motors and motor systems. At present, both markets and policy-makers tend to focus exclusively on individual system components, such as motors or pumps, with an improvement potential of 2 to 5 per cent instead of optimizing systems (McKane et al, 2008).

According to McKane et al (2008), the barriers to uptake of more efficient motors are foremost institutional and behavioural, rather than technical. The fundamental problems are lack of awareness of the energy-efficiency opportunities by firms, suppliers and consultants; there is a lack of understanding on how to implement energy-efficiency improvements, and a consistent organization structure for energy management within most industrial facilities is often absent. At the institutional level, there is a general lack of standards. Without performance indicators that relate energy consumption to production output, it is difficult to document improvements in system efficiency (McKane et al, 2008).

Energy efficiency in motors and drives is generally considered to be cost effective (i.e. the more efficient motors and systems pay the additional cost (more material in steel and copper, additional power electronic components, additional labour for design and engineering, testing, etc.) within less than two years). Especially in new equipment, there is no reason whatsoever not to buy and install optimally designed and highly energy-efficient motors and electronic adjustable speed drives where feasible (SEEEM, 2006). There is a wide variety of electric motor producers with some of the largest players from the OECD, while China also has a significant number of large producers. Motors are sold from the manufacturer to three different channels: large industrial end-users, distributors who sell them to small end-users, and original equipment manufacturers (OEMs) who put them into complete systems. Only in the first channel is there a direct link between initial cost and quality and energy savings that will result from the installation of efficient motor systems.

A number of national and international activities are in place to promote energy-efficient motors and provide standards (SEEEM, 2006; Saidur, 2010): the International Electrotechnical Commission (IEC), the International Conference on Electrical and Electronics Engineering (ICEEE) and other organizations have provided standards for testing the energy efficiency of electric motors. CEMEP in Europe, NEMA in the US and many other organizations have launched labelling schemes and voluntary standards for high-efficiency motors. Mandatory minimal energy performance standards have been enacted in the US, Canada, Australia, New Zealand, Brazil, China and Mexico. The Motor Challenge campaign has increased awareness, competence and acceptance of efficient electrical motors in the US and Europe. Similar campaigns have been started in Australia, China and other countries. An elaborate database for energy-efficient motors is provided by EuroDEEM. The Collaborative Labelling and Appliance Standards Programme (CLASP) has worked internationally to harmonize standards and labels. APEC–ESIS has worked on harmonized and effective energy efficiency standards in Asian countries.

Discussion

The four cases suggest that significant reductions of GHG emissions can be realized by a more rapid diffusion of energy-efficient and renewable-based technologies. However, the path to more rapid acceleration of these technologies is not straightforward. First of all, the diversity of the technologies calls for approaches tailored to the specific characteristics of the technologies, users and the global value chains that they represent. Those technologies fulfilling the needs of households, such as solar panels and lighting, require a different set-up of mechanisms relative to those oriented to large industries, such as cement and high-efficiency motors. Moreover, energy-use patterns within developing countries differ widely between the poor and middle classes, and mechanisms will need to exploit various delivery models to reach those different groups effectively. The technologies differ with respect to the type and nature of investments they require and their complexity; and this has to be reflected in the proposed mechanisms. The nature of global value chains and the integration of developing countries within those value chains also differ by region. Whereas several Asian countries have gained access to some of the value chains for the identified technologies, the role of other developing countries in global value chains is much more limited.

Second, adequate technological capabilities and absorptive capacity are key requirements for the successful spread of the technologies outlined in the case studies here. 'Technology flows can be embodied in foreign direct investment (FDI), intermediate goods, capital equipment, or licensing, but may have little or no effect on development or growth without absorptive capacity' (Narula, 2004, p3). Host environments differ widely across developing countries. The East Asian newly industrializing countries (South Korea, Taiwan, Singapore and Hong Kong) have developed strongly supportive enabling environments and effective absorptive capacity for the acquisition and exploitation of a range of technologies, including high-tech manufactures. They have built relatively effective 'national systems of innovation' and play an increasing role in strategy technology alliances, partnerships and agreements between countries and firms from the North and South (Archibugi and Pietrobelli, 2003). China made significant progress in this respect during the last two decades. For example the level of R&D as a percentage of China's GDP rose from 0.7 to 1.1 per cent during 1997 to 2002; China aims to increase this to 2.2 per cent by 2015, while in most African countries (with the exception of South Africa) declining trends were observed, with starting levels of R&D spending already well below 0.5 per cent of GDP (UNIDO, 2005). China has become a major recipient of FDI, while for the cases analysed here, Chinese firms take up an increasing share in domestic and international production of energy-efficient lighting, solar panels, high-efficiency motors and cement production (and by acquiring an increasing number of technology licences).

Nevertheless, barriers of access to environmentally sound technologies and the availability of financing are still cited as the major constraints for further upgrading and delivery of technologies for mitigation and adaptation. For example, the G77 and China have proposed to set up a technology mechanism under the UNFCCC, cited at the beginning of this chapter, which particularly aims at increasing access to, and financing of, environmentally sound technologies, including through co-development of technologies and intellectual property rights sharing (UNFCCC, 2008b).

