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Diffusion of renewable energy technologies: Case studies of enabling frameworks in developing countries

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Diffusion of renewable energy technologies

Case studies of enabling frameworks in developing countries

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Technology Transfer Perspectives Series

Diffusion of renewable energy technologies

Case studies of enabling frameworks in developing countries

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Director
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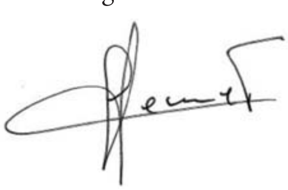
Foreword

I am pleased to introduce the first edition in the new Technology Transfer Perspectives series, which aims to share different views about enabling frameworks and best practices for technology transfer in the area of climate change. This publication is being released in parallel with one entitled Technologies for Adaptation. Both publications stem from the global Technology Needs Assessment (TNA) project that UNEP and the UNEP Risø Centre are implementing in 36 countries in Africa, Asia, Commonwealth of Independent States and Latin America. Funding for the project is provided by the Global Environment Facility.

This publication directly relates to one of the main outputs of the TNA process – the Technology Action Plan, or TAP. These TAPs comprise essential elements of an enabling framework for specific sectors and technologies; that is they bundle for a country the realistic and appropriate set of actions and policies that can help overcome barriers to deployment and diffusion of prioritised existing technologies. Because the TNA process uses flexible, participatory methods that allow countries to adapt to meet their particular circumstances, TAPs can also help countries developing Low Carbon Development Strategies and Nationally Appropriate Mitigation Actions.

The case studies and arguments presented in this edition provide insights for governments on how to reform their policies and institutions so as to provide clear and stable incentives that promote diffusion of climate-friendly technologies. What emerges is that there is no 'one-size-fits-all' solution to the successful transfer and diffusion of modern technologies. Context clearly matters, particularly when it comes to expanding the use of renewable energy resources with their site-dependent characteristics.

The transfer of mitigation and adaptation technologies to developing countries is enshrined in the United Nations Framework Convention on Climate Change. UNEP has for the last decades provided both international leadership and direct policy and technical support to developing countries seeking transfer of climate-relevant technologies. With this new series we continue that tradition.



Sylvie Lemmet

James Haselip, Ivan Nygaard, Ulrich Hansen and Emmanuel Ackom
UNEP Risø Centre, Denmark

Editorial

This publication is the first in a series entitled *Technology Transfer Perspectives*, which is intended to be a forum for collecting and sharing experiences among researchers, practitioners and policy-makers involved in technology transfer and diffusion in the context of climate change. For this first edition, we bring together a number of case studies from around the world, all of which concern themselves with the basic question of how to create an 'enabling framework' for the transfer and diffusion of renewable energy technologies (RETs) in developing countries. While this is relevant to policy-makers in most developing countries, we hope the publication will be of special value for the national Technology Needs Assessment (TNA) committees and national consultants in 36 developing countries, who are currently in the process of developing such enabling frameworks as part of their Technology Action Plans.

Despite the global economic recession, total investment in renewable energy reached an all-time high of $211 billion in 2010, more than seven times the figure invested in 2004 (REN21, 2011). In addition, global investment in new renewable energy generation capacity in 2010 exceeds that of new fossil-fuel based electricity generation. For the first time, developing countries overtook developed countries in terms of investments in renewable energy companies, utility-scale generation and biofuel projects (UNEP-GTREI 2011; REN 21, 2011). Thus, while investment in renewable energy has traditionally been dominated by OECD countries, in particular the countries of the EU and North America, the recent boom is also occurring in developing countries (REN21, 2010).

However, this optimistic-sounding picture should be balanced by an awareness of mainstream forecasting for global energy demand growth. Chief among these is the International Energy Agency's (IEA) flagship, the *World Energy Outlook* publication, which suggests that non-OECD countries will account for 93% of projected energy demand growth under their 'New Policies Scenario' (2008-2035). These figures show that, while CO_2 emissions in most developing countries are currently of little importance for global emissions, this picture may change in the future, and it calls for progressive action to de-couple the relationship between energy consumption and CO_2 emissions. Therefore future economic growth and development must be achieved by a transition to the use of low-carbon technologies in developing countries, which will include an accelerated transfer and diffusion of RETs and other climate mitigation technologies, as well as a significant scaling-up of associated investments.

In countries that have high net energy imports, there is a greater need and justification for expanding the role of domestic renewable energy sources. Examples from a recent study conducted by the Global Network on Energy for Sustainable Development (GNESD) suggest that governments should establish dedicated and authorised agencies responsible for promoting, initiating and financing renewable energy projects and programmes. In addition, it is known that a proven government commitment and clearly set government targets are fundamental in giving confidence to private investors who are seeking to develop renewable energy projects. The oft-cited success of the Brazilian biofuel programme was mainly due to clear and consistent policies and targets, as well as government subsidies, set at an early stage (GNESD, 2010). However, as some of the articles in this edition argue, in order to achieve the rapid transfer and diffusion of RETs more targeted and dedicated action is needed.

As a concept 'technology transfer' has various definitions, many of them technical and specific. Generally, technologies comprise 'hardware' and 'software' elements and also incorporate the management systems, human resources and institutional infrastructure necessary for the successful operation of any given installed technology, sometime referred to as 'orgware'. Thus, the transfer of technology involves both the exchange of codified proprietary knowledge, tacit know-how and organisational practices, as well as technical artefacts, machinery and components (IPCC, 2000). Technology transfer is made up of transactions, often between private companies, for the purchase, franchising or licensing of technology hardware and/or software intended to meet a specific need. In the context of climate change the International 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…' (IPCC, 2007). Here, the concept of technology transfer denotes the international or cross-border exchange and flows of the above-mentioned technological artefacts, knowledge and organisational capacities. Furthermore, technology transfer is understood as comprising the introduction of a new or relatively unfamiliar technological concept in the recipient country. Although such technology flows have conventionally been conceptualised as mainly North-South, the importance of South-South and South-North technology transfer has increasingly become apparent under the continuing processes of economic and cultural globalisation.

The articles in this edition focus mainly on policies aimed at promoting technology 'diffusion', which itself both depends upon and drives technology transfer. By diffusion we understand the dissemination or uptake of specific RETs, for example, wind turbines in a national context. In contrast to technology transfer, therefore, the concept of diffusion concerns the (accelerated) spread of an existing or relatively familiar technology within national borders. However, it is clear that such conceptual categorisations may be problematic, for example, regarding large countries such as China or India, where the flow of technology and knowledge between sub-national states may be categorised more appropriately as technology transfer. It may also be difficult to distinguish technology transfer from diffusion in cases where a new technological concept is introduced gradually and therefore becomes increasingly familiar, characterised by a gradual uptake in a given country. However, we find it useful to distinguish the two concepts in the present edition to provide some clarity and simplicity in addressing the complex issues at hand.

The main focus of the work presented in this edition concerns how to establish a viable 'enabling framework' conducive to enhancing and facilitating the accelerated diffusion of RET's in developing countries. Here, we understand an enabling framework as something broader than a set of specific policies, to include the country-specific circumstances that encompass existing market and technological conditions, institutions and practices. Throughout the individual articles in the present edition, the concept of an 'enabling framework' is used interchangeably with 'enabling environment', which we understand as being essentially the same. While recognising that the success of any given enabling framework is context-dependent, it is argued that an effective framework for scaling up RET-related investments can be constructed in any country through the implementation of specific policies, adapting the lessons of what has worked elsewhere. Therefore, establishing an enabling framework means thinking more about creating markets, not projects (Martinot, 2002). It is important to clarify that markets are rarely 'free' in the true sense of economic liberalism, and in developing countries energy markets are often heavily regulated and subsidized. To enable RETs to meet an increasing proportion of the demand, markets need to be freed, created or stimulated, supported and regulated by governments and wider stakeholders. As such, a market can be thought of as a self-sustaining mechanism to achieve technological change over time (Haselip, 2007). Developing stable market conditions for renewable energy is an inherently more sustainable means of achieving a transition to a low-carbon economy than a series of externally financed projects.

So how can developing countries create the enabling framework for self-sustaining markets in renewable energy? First of all, a systematic approach must be taken to understanding the barriers that exist to the deployment and diffusion of specific technologies. The exact barriers that countries face depend upon national circumstances, but can be classified in political, economic, financial, legal, regulatory, technical, institutional or socio-cultural terms (Boldt et al., 2011; Painuly, 2001). A thorough understanding of the barriers and knowledge of policy measures having been successfully applied in other countries is a good basis for conceptualising and proposing efficient and context-specific measures or elements of an enabling framework for the transfer and diffusion of RETs. By adding to a bulk of literature on the experiences with enabling frameworks for specific renewable energy technologies, such as biofuels in Tanzania (Romijn and Canidls, 2011), solar PV in Africa (Nygaard, 2009) or a national programme for renewable energy in Sri Lanka (WB, 2006), we believe this edition provides valuable input to understanding the challenges and opportunities involved through the example of policy measures applied elsewhere.

The edition presents nine articles, which cover case studies from Africa, Asia and Latin America. The first section consists of four articles that address enabling frameworks for the transfer and diffusion of specific technologies, including solar water heaters, cookstoves and wind turbines.

The edition is opened by Samantha Ölz, (formerly International Energy Agency, France) who provides an encouraging account of how a long-term effort and a combination of investment subsidies and consumer loans managed and guaranteed by the state-owned utility, alongside other accompanying measures, have enabled Tunisia to achieve growth rates in the Solar Water Heater (SWH) market of more than 25% for several years. In her analysis of South Africa's support for SWHs, Ölz concludes that the mixed experience with investment cost subsidies highlights the risk of unpredictable changes to subsidy levels due to their dependence on public budgets and the importance of streamlined administrative procedures to attract end-users. She argues that when direct financial incentives are implemented they should offer incentives by energy (kWh) or capacity (kW or m^2) rather than as a percentage of installed cost. This reduces the likelihood of market-price distortions and the prevalence of oversized installations.

The second article by Emi Mizuno (Climate Strategies, Cambridge, UK) investigates the development of the wind energy industry in India, with a special focus on the factors that determine what she calls a replicable technology transfer between European and Indian companies. She argues that foreign direct investment, the formation of technology partnerships and technology capacity-building do not automatically guarantee continuous technology upgrading and replicable technology transfer. It is equally important to create what she calls a sizable and performance-oriented market, as well as to avoid market fluctuations by stop–go politics. She argues that technology transfer is process-oriented and therefore sensitive to market fluctuations. Consequently, she calls for an overall long-term consistency of policy frameworks, albeit one which allows for sound adjustments. This is to achieve efficient diffusion of wind technology, but certainly also to achieve an efficient transfer to and uptake in Indian companies.

Following this, Robert Bailis and Jasmine Hyman (Yale School of Forestry and Environmental Studies, USA), discusses the barriers to and drivers for the dissemination of what they term clean-burning fuel-efficient cookstoves. They point to the fact that, while the threat of deforestation was a main driver in the 1970s, the main concern now is the need to reduce indoor air pollution and GHG emissions. As these benefits are 'public goods' not directly acknowledged by the cookstove users, programme developers need to understand the complex social factors that determine user preferences for stoves. Stoves need to be attractive to the consumer. Further, because of the higher price, subsidies of some form are generally needed to enhance the diffusion of clean-burning fuel-efficient cookstoves. In this respect, carbon finance mechanisms are seen as a promising financing option. Finally, the authors point to some opportunities for the large-scale industrial production of stoves in contrast to small-scale artesanal production, which has been the norm for the last thirty years of stove dissemination.

Wind energy technology is again the topic of analysis by Isaac Dyner, Yris Olaya and Carlos J. Franco (National University of Colombia), who propose elements of an enabling framework to accelerate investment in the technology in Colombia. Their article provides an account of existing policy measures for wind energy in a number of South American countries and an analysis of the gaps in the current Colombian framework for wind power, arguing principally for the use of feed-in tariffs and portfolio standards.

Following these four articles, which focus on specific technologies, the next section comprises five articles that analyse enabling frameworks for multiple RETs. Here, the opening article by James Haselip (UNEP Risø Centre) focuses on the design and relative success of renewable energy feed-in tariffs in various countries, with the aim of identifying useful lessons for developing countries. The author stresses that FITs are not the 'be all and end all' of renewable energy policies, but rather should be seen as a framework to build wider support for RETs. Nonetheless, if FITs are properly designed and backed by a stable and committed government, they provide a simple, transparent and efficient measure to increase the share of electricity generated by RETs. In a developing country context it should be remembered that, despite the long term rise in fossil-fuel prices, most grid-connected RETs require financial support in order to compete with conventional fossil-fuel sources and large-scale hydro. This means that sustainable financing needs to be ensured, either by cross subsidies within the grid, by subsidies from government or by external sources, such as climate finance mechanisms.

Continuing the analysis of feed-in tariffs, Anna Pegels (German Development Institute), focuses on the challenges involved in implementing this policy, which is popular in many OECD countries, in South Africa, where a FIT was in place for two years before it was abandoned in favour of a competitive bidding process in 2011. According to the author, this occurred because the government had social priorities other than the deployment of renewable energy technologies. Secondly she points to the lack of coordination and capacity at the policy-making level, as well as the strong fossil-fuel lobby groups that were able to influence the policy-making process.

Judith Cherni (Imperial College, London) addresses renewable energy policies and lessons from Latin America, in particular Argentina, Brazil and Peru. Her article looks specifically at how feed-in tariffs, quotas and competitive bidding have developed in the region, and while noting the limited expansion of RET in the region she draws some lessons from their experience. The author makes the point that, while emission reductions are an important objective of the promotion of renewables in OECD countries, this is of less importance in Latin America. Instead, she argues that developing positive market conditions for independent power producers, addressing regional shortfalls in energy supply and tackling the problem of energy poverty among poor rural populations determine the character of renewable energy policy in Latin America.

Focusing on India, Darshini Ravindranath and Srinivas Shroff Nagesha Rao (UNDP, New Delhi) provide an analysis of experiences with the diffusion of bioenergy technologies. Over the last two decades, the government of India has developed a number of policy instruments to support bioenergy development, including tariff support, capital and interest subsidies. The country currently derives 25% of its net primary energy from biomass. Despite this, the authors consider the rate of spread of bioenergy technologies in India to have been relatively slow due to institutional, technical informational, market and financial barriers. In addition to fine-tuning existing measures, the authors identify a list of new concrete actions aimed at accelerating the use of bioenergy technology.

In our final article, Krishna Ravi Srinivas (RIS, New Delhi) addresses the role of intellectual property rights (IPR) in the context of technology transfer. The article reviews the various scholarly positions on the role of IPR in facilitating or hindering technology transfer. Srinivas argues that, while at the political level there are proponents for both extreme positions regarding the role and importance of IPR, scholars have advanced more nuanced positions, mainly claiming that it should be evaluated on a case-by-case basis. On this basis, the article examines how open innovation or open source models, whereby market actors share intellectual property rights within a larger group, could play an important role in facilitating the transfer of climate-friendly technologies.

Overall, the nine articles presented in this edition provide a wealth of detail, which is worth studying because, as is often the case with policy-making, the devil lies in the detail. By drawing lessons from the transfer and diffusion of various technologies across all three continents, a general pattern emerges which can be summerised in six general points, highlighting the need for:

1. A combination of measures

Most of the contributors urge that a combination of measures to build a coherent policy or enabling framework is important to ensure cost-efficient transfer and diffusion of a specific technology. Barriers may be political, economic, financial, legal, regulatory, technical, institutional and not least cultural, and therefore measures need to respond to the same categories to achieve change.

An illustrative example of the effect of a programme comprising a combination of measures is the solar water heater programme in Tunisia. This programme combines financial incentives such as a 20% investment subsidy, subsidized interest rates and consumer loans managed and guaranteed by the state-owned utility and paid back through electricity bills. Added to this are measures such as quality standards, certification schemes, supplier accreditation schemes, extensive public awareness-raising campaigns, practical training for installers and capacity-building programmes for government officials and financiers.

2. External financing mechanisms

Except for countries that are highly dependent on electricity from diesel generators, RET-generated electricity is in general more expensive than electricity from traditional fossil fuel-based technologies or from large-scale hydropower. This means that financial measures are often necessary in the first stages of technology diffusion, when market actors are few and there are limited opportunities to develop economies of scale. In most developed countries the burden of economic incentives has been paid by taxpayers (direct subsidies) or electricity consumers (cross subsidies). While this has politically viable in most developed countries and in some developing countries such as India, developing countries will often not be able to mobilise the political will to meet such extra costs, especially if the subsidised share of renewable energy become considerable.

Although several authors have mentioned carbon finance schemes as an important source of finance, this will only partly meet the financing gap. The Tunisian SWH programme was partly financed by carbon credits, but for non-Least Developed Countries (LDCs) the conditions in the post-Kyoto regime are uncertain. However, LDCs will remain eligible to benefit from both the voluntary and the European carbon trading scheme after 2012, and Bailis and Hyman see carbon finance as an important financing source for subsidizing improved stoves. Also, as noted by Cherni, FIT or investment subsidies can be partly financed by carbon credits. However, several authors in this edition have made reference to the need for international support to finance programmes in part, and there is a built-in obligation to provide international finance to the GET FIT initiative targeting renewables, an example discussed by Haselip.

In this regard, the ongoing negotiations under the UNFCCC have developed a framework for international technological and financial support to developing countries. Thus, the Nationally Appropriate Mitigation Actions (NAMAs) being implemented by developing countries under a new post-2012 climate-change regime should be conducive on the transfer of technological and financial resources from developed countries (UNFCCC, 2007). Although many issues remain uncertain at present regarding the future of NAMAs, it would appear that such country-defined international mechanisms are most likely to provide the means for establishing viable enabling frameworks for RETs in developing countries.

3. Simple and transparent financing

Successful economic incentives can take many forms, though any given enabling framework is of little value if it fails to provide the clear, transparent and stable conditions necessary to attract investors. Several contributions in this issue urge that financial measures should be transparent and simple, and it is these two features that are the key to understanding the success of the feed-in tariffs. FITs are easy to communicate and provide a predictable means to reduce the cost of support for RETs gradually by moving towards market parity. Simplicity and transparency are also central in the Tunisian SWH programme, where investment and loan subsidies are the same for all consumers, regardless of the size of households or incomes. Supporting the same argument, Mizuno laments that financial measures for wind power in India were too complicated, consisting of feed-in tariffs, third-party sales, tax reductions and wheeling[1] benefits, with the effect that in practice the feed-in tariff was never used. Tax reductions, options for wheeling and high industrial tariffs in India made it more profitable for industries to invest in wind power and use it for internal consumption (captive power) than to sell electricity to the grid with the support of a feed-in tariff.

4. Identify and address non-financial barriers

Non-financial barriers to scaling up the transfer and diffusion of RETs is equally, if not more important than the financial barriers. To quote Deutsche Bank, 'it is useful to outline international financial incentives, but such interventions will not be successful on their own if they do not fit within national regulatory, legal and policy frameworks' (DBCCA, 2011).

Non-financial barriers can include complex cultural barriers to applying certain technologies, as noted by Bailis in the case of improved cookstoves. They can also be relatively simple, reflecting a paucity of public information and awareness regarding RETs and their proper applications and benefits, or they can comprise inappropriate and non-enabling regulatory, legal and institutional frameworks, which may be technically easy, but politically difficult to change. As such, many countries will need customised technical assistance, capacity-building and planning assistance to conduct detailed assessments of the specific regulatory and non-market barriers to developing an enabling framework for investment in renewable energy. To a large extent, the global TNA project is designed to address these all-important activities at the pre-investment stage.