A number of conclusions can also be drawn more specifically for the selected technologies. Energy-efficient lighting is the most straightforward case because it represents a not too complex form of substitution of existing products by a new generation of better products. There is also broad political and industrial support for the phase-out of incandescent lighting which offers a route to a global agreement on energy-efficient lighting and the phase-out of incandescent lighting. Apart from global partners (OECD countries, developing countries and the lighting industry), such an agreement needs to be accompanied by stakeholder collaboration at national and regional levels. At national levels it is important to develop strategies and regulations to prevent inefficient lighting from resurfacing, and it is crucial to safeguard the quality of energy-efficient lighting by setting up standardization and testing organizations. Programmes such as Lighting Africa can also act as vehicles for diffusion, while taking into account the specific needs of various user groups, such as poor households and micro-businesses. Large companies such as Philips are setting up multi-stakeholder partnerships with developing countries to jointly manufacture energy-efficient lighting (Morsink et al, 2011) and are developing ways of selling their products to the 'bottom billion' to open up new markets. Governments support widespread uptake of lighting EST because it lowers peak grid power demands and substantially reduces the need for increasing generating capacity.

For solar panels, it is important to distinguish between the group of countries that are actively involved in solar panel production and the group that are mainly involved in application of solar panels in local electricity systems. For some of the more advanced Asian countries that have gained access to the solar panel production value chain, the focus can be on facilitating access to technology in the form of co-development programmes (such as for multi-crystalline panels, but also for the emerging thin-film technologies) and sharing IPRs. The focus can also be on expanding global silicon production with the participation of developing countries. Another type of approach should focus on supporting the build-up of regional platforms the for interaction of key stakeholders and knowledge centres that apply lessons learned from the many solar home systems that have been installed in relatively poor rural areas in developing countries and that act as catalyst for standardization processes.

With regard to cement production, technology agreements need to focus particularly on the options available to increase the amount of blended cement, and on diffusing best practices with regard to energy management, which can also involve developing low-carbon energy provision for this rather energy-intensive industry. This requires the build-up of energy management expertise and of effective channels to bring support to the many smaller cement companies in developing countries. For the larger cement industry operations, pilot projects for carbon capture and storage could also be part of a mitigation package.

High-efficiency motors include a range of technologies and applications across all industries. Mechanisms need to focus on two key aspects. First, there is still much to be gained by replacing less efficient motors by high-efficiency electric motors. Key components are awareness-building and information campaigns and incentives to lower the higher costs of these high-efficiency motors relative to the less efficient ones. Second, there is a need for energy management expertise and for improving energy management across the board of industries.

As mentioned in the introduction, an important element for effective technology transfer is the creation of an enabling environment in the recipient country, which is defined as 'government actions, such as fair trade policies, removal of technical, legal and administrative barriers to technology transfer, sound economic policy, regulatory frameworks and transparency, all of which create an environment conducive to private and public sector technology transfer' (IPCC, 2001, p26). This implies that country-specific social and institutional contexts need to be taken into account. For many cases, the lack of fine-tuning to the specific socio-cultural and institutional context has been a contributing factor to the failure of technology transfer. Incorporation of a needs assessment and active national and local stakeholder involvement and contribution is one way to prevent this. Such a multi-stakeholder approach also holds promise for the build-up of local technological capabilities that are deemed crucial for any effective technology transfer. Enabling factors such as infrastructure and a supportive political, legal and regulatory framework are highly relevant; but most critical seem to be partnerships with multiple stakeholders from the private and public sectors and from civil society because these will bring in local knowledge, leverage and human and infrastructural resources (Morsink et al, 2011). With these capabilities a multi stakeholder partnership can influence the creation of an enabling environment for technology transfer.

A further general perception is that effective technology transfer to developing countries is hampered by limited access to knowledge and the proprietary nature of technologies (i.e. IPRs). However, the role of IPRs as a barrier is far from clear. A general review suggests that middle-income countries prefer relaxed IPRs, whereas low- and high-income countries benefit from good IPR protection (Falvey et al, 2006a, 2006b); and it is clear that there are conflicting discourses about the role of IPRs in development versus technology diffusion (Ockwell et al, 2010). Nonetheless, development of a more open innovation structure could facilitate participation from developing countries. One part of such a strategy could be the creation of a global Knowledge Fund, an idea developed by Lynn Mytelka in which patents of technologies critical to fundamental human needs (e.g. for food, drugs and ESTs) can be deposited (Mytelka, 2007). Financial resources should be put into the fund to ensure that appropriate local capabilities are developed in enterprises, knowledge institutes and the public sector in developing countries ensure that when patents are being utilized, the tacit knowledge required to work these patents in a local context is transferred (Mytelka, 2007). While the Knowledge Fund is basically designed as a global organization, national and regional knowledge centres, such as climate innovation centres (Sagar, 2010), could play a key role in facilitating the further application and diffusion of the knowledge, skills, and engineering practices and technologies to local entrepreneurs, firms and other relevant stakeholders.

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