5. Careful design, tailored for each country

An enabling framework should aim to 'de-risk' renewable energy projects for investors and ensure a profitable investment. At the same time, contributors to this publication emphasise that consideration must be given to safeguarding governments and consumers in developing countries against policies that would lead to unnecessary increases in energy prices and/or an inequitable distribution of the energy access benefits that result from an expanded use of renewable technology. To ensure that measures are carefully designed, there may be a need for targeted technical assistance in the design phase, as there is plenty of experience to draw on from both OECD countries and developing countries themselves in how to design financial support mechanisms so that they do not provide unrealistically high profits for investors at the expense of low-income consumers. Regarding the careful design of measures, Cherni emphasises that policy will be more attractive to both private and international aid organisations if renewable energy schemes incorporate aspects such as access to energy in rural areas and social equity components that do not necessarily respond to free-market ideology.

6. Measures that are stable and predictable

Most contributors touch on the need for predictability and long-term stability of policy measures in order to attract investment. Mizuno claims that stop–go policies in support of wind energy in India have negatively influenced not only the rate of diffusion of wind technology in the country, but also the level of technology upgrading and uptake by Indian producers. Ölz shows how stop–go policies in the initial phases of the Tunisian SWH programme negatively affected the diffusion of SWH, while Pegels shows how lacking a standard PPA, a general mistrust of the stability of the FIT regime and a radical change in feed-in tariffs early on put off investors from signing renewable energy contracts in South Africa. The predictability and long-term stability of any given enabling framework is crucial to attract investment in renewable energy. Equally, the longevity, or political sustainability, of the enabling framework is all the more important given that RETs tend to have high up-front capital costs, meaning that cost recovery or pay-back times are generally longer than they are for non-renewable energy projects.

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Endnote

1. Wheeling refers to power transmission, for example, when private investors in a wind farm are allowed to use the public grid to transport their wind-produced electricity for internal company consumption placed elsewhere. The utility usually charges a fee per kWh for the wheeling service.

Section I: Enabling frameworks addressing specific technologies

Kuyasa Solar Water Heating Project in Kuyasa, Capetown
Photo: Jasmine Hyman

Samantha Ölz
Formerly of the International Energy Agency

Fostering solar water heating: Policy experiences and lessons from South Africa and Tunisia

Abstract

This paper assesses experiences with the implementation of policy support for solar water heater (SWH) technology in Tunisia and South Africa, with the aim of drawing lessons from these two illustrative cases for other developing and emerging economies whose interest in tapping this zero-fuel renewable heat option for domestic hot water and low-temperature industrial processes is burgeoning. Worldwide, SWH technology is the largest contributor to global supply of all solar energy technologies, with an installed operating capacity of 172 GW by the end of 2009, established markets in China and Europe, and rapidly expanding penetration in other emerging economies, such as Turkey, India and Brazil.

Tunisia and South Africa are two countries with detailed policy commitments to encouraging SWH. While both countries have substantial solar resources, which could potentially satisfy a large share of their increasing hot water needs and contribute to managing growing electricity demand (peak shaving), solar hot water currently still only meets a small, if growing share of their respective heat demand. Notwithstanding similar policy objectives, Tunisia and South Africa have followed different implementation paths and encountered varying levels of success in encouraging the uptake of SWH, with Tunisia playing an important role as a pioneer in North Africa.

This article explores these two countries' different policy choices and the economic and non-economic barriers that stand in the way of greater SWH market penetration. The analysis concludes by identifying the effective policy options that can be drawn from the two countries' experiences for developing and industrialised country contexts.

Introduction

Important drivers for policy interest in SWH, as for most renewable energy technologies, include energy security concerns, fuel mix diversification, climate change mitigation effects, and industrial and economic development opportunities. Nevertheless, to date policies encouraging the development and deployment of renewable heat technologies are, in general, less widespread than for renewables-based electricity or biofuels for transport. Moreover, progress has been comparatively modest in many developing countries, although where policies exist, SWH is a major focus.

This article analyses experiences with the implementation of policy support for solar water heater (SWH) technology in Tunisia and South Africa. The two countries, which both benefit from substantial solar resources, have made different policy choices to encourage the market uptake of SWH which could potentially satisfy a large share of their increasing hot water needs, as incomes rise and contribute to managing growing electricity demand. These two cases illustrate lessons for other developing and emerging economies for creating a favourable environment to foster this zero-fuel renewable heat option for domestic hot water and low-temperature industrial processes in the African context.

The article is structured as follows. The first section discusses the relevance of heat in energy use and the potential contribution of SWH in satisfying growing heat demand in non-OECD countries. The second section sets the context with a brief description of the global trends in SWH markets, economics and policies. A third section compares the policy experiences of Tunisia and South Africa in supporting SWH, their achievements and the economic and non-economic barriers encountered. The fourth and final section derives the lessons learned for effective policy implementation and proposes recommendations for stimulating and sustaining SWH market penetration in Africa.

Demand for heat and the contribution of SWH

Heat represents the largest share of final energy use worldwide – 47% in 2008 – with the largest contributions stemming from industrial demand for process applications and residential demand for cooking, water and space heating (IEA, 2010a). Even countries with warm climates show high shares of final energy use for heat, such as 57% in Tunisia and 45% in South Africa, despite their relative lack of space heating demand. This is mainly due to a climate-independent need for heat in industrial processes and cooking and a relatively climate-independent heat demand for domestic hot water (IEA, 2010b).

Fossil fuels continue to dominate the fuel mix for heat in many countries, e.g., in South Africa, where coal (54%) and oil (11%) dominate final energy consumption for heat, and Tunisia, with 44% of oil and 30% of natural gas in the heat fuel mix (IEA, 2010a). Moreover, the traditional use of biomass (in the residential sector) represents a large share of residential energy consumption in many developing countries, including South Africa and Tunisia (IEA, 2010a). The traditional use of biomass refers to the unsustainable management of biomass resources, such as wood, charcoal, crop residues and animal dung, and their use for cooking and water heating at low efficiencies with conventional stoves, which causes high particulate emissions with serious health impacts. The use of modern renewables, i.e., excluding traditional biomass, can alleviate the concerns relating to energy security, fuel mix diversification, climate change, and the social and health impacts of continued reliance on fossil fuels and inefficient biomass for heat.

While the potential for renewable energy technologies (RETs) to supply heat is substantial in many countries, modern renewables satisfied a mere 10% (312 Mtoe[1]) of total global heat demand in 2008 (IEA, 2011a). Renewable heat (RES-H) can be produced more efficiently and sustainably by the use of biomass in efficient stoves or installations, solar thermal heat and geothermal heat. Worldwide, biomass plays the predominant role in renewable heat production: for example, in OECD countries, 94% of renewable heat (produced in commercial plants and decentralised systems) came from biomass in 2009 (IEA, 2011b). While still only representing 3% of modern renewable heat in 2008, solar thermal heat has grown rapidly from a low base, mainly due to solar water heaters in China (IEA, 2011a).

In non-OECD developing and emerging economies, heat demand is expected to increase significantly to 2050 as the buildings and industrial sectors grow rapidly. In the buildings sector, which encompasses the residential and service sectors, global final energy demand is projected to grow by 60% between 2007 and 2050 in the IEA's business-as-usual scenario (IEA, 2010d). The bulk of this demand increase stems from developing countries, as their building stock expands in line with their growing populations, household numbers and higher building stock turnover rates (ibid.).

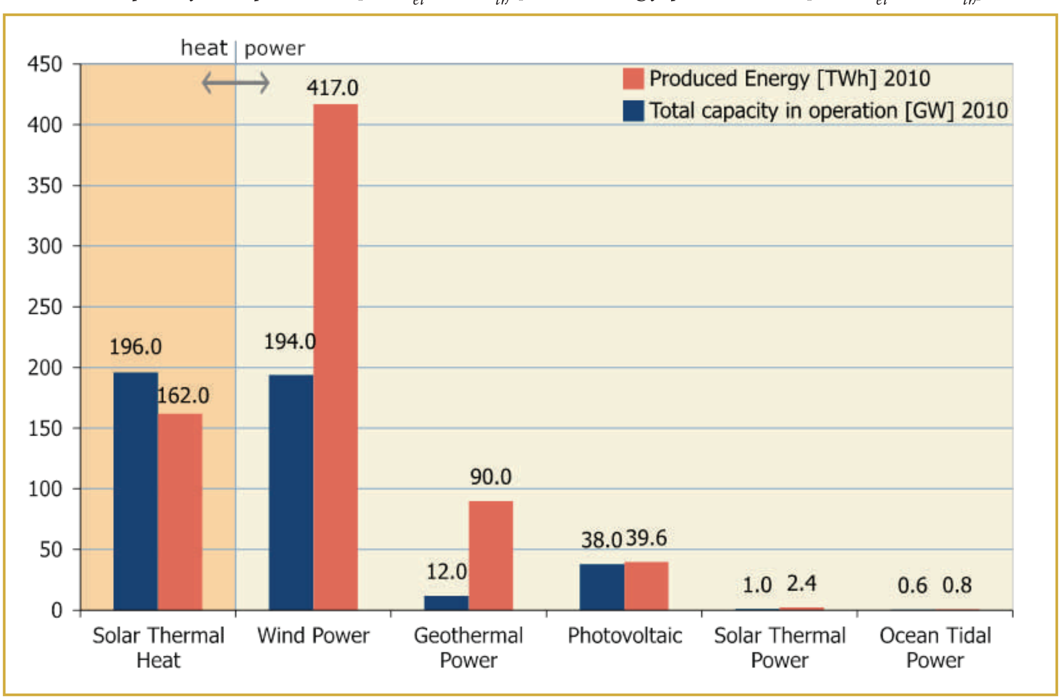
Moreover, countries with limited space heating demand, such as South Africa and, to a lesser extent, Tunisia, often lack the energy infrastructure to address this demand, which means that the demand for domestic hot water is often satisfied with electric water heaters. Rising affluence is often related to a rising demand for services such as domestic hot water. This often imposes additional peak demands on electricity grids that can be already overburdened by regular power demands, which also increase as economies develop. Renewable heating technologies, especially decentralised applications such as SWH, can help tackle this threat to grid stability.

Global trends for SWH

SWH market status

At the global level, solar water heating (SWH) is a technically and commercially mature renewable heat option for domestic hot water and low-temperature industrial processes. An overview of the main aspects concerning SWH technologies is available in Annex 1. Worldwide, SWH is the largest contributor of all solar technologies to global energy supply, as illustrated by Figure 1 with estimated operational capacity for 2010.

Figure 1. Total capacity in operation [GW_{el}^{v}; GW_{th}^{2}] and energy production [TWh_{el}; TWh_{th}], 2010



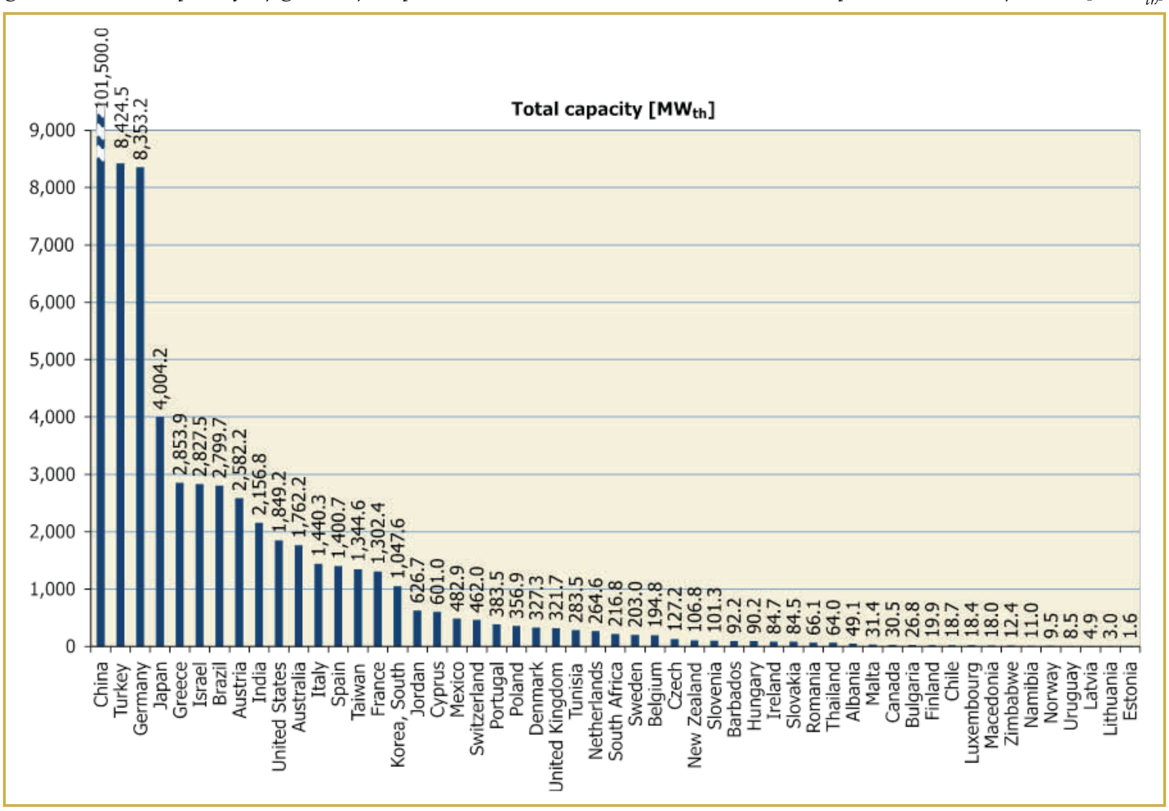
Source: Weiss and Mauthner, 2011

Around 60 million households worldwide use solar thermal collectors, and global market growth averaged 21% between 2000 and 2009 (Fawer and Magyar, 2009; Weiss and Mauthner, 2011). The solar thermal collector capacity in operation worldwide at the end of 2009 equaled 172.4 GW_{th}.[3],[4] Between 2004 and 2009, the annually installed glazed water collector area worldwide almost tripled, and the average annual growth rate between 2000 and 2009 was 20.9%. The market has seen a major shift, with very high growth rates in China, where capacity now amounts to 101.5 GW_{th} or 59% of the global total. While small-scale, single-family domestic applications represented 90% of the operational Chinese SWH market in 2009, large SWH systems for broader and more sophisticated uses are rapidly gaining market share. Together, applications in apartment buildings, tourism-sector installations (e.g., hotels), public-sector institutions (e.g., hospitals), combination hot water and space heating systems and low-temperature industrial processes constituted 30% of newly installed 2009 capacity (Weiss and Mauthner, 2011).

Other significant markets exist in Europe (32.5 GW_{th}), e.g., Germany, Italy, Spain, Austria and France, and the United States and Canada (15.0 GW_{th}). Emerging economies show rapidly expanding market penetration, such as Turkey (8.4 GW_{th}), Brazil (3.7 GW_{th}) and India (2.2 GW_{th}). In 2009 the worldwide market grew by 25.3%, with 36.5GW_{th} of newly installed capacity. China installed 89% (29.4 GW_{th}) of the total compared with 10% (3.7 GW_{th}) in Europe (ibid.). Figure 2 displays the total operational capacity for glazed collectors, that is, excluding unglazed collectors for swimming-pool heating.[5]

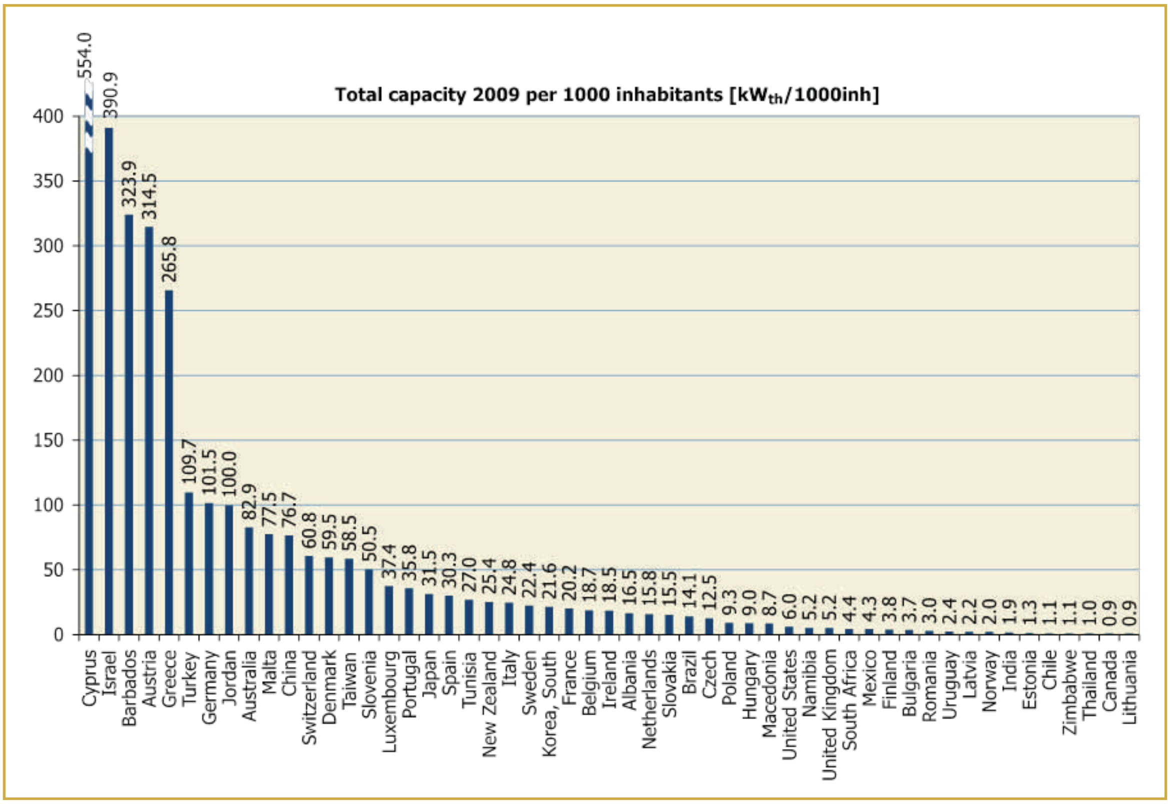
In contrast, in per capita terms (per 1000 inhabitants), several small countries continue to rank highest. In 2009, Cyprus had a per-capita operational capacity of 554 kW_{th}, followed by Israel (391 kW_{th}), Barbados (324 kW_{th}), Austria (315 kW_{th}) and Greece (266 kW_{th}) (Figure 3). Especially Austria's position as a leader in per-capita and total operational capacity underscores the crucial role of targeted and coherent policy support in building a sustainable SWH market, despite

Figure 2. Total capacity of glazed flat-plate and evacuated tube collectors in operation, end of 2009 [MW_{th}]



Source: Weiss and Mauthner, 2011

Figure 3. Total capacity per 1,000 inhabitants of glazed flat-plate and evacuated tube collectors in operation, end of 2009, [kW_{th}/ 1000 inhabitants]



Source: Weiss and Mauthner, 2011

relatively unfavourable solar irradiation levels (1126 kWh/ M^2/ year).

Germany's long-standing leadership in the global solar photovoltaic market[6] constitutes a parallel example of renewable electricity. Strong and predictable policies and incentives underpin Germany's success despite the country's relatively poor solar resources (for more information, see article by Haselip on 'feed-in tariffs' in this volume).

In terms of the supply chain, European and Chinese producers dominate the global solar thermal industry. While Chinese collector production was estimated to eclipse that of European manufacturers by a factor of six in 2008 (28 million M^2 versus 4.8 million M^2), most of this is destined for the domestic market. Exports, though increasing in absolute terms, represent only 5-10% of production volume (Fawer and Magyar, 2009; Li and Ma, 2009). Nevertheless, concerns persist among industry analysts about the inferior collector quality offered by many Chinese producers, though these are being addressed by stringent product standards recently imposed by Chinese regulators (ibid.).

The solar thermal industry is relatively labour-intensive, with more than half of total employment in the installation and maintenance phases, so it offers significant potential for macroeconomic benefits (Hardie, 2011). Global employment in 2009 was estimated at 270,000 jobs in production, installation and maintenance (Weiss and Mauthner, 2011).

Cost trends[7]

The costs of providing heat from solar collectors depend heavily on:

(i) the collector energy yield, which is a function of the solar resource available in a particular location and of the efficiency of the SWH system,

(ii) the system purchase price and installation costs, which in turn depend on the availability of a supply chain operating at sufficient scale to provide low cost collectors, and

(iii) the solar fraction, which indicates the proportion of the total hot water load provided by solar thermal collectors.

In favourable conditions, the technology can be cost-effective and offers payback periods comparable with conventional water heaters. For example, a cost comparison of water heaters in China indicates that, although the upfront cost of solar water heaters is higher than electric or gas water heaters, the average annualised life-cycle cost over the heater lifetime is considerably lower (Table 1).

Tropical and sub-tropical countries, such as South Africa and Tunisia, with high insulation levels ranging from 1700-2600 kWh/M^2/ year (Edkins et al., 2010a; GTZ, 2009), can generally benefit from relatively low average costs of thermosiphon systems, which can be mounted on building roofs in frost-free climates, and from relatively high average solar fractions due to high solar energy yields and small hot water loads, which translate into lower system life-cycle costs and payback periods.

SWH policy environment

Policy support for renewable heat is low compared with renewables-based electricity or biofuels for transport. Policy design for renewable heat differs from renewable electricity due to a number of key differences between the delivery and trade of heat and electricity (Connor et al., 2009).

Some countries, such as China and Israel, which both have substantial solar resource potentials and relatively high commercial energy prices now have high market shares for SWH systems without relying on continuing incentive support. In China, by 2008 the market share for SWH systems had reached over 50% in urban areas, more than tripling from about 15% in 2001 (IEA, 2010b). In 2007, Israel had over 1.3 million solar water heaters in about 90% of residences, covering about 4% of the country's energy demand and reducing its electricity consumption by 8%. In both countries, the market was enabled by a combination of concerted R&D efforts, energy efficiency and building regulations, the development of an integrated domestic supply chain, favourable resource conditions which promoted market-driven growth, energy security concerns relating to high and volatile conventional energy prices and major cost reductions for SWH technology (ESTIF, 2007; Li and Ma, 2009; IEA and RETD, 2007). In Israel, due to the solar obligation[9] for new buildings introduced in 1980, solar thermal has reached the critical market size

Table 1. Cost comparison of water heaters in China

	Electric water heater	Gas water heater	Solar water heater
Hot water supply (litres/day)	100	100	100
Equipment investment (USD)[8]	186	155	279
Annual operating cost (USD)	78	54	0.78
Lifetime (years)	8	8	10
Average annual cost (USD)	101	87	29

Source: Li and Ma, 2009

necessary to generate self-sustained growth without any subsidies (ESTIF, 2007).

Capital grants, i.e., direct financial subsidies for purchasing SWH systems, are the most widely implemented financial mechanism to date for this technology option. In successful cases, a range of other supporting financial and non-financial measures has backed up these investment incentives.[10] For example, in Austria, where 20% of all single-occupancy residences have solar heating, solar energy has been given priority in R&D programmes and regional strategies for over twenty years, backed up with accompanying socioeconomic research and supported by regional investment subsidies. Less widespread financial instruments used to support SWH deployment are fiscal incentives and low-interest loans. Complementary regulatory measures include solar obligations, which require a certain proportion of heat to come from solar energy.

Besides well-designed financial support to foster SWH market uptake, non-financial measures, including concerted awareness-raising among end consumers and the finance sector, adequate training for installers and maintenance technicians, and stringent quality standards for system hardware, are fundamental ingredients in the different 'recipes for success' implemented by market leaders, such as Austria, Germany, Greece and Israel (for detailed information, cf. IEA and IEA-RETD, 2007; IEA-RETD, 2010; Connor et al., 2009). This underscores the crucial importance of embedding incentive support in a coherent overall policy framework that tackles non-economic barriers, such as administrative hurdles, lack of information and training, and social acceptance issues (IEA, 2008b).

Though the largest policy-driven SWH markets remain primarily (net energy importing) industrialised/ OECD countries, developing and emerging economies, especially those with good solar resources, are also increasingly introducing targets and policies to encourage the use of SWH. Countries with solar hot water targets include Morocco, Mozambique, Uganda, China and India. Municipal governments in developing countries are expanding their role in promoting SWH, mirroring similar trends for renewable electricity and low-carbon transport technologies, and often stimulating national or federal policy implementation. Besides demonstration projects, regulatory policies mandating the use of SWH in new constructions are a key measure advocated by local governments, linked to the desire to exploit their communities' low-carbon development potential. Relevant examples include Cape Town in South Africa (discussed in the South Africa case study below), several large cities in Brazil, such as Porto Alegre, Rio de Janeiro and São Paulo, China, e.g., Kunming and Dezhou, and India, e.g., Nagpur (REN21, 2011).

The subsequent case studies exploring experiences in promoting SWH in two developing countries with high solar resource potentials, Tunisia and South Africa, illustrate the fundamental importance of creating supportive framework conditions which enable the SWH market to grow sustainably and eventually become self-supporting without incentive support.

Case studies: Tunisia and South Africa

Tunisia is an example of a country showing marked success with its SWH policy support programme, which has spurred similar policy initiatives in neighbouring developing countries such as Egypt, Morocco and Algeria, as well as in other world regions, for example, Mexico. In comparison, South Africa's more recently introduced SWH policy measures, though impressive on paper, have had a less marked impact on market growth to date, with slower progress towards the established policy targets.

The impacts of the SWH policy programs in Tunisia and South Africa are evaluated here according to several key qualitative criteria and quantitative indicators:

Assessment of the support policies (adapted from Hack, 2006)

- Administrative ease:
    - *For applicants:* a high administrative burden involved in accessing the support incentive can represent a strong disincentive for potential applicants.

- o *For the implementation body or programme provider:* related transaction costs include costs of administration and monitoring, and possibly the establishment of a new implementation agency.

- *Institutional capacity:* regulatory bodies and implementing agencies need sufficient competence to ensure effective and cost-efficient policy implementation towards achieving market targets.
- *Public awareness and acceptance:* The main beneficiaries of support incentives, namely the end consumers, require adequate information in order to be sufficiently interested in accessing the promoted incentives on the scale targeted by policy-makers. A comprehensive and transparent discussion of the socioeconomic impacts of large-scale SWH use can foster public acceptance.
- *Stringent quality assurance:* to instill public confidence in the technical maturity and quality of SWH systems and help establish a viable national SWH supply chain, appropriate training for installation and maintenance personnel and stringent system certification with strong technical standards and regular monitoring are crucial.
- *Market orientation and private-sector participation:* it is important for private-sector stakeholders (suppliers, installers, financial intermediaries) to be involved in policy design and implementation, e.g., as information and delivery channels for financial incentives. This will allow the policy to be suitably aligned with industry needs and financial sector capacities.
- *Credibility and predictability of the policy measure:* this ensures that potential investors have adequate confidence in the stability of the support system, which in turn reduces the perceived risk and the risk premium required by them (IEA, 2008b).
- *Sustainable impact on market development:* policy support should be designed in such a manner as to build market competitiveness towards the goal of making SWH market growth self-sustaining without promotional incentives. Incentives should be transitional, decreasing over time, to encourage earlier deployment but encourage market competitiveness (IEA, 2008b).

Quantitative policy impacts

- Capacity additions since inception of policy support
- Average market growth rate since inception of policy support
- Investment volume
- Carbon emission reductions
- Domestic industry growth
- Employment creation

Table 2 compares key market, policy and resource data relevant for evaluating the SWH policy experiences of the two countries examined. In order to place the SWH framework conditions and market performance of Tunisia and South Africa more fully in context, summary data for Austria, one of the global market leaders, is also provided.

Tunisia

Background

Tunisia's energy market is relatively small, with a population of 10.5 million in 2010. With its high standard of living (e.g., literacy and education) the country has the third highest human development index ranking in Africa and ranks as the most competitive economy on the continent (40th in the World Economic Forum's global competitiveness ranking 2011-12).[21]

Tunisia has excellent solar irradiation levels (see Table 2), with more than 3200 hours of sunshine per year, and estimates suggest that SWH could meet about 70-80% of Tunisia's residential hot water demand (Menichetti and Touhami, 2007). However, despite the large potential that SWH presents, the country continues to rely heavily on (subsidised) conventional

Table 2. Key SWH-relevant data for Tunisia and South Africa

	Tunisia	South Africa	Austria
***Success indicators*[11]**			
Total installed solar thermal collector area [m^2]/ capacity [MW_{th}] in operation (2009)	405 000 m^2/ 283.5 MW_{th}	1 063 360 m^2/ 744.4 MW_{th}	4 305 792 m^2/ 3014.3 MW_{th}
Share of glazed : unglazed collectors in operation (2009)	100% : 0%	29% : 71%	86% : 14%
Additional glazed[12] collector area [m^2]/ capacity [MW_{th}] installed in 2009	85 000 m^2/ 59.5 MW_{th}	34 000 m^2/ 23.8 MW_{th}	356 544 m^2/ 249.6 MW_{th}
Penetration of glazed collectors (per 1000 inhabitants) [kW_{th}] (2009)	27[13]	4.4[14]	314.5
Policy support			
Start of SWH policy support	Stop-and-go sporadic nature: - Initial policy strategy: early 1980s - GEF/Belgian programme: 1996-2001 - Current incentive framework (PROSOL): since 2005	2008	Mid-1980s
SWH-related target	2010: 255 000 m^2 collector area installed 2011 (2007-2011 11th Five-Year Development Plan): 540 000 m^2 collector area installed 2014 (2010-2014 12th Development Plan): 750 000 m^2 collector area installed	- RE Target by **2013** (set in Renewable Energy White 2003): 10 000 TWh by 2013 (13-23% SWH: 1 300-2300 TWh) National Solar Water Heating Programme: - **2014**: 1 million SWH systems installed (approx. equivalent[15] to min. 2 500 000 m^2) - 2020: 5 million SWH systems installed (approx. equivalent to min. 12 500 000 m^2)	- Overall RE targets by 2020 (EU Directive): 34.2% share of RE in gross final energy demand. - Official estimate of 2020 share of RE heating and cooling: 32.6% - Official estimate of 2020 share of solar heating in RE heating and cooling: 6.4%

contd.

Main SWH policies and incentives	- Renewable energy framework law (2004), revised in 2009 - Incentive programmes (grouped as PROSOL) since 2005: Capital grants, low-interest loans (via SWH suppliers) by commercial banks - Mandatory use of solar water heaters in new public buildings	- Solar Water Programme (2008) (i) Capital cost rebates and insurance to replace broken electric water heaters (for high income households) (ii) Bulk purchasing by dedicated SWH organization for mass rollout to low- and middle-income households through energy service companies (ESCOs)	- Federal level: Capital/investment grants - State/Provincial level: capital grants, concessional/ low-interest loans and extended loan periods
External factors			
Annual average Global Horizontal Irradiance [kWh/m^2/year] (Rating)[16]	1 980 (H)	2 282 (H)	1 126 (L)
Relative conventional energy costs (electricity/ gas or coal)	M/L	L/L	M/H
Relative cost of SWH technology[17]	H	H	H
Electrification rate (2009)[18]	100%	75%	100%
GDP (PPP[19]) per capita (2010) in USD	9,454	10,518	39,761
Human Development Index (HDI) ranking (2010)[20]	83rd (of 172 countries)	113th (of 172 countries)	25th (of 172 countries)

Based on (IEA-RETD, 2010) and (Hardie, 2011)

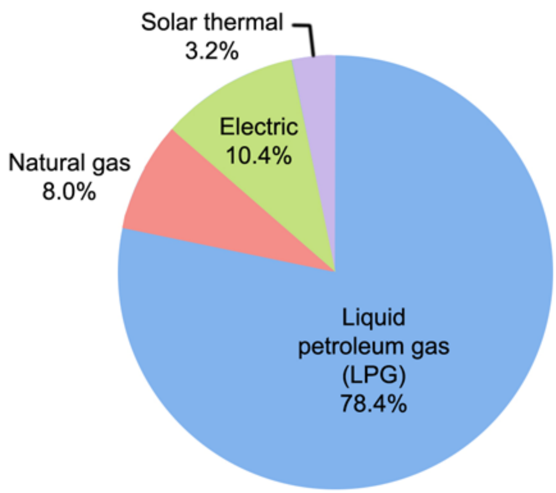
Sources: UNDP, 2011; IEA, 2010b; Weiss and Mauthner, 2011

fuels, with import levels continually rising (IEA, 2010a), as well as electricity for water heating (Figure 4).

This contrasts sharply with Israel, another country with similar solar resources in the Middle East and North Africa (MENA), which has, since the 1980s, installed a large amount of SWH. By 2009, close to a million systems, nearly exclusively for domestic hot water, with an installed capacity of 2848 MW_{th} were calculated to be in operation in Israel (cf. Figure 2), that is, ten times Tunisia's operational capacity (cf. Table 2) (Weiss and Mauthner, 2011).

Principal strategic drivers for Tunisia's policy interest in promoting SWH are (i) improved energy security

Figure 4. Shares of water heater types, Tunisia



Note: LPG refers to liquid petroleum gas

Source: Menichetti and Touhami, 2007

by reducing reliance on fossil fuel imports and diversifying the country's fuel mix, (ii) stemming the projected growth in electricity demand, especially peak load, which is partly due to the increasing use of electric water heaters, especially among the urban population, and (iii) providing industrial growth and employment opportunities in the face of a high 19% total unemployment rate, especially among generally highly educated young adults.

SWH market and policy experiences in Tunisia

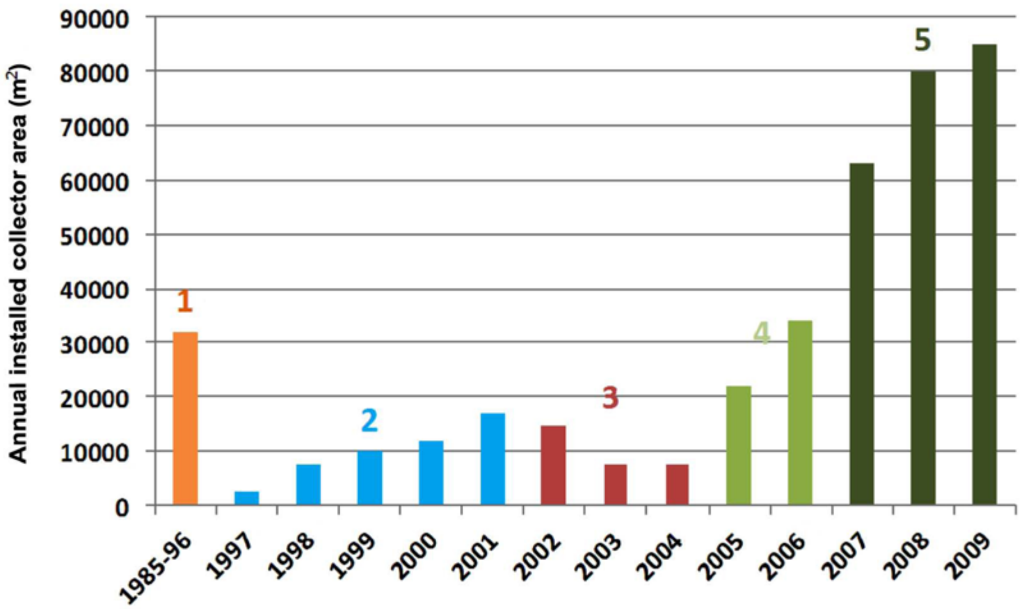
Tunisia has a long-standing interest in exploiting its renewable energy resources, which is visible in the creation of a dedicated National Renewable Energy Agency (ANRE) in 1985, which was replaced by the National Energy Management Agency (ANME) in 2004. Tunisia's policy support for SWH can roughly be divided into five phases (cf. the different colored phases denoted by numbers in Figure 5).

Figure 5 illustrates the marked impact on market growth in Tunisia of the 'stop-and-go' implementation of SWH policy programs.

The country first introduced a solar thermal strategy in 1984, though it showed little success in the absence of joined-up incentives and due to persistent system quality issues relating to the poor quality of the SWH hardware and a weak maintenance and after-sales service network (Alcor and Axenne, 2004). By the 1990s, the nascent SWH industry was in decline.

In a second phase, from 1996 onwards, the government aimed to revitalise the SWH market by improving the competitiveness of SWH relative to the dominant conventional LPG option, with a USD 7.3 million project financed through multilateral cooperation (the Global Environment Facility and the Belgian government). The involved capital cost subsidies (35% of the system capital cost) stimulated further SWH market growth. By the end of 2001, when the available subsidy budget (USD 6.6 million) had been exhausted two years ahead of schedule, 50,000 M^2 of new solar thermal panels had been installed, and eight suppliers (including three manufacturers) and over 130 installers were operating in the market, with a total of 260 new jobs created (Missaoui and Amous, 2003; Menichetti and Touhami, 2007).

Figure 5. SWH market development in Tunisia, 1985-2009



Note: The data for 1985-1996 refer to the cumulative installed collector area as of the end of 1996

Source: Menichetti and Touhami, 2007; Weiss and Mauthner, 2011

In the third phase, which followed the abrupt termination of the GEF project due to the depletion of its earmarked funds, the Tunisian SWH market dropped off dramatically, with annual sales more than halving from 17,000 square metres (M^2) in 2001 to 7,500 M^2 in 2005. This negative growth phase can be attributed to (i) the SWH market not yet having reached commercial maturity, i.e., still requiring incentive support, and (ii) persistent non-technical barriers, such as the lack of consumer financing options for SWH, the continued subsidisation of conventional fossil fuel options and the negative perception of domestically manufactured systems, despite the introduction of a quality control system (MVV decon and Wuppertal Institute, 2010).

In a fourth phase from 2005, the persistence by Tunisia's energy management agency ANME in improving the framework conditions to ensure a sustainable SWH market led to the PROSOL end-user financing facility for SWH, initiated by ANME and the (former monopoly) state-owned utility Société Tunisienne de l'Electricité et de Gaz (STEG) with support from the United Nations Environment Programme (UNEP) through the Italian-backed Mediterranean Renewable Energy Programme (MEDREP). The objective of PROSOL was to accelerate the penetration of solar water heating in Tunisia by targeting domestic financial institutions.

The innovative aspect of PROSOL lies in its efforts to actively involve all sector stakeholders, particularly the finance sector. By identifying new lending opportunities with the aid of targeted capacity-building, domestic banks started building dedicated loan portfolios.

The main features of the PROSOL financing scheme were:

- The provision of loans by commercial banks to residential consumers (via accredited system suppliers), covering about 70% of SWH system costs, which were repaid through the electricity bill. The monthly loan repayments were structured to match current monthly spending on other forms of energy.

- The commercial banks involved agreed to subsidised interest rates, gradually phased out after eighteen months, and extended five-year consumer loan periods, based on a guarantee by STEG.[22]
- A 20% capital cost subsidy, funded by the Italian government, for 200-litre and 300-litre systems up to TND 100 (USD 71.9)[23] per square metre (M^2) of collector surface.
- Consumer eligibility for PROSOL was linked to having an existing electricity supply contract with STEG, which was authorised to cut electricity provision in case of non-payment, which in turn led to low levels of payment default. This utility-channeled billing helped reduce the loan default risk perceived by banks, which accepted lower-than-commercial loan repayment rates for residential SWH system owners.

In this manner, end-users only paid a small part (approximately 10%) of the SWH system costs. SWH suppliers, on the other hand, were exposed to high debt levels, as they were the banks' intermediaries and passed on the financial support to their residential customers, the final beneficiaries of PROSOL.

A series of supportive accompanying measures were introduced, consisting of quality standards, certification and supplier accreditation schemes, extensive public awareness-raising campaigns, capacity-building programs for ANME officials, financiers and installation training (GTZ, 2009).

The cost of the two-year programme amounted to USD 2.4 million funded by the Italian government, with USD 1 million used by UNEP for the interest rate subsidies and USD 1.4 million by ANME for the capital cost subsidies and public awareness campaigns (Hack, 2006). An independent third party audited the programme in early 2007, which ensured transparent monitoring.

The initial PROSOL programme, which lasted until the end of 2006, had a rapid and visible impact on market development:

- The SWH market tripled within PROSOL's first year to 23,000 M^2 (7,500 systems) installed by the end of 2005. In 2006, the 34,000 M^2 annual surface area installed surpassed the cumulative capacity installed between 1985-1996 (cf. Figure 5). Flat-plate collectors constituted the majority of systems, although evacuated tube collectors are steadily increasing in market share, from 2.5% of new installed collector area in 2007 to 17.4% in 2009 (Weiss and Mauthner, 2011). According to the available data, the whole SWH collector area is used for hot water production in the residential and commercial sectors, with no surveyed solar swimming-pool heating (Weiss and Mauthner, 2011).
- The supply chain expanded substantially after the GEF project (phase 2): the number of SWH equipment suppliers increased to 14, among them six manufacturers, while there were 384 installers.
- Bank loans (by two partner financial institutions) to 20,000 households represented a value of more than USD 12 million, leveraging the programme cost five-fold. Tunisia's sophisticated financial and credit markets and highly educated work force certainly played an important role in ensuring the rapid expansion of credit-based financing for SWH.

An important external factor contributing to the sustained market growth for SWH in Tunisia is the large size of the country's middle class,[24] representing 45.6% of the population in 2010 (AfDB, 2010), with relatively high levels of disposable income and high education levels, as indicated by its HDI ranking (cf. Table 2). Home ownership averages 80% of households, thanks to affordable mortgages and low interest rates. Owner-occupiers are more likely to purchase an SWH system with high upfront capital costs or to obtain a relevant loan, as the benefits of reduced fossil energy consumption accrue directly to them. The opposite is the case for landlords and tenants, who have 'split incentives'.[25]

In a fifth phase, which continues to date, the successful outcomes of PROSOL and the enhanced capacity in its implementation agencies prompted the Tunisian government to set ambitious deployment targets and institute a similar SWH support framework, with several improvements, as well as additional financing measures in national legislation. Policy support for SWH is embedded in Tunisia's wider energy efficiency and climate change strategy, which aims (i) to reduce the country's energy intensity by 3% per year between 2008 and 2011, and (ii) to reduce primary energy consumption by 20% over the same period relative to a business-as-usual baseline scenario assuming no energy efficiency measures.

In 2005, the Tunisian government promulgated a framework law, which introduced wide-ranging support for energy efficiency and renewable energy activities, including solar water heating projects in the residential and commercial sectors:

- A 20% capital cost subsidy, up to TND 100 (USD 71.9) per square metre (M^2), for all new SWH installations.
- The interest rate for bank loans for residential use was set at the 'Tunisian money market monthly average rate (TMM) + 1.5%'. Thus, in July 2011 for example, the interest rate charged would have been 4.25% (TMM) + 1.5% = 5.75%.
- The financial support for SWH systems stems from a newly implemented energy efficiency fund FNME. These incentives are funded by tax revenues from motor vehicle registrations and VAT and custom duties on air-conditioning systems.
- Indirect tax benefits: exemption of SWH systems from VAT and reduced 10% customs duties.
- Regulatory policy mandating the use of SWHs in new public buildings.

These measures have helped level the playing field between SWH systems and the subsidised fossil fuel alternatives, LPG-fueled and electric boilers.

Since 2007, Tunisia has developed three new financial support mechanisms based on PROSOL for the residential, tertiary (service and tourism) and industrial sectors:

1. The 'PROSOL II' programme introduced improvements to the existing residential PROSOL initiative co-financed by UNEP. The main changes include the direct granting of loans to residential customers to reduce the debt burden on suppliers, a wider choice of loan/credit levels and the simplification of administrative procedures. By the end of 2008, 80,000 M^2 of collector surface had been installed, and a network of 30 suppliers and 733 installation and service professionals created. The programme aims to install 390,000 M^2 of solar collectors in the residential and small business sectors by 2011.
2. The 'PROSOL Tertiary' programme, implemented in late 2007, targets SWH system penetration in tourism-related complexes, such as hotels, public bathhouses and collective buildings, e.g., private clinics. An innovative component is an incentive to cover maintenance costs, the absence of which had contributed to a substantial share of earlier SWH systems installed during the GEF project no longer functioning by 2007. Nevertheless, contrary to the success of the residential PROSOL programme, PROSOL Tertiary failed to achieve its installation target of 45,000 M^2 collector area in 80-100 hotels between 2007-2009, having installed only some 2,000 M^2 in 19 hotels by early 2011 (MEDREC, 2008; CFO, 2011).

   The lower demand in the tertiary sector than in the residential sector, despite a higher 30% investment cost ceiling, is due to several challenges:

   - Higher administrative burdens.
   - The incentives only include capital cost subsidies: no bank loans are offered.

- o Hotels remain skeptical about the technical maturity of SWH systems in the face of constant hot water demand.
- o Commercial installations can obtain subsidised natural gas, which is cheaper than the LPG alternative for residential consumers.
- o An additional obstacle might be the possibility of insufficient carbon finance revenues (detailed below), which were expected to replace the financing from the Italian government and UNEP from 2009 onwards.

3. The 'PROSOL Industrial' initiative, introduced in 2008, targets industries able to use solar thermal heat in their processes, e.g., food processing. Forty prefeasibility studies had been completed by the end of 2010.

Recognizing that annual SWH market growth was averaging 20-30% (cf. Figure 5) and that the installed SWH collector area in 2009 (405,000 M^2) was fast approaching the earlier target of 540,000 M^2 by 2011, the Tunisian government set a much more ambitious target of installing 750,000 M^2 over the period 2010-2014. Such a market expansion to approximately 1 million M^2 cumulative capacity by 2014 would involve market growth rates comparable to those in much larger and more populous countries such as Spain or Italy (Menichetti and Touhami, 2007).

In late 2009, the government boosted the ambition level of its solar energy promotion with the launch of the first Tunisian Solar Plan (TSP) 2010-2016. The TSP aims to increase the country's share of (non-biomass) renewable energy in primary energy from 0.8% in 2008 to 4.3% in 2014, within an overall objective to reduce energy consumption by 20% and reduce annual greenhouse gas emissions by 1.3 million tonnes of CO_2 eq. (representing 6.3% of the country's 2008 fuel combustion-related CO_2 emissions) between 2010 and 2016. This is a tacit acknowledgement on the part of the previous Tunisian government that the previous policy framework had been insufficient to achieve the earlier target of 11% renewable energy in primary energy demand by 2011. The USD 2.6 billion strategy, relying heavily on private-sector participation and foreign developers, covers forty projects relating to the use and manufacturing of SWH systems, solar photovoltaic systems, and concentrating solar power units for electricity generation.

Notwithstanding the change in regime in January 2011, the new Tunisian government is showing a commitment to continue supporting the widespread adoption of energy efficiency and renewable energy policies towards achieving their targets.

Tunisia's involvement in international cooperation projects on renewable energy and climate change serves to complement and reinforce the sustainability of its existing national policy efforts. 'PROSOL II' and 'PROSOL Tertiary' programs have both been approved as a programmatic Clean Development Mechanism (CDM) activity. Revenues from the sale of CDM carbon credits from both programs will be used to fund the PROSOL tertiary programme. International donor funding also forms part of the TSP.

The successful establishment of a self-sustaining SWH market through PROSOL has stimulated a new multilateral initiative to transform and strengthen SWH markets globally, established in 2009 in five countries (Algeria, Lebanon, India, Mexico and Chile) (Usher, 2010). The programme focus, as in PROSOL, is on designing and implementing tailored financing mechanisms to make capital-intensive SWH competitive with conventional heating systems in the different markets and on building stakeholders' capacity.

Assessment of Tunisia's SWH policy support

Tunisia's experience with the PROSOL umbrella of SWH policy programs is assessed against the different evaluation criteria. Due to a lack of consistent data on programme monitoring and verification, Table 3 uses qualitative scores – positive (+), neutral (o) and negative (-) – to make the assessments comparable between Tunisia and South Africa.

Table 3. Evaluation of Tunisia's SWH policy promotion

Indicator	Score	Details
Administrative ease for the applicant	+	Very simple mechanism
Administrative ease for the implementation agency	+	- The pre-existing infrastructure of the public utility *STEG* can be used for the loan payback - Low bureaucratic effort, because banks and producers can be involved as well
Institutional capacity	+	The Tunisian energy agency ANME already had long experience of managing renewable energy and energy efficiency programs before the introduction of PROSOL. The emphasis on capacity-building within the initial PROSOL program helped further enhance the ability of the Tunisian implementing body to effectively manage and monitor the policy promotion for the large-scale deployment of SWH systems.
Public awareness and acceptance	+	The wide-ranging and focused information campaigns across all communication media in Tunisia, which formed part of the PROSOL program design and were organized by ANME with support from the international project partners, have helped inform the educated population about the costs involved and the benefits gained from using SWH.
Stringent quality assurance	+	Current situation: SWH products must meet technical requirements, efficiency and performance standards set by ANME Quality labels are gradually being introduced: - PROSOL installers: require Qualisol certification - PROSOL suppliers: no product quality label yet implemented in the Tunisian market. Ongoing national regulatory move to make EU quality label for collectors Solar Keymark mandatory for PROSOL accreditation.
Private sector participation and market orientation	+	Participation of banking sector, producers, the national energy agency as well as the public utility *STEG*
Credibility and predictability	+	• Credible framework, because incentive framework remains unchanged for households for the duration of support • Predictable policy with targets and policy support embedded in multi-year economic development plans • The financial sector gained confidence, so that banks finally began to offer credits directly to households to purchase SWHs.

contd.

Sustainable impact on market development	o	• PROSOL has fostered the establishment of solar thermal industry • The credit-based system and market growth has become self-sustaining with the phase-out of interest subsidy on the residential (and small business) loans. • However, the medium-term funding for the SWH capital cost subsidies needs to be placed on a more sustainable footing, because the revenue stream from the national energy efficiency fund FNME is highly cyclical. The dependence on the public budget and therefore on economic cycles presents a high risk of diversion of revenue for other purposes.
Capacity additions since inception	+	• PROSOL-linked results (end of 2009): 285 000 m^2 installed collector surface (95 000 units) • Total cumulative capacity installed in Tunisian market (end 2009): 405 000 m^2
Average annual market growth rate	+	Since PROSOL inception (2005-2009): 29% average annual growth rate
Investment volume	+	• Total SWH market value for period 2005-2008: USD 80 million • Bank loans: USD 47 million (end 2009), compared with USD 2.4 million cost of initial PROSOL program • Avoided LPG subsidies: about USD 17 million (TND 19.7 million) in 2005-6.
Carbon emission reductions	+	PROSOL results: 0.55 million tonnes of CO_2 equivalent (2.7% of Tunisia's carbon emissions from fuel combustion in 2008)
Domestic industry growth	o	2009: 1000 qualified installers (tenfold increase rel. to 2002); 42 suppliers (fourfold increase rel. to 2002); 6 manufacturers (as of 2008) – the current market seems to still depends on imported systems, e.g. from China
Employment creation	+	As of end 2010: approximately 5000 jobs in manufacturing, importing and supplying SWH systems

Sources: author's own analysis; Hack, 2006; Usher, 2010; Menichetti and Touhami, 2007; Weiss and Mauthner, 2011; IEA, 2010e

South Africa

Background

South Africa has an excellent solar resource (cf. Table 2), with up to 3800 hours of sunshine per year, even in large metropolitan areas, where most of the projected energy demand growth is concentrated (Edkins et al., 2010a). SWH's very high technical potential could meet about 80% of South Africa's residential hot water demand (ibid.). Water heating represents a relatively large 40% share of residential electricity use, which in turn constitutes 17% of the country's total electricity consumption (Hardie, 2011). However, despite the large potential that SWH presents, the country continues to rely heavily on electricity for water heating in urban electrified areas[26] and traditional unsustainable use of biomass in rural non-electrified areas.

South Africa's energy market is relatively large, with a population of 49.3 million in 2010. Its medium human development ranking is lower than Tunisia's, with high levels of inequality in terms of income and access to education (cf. Table 2). The country ranks as the third-most competitive economy on the continent (50th in the World Economic Forum's global competitiveness ranking 2011-12).[27]

The country's electricity sector is characterised by:

- a monopoly supplier, Eskom, which also dominates generation capacity;
- a history of supplying cheap electricity, generated by domestic coal resources, with non-cost recovering tariffs and high levels of non-payment by customers;
- a lack of investment in generation and transmission capacity and resulting electricity shortages. This led to a wave of rolling blackouts and power rationing after 2008; and
- a relatively low 75% overall electrification rate in 2008 (88% in urban areas, 55% in rural areas) (Edkins et al., 2010a).

South Africa's principal driver for promoting SWH systems is the aspiration to reduce energy consumption, as electric water heaters, which are the main heating option, contribute to peak power demands and frequent power rationing. Notwithstanding the energy-intensive nature of South Africa's major economic sectors, electricity demand has increased disproportionately (53% between 1990 and 2008), while no new generating capacity was commissioned between 2000 and 2006.

Additional strategic reasons for introducing a SWH policy framework are (Hardie, 2011):

- Reducing the economy's carbon intensity: South Africa's reliance on domestic cheap fossil fuel sources has meant that the country is an inefficient energy user and one of the world's leading contributors to greenhouse gas (GHG) emissions (13th largest global emitter and eighth highest per capita emitter (IEA, 2010e)).
- Industrial growth strategy: Large-scale SWH market and industry development has a high potential to generate wide socio-economic benefits, including job creation to combat high unemployment[28] (which is prevalent among disadvantaged black youth), local manufacturing capacities and export opportunities (Edkins et al., 2010b).
- Energy poverty reduction and social uplift: There is growing policy awareness that SWH use can alleviate energy poverty by reducing the vulnerability of low-income households, which often do not have access to electricity, and increasing their social, financial and physical capital stock (Wlokas, 2011).

SWH market and policy experiences in South Africa

South Africa's solar water heating market is made up of a large share of unglazed collectors (cf. Table 2), which, because of their low efficiency (no thermal insulation nor physical protection), are mostly used for swimming-pool heating. This market segment, which shows relatively constant growth, is generally not supported by incentive policies and therefore is not the focus of this article.

In comparison, the glazed collector (flat-plate and evacuated tube) market sector has not experienced smooth and constant growth in the past thirty years. Following an early growth spike in 1979-1983, the market stagnated until 2005. While a general renewable energy target of 10,000 TWh by 2013 (about 4% of projected electricity demand) was set in the 2003 Renewable Energy White Paper, towards which SWH was projected to contribute 13% (or 1,300 TWh), the target was not accompanied by a policy framework.

Instead, rapid SWH market growth (see Figure 6), with system sales increasing by 42% annually, coincided with the extended period of power curtailment and load shedding between 2005 and 2008, due mainly to a concerted information campaign by Eskom (Edkins et al., 2010a). However, domestically manufactured supply lagged considerably behind demand growth at that time, with a national manufacturing supply of 10,000 M^2 compared to 30,000 M^2 of glazed collector demand in 2008 (Edkins et al., 2010a).

Successful municipal strategies to support SWH paved the way for a national SWH programme. In 2006 Cape Town implemented its energy and climate change strategy, which included a 2010 goal of a 10% penetration of SWH in all households and in municipality-owned housing. In total, this represented approximately 88,000 systems. To achieve its target, the city government has drafted an energy-efficient water-heating by-law or building regulation requiring the installation in new housing, public buildings and extensions to existing buildings of SWHs or other energy-efficient water-heating equipment using a maximum of 30% of the energy of a standard electric standard hot water boiler. However, legal challenges have delayed the building regulation's implementation since 2007.

Pilot projects in the Cape Town metropolitan region, e.g., Kuyasa (2,300 SWH systems), the first South African CDM project and the first Gold Standard CDM project worldwide, and in Nelson Mandela Bay Municipality (60,000 SWH systems), tested innovative financing mechanisms. In a leasing model, accredited energy service companies (ESCOs) or a municipal SWH entity install SWH systems for participating customers, who pay a fixed municipal service levy through their monthly water bill to repay the SWH investment cost. The ESCO or municipal SWH entity remains the owner of the system until the initial cost outlay is recovered. Municipal SWH entities, which are responsible for mass rollouts of SWH system for low-income groups, have the benefit of being able to buy down individual system costs.

In response to the electricity supply crisis, Eskom initiated a demand-side management (DSM) programme in 2008, which also comprised a National Solar Water Heating Program (NSWHP) to contribute to achieving the 2013 renewable energy target. Revenue from annual average electricity tariff increases of 25% between 2010 and 2013 is partly dedicated to financing the government's renewable energy strategy, including Eskom's SWH subsidy scheme, detailed below.

The phased programme objectives are to (i) install 1 million SWH systems by 2014, and (ii) 5 million systems by 2020, which is projected to be equivalent to a 50% share of residential water heating. The NSWHP adopts a phased approach in order to increase national SWH production capacity and create a high-quality supply chain, which is anticipated to benefit from industrial financing:

- Annual installation capacity should increase from 35,000 units in 2009 to 250,000 units by 2013/14.

  Annual manufacturing capacity should increase from currently 20,000 units per year to 200,000 units by 2013/14 (Hardie, 2011).

The NSWHP divides the potential SWH market into three target segments by income bracket:

1. High-income group (income levels above ZAR 16 000 – USD 2322[29]), with a market size of approximately 1.2 million households.
   - o The target in terms of installed systems is 210,000 by 2014 and 560,000 by 2020.
   - o The main incentives applied are (i) an Eskom-administered capital cost subsidy or rebate scheme, and (ii) compulsory replacement of phased-out electric water heaters by SWH systems by home insurers.
   - o Rebates are available for (domestically manufactured and imported) systems supplied by accredited producers and installers, which satisfy the minimum standards set by the national standards bureau. Rebate levels are subject to decreases depending on the evolution of market growth.
2. Middle-income group (income levels ZAR 6,000-16,000 – USD 871-2322xxviii), with a market size of approximately 3 million households.
   - o The target in terms of installed systems is 450,000 by 2014 and 1,750,000 by 2020.

- o The main measure with which to achieve these ambitious targets is the introduction of a dedicated SWH entity, with a national mandate to procure SWH systems for mass rollout. The main aim of such a SWH 'champion' is to provide affordable systems by bulk-buying low-cost quality units, e.g., through standard offers, tendering large supply contracts and carefully managing the supply chain. This delivery mechanism is expected to make use of leasing schemes with energy service arrangements, as in the Cape Town pilot project.

3. Low-income group (income levels below ZAR 6,000 – USD 871), with a market size of about 6.6 million households.
    - o The target in terms of installed systems is 340,000 by 2014 and 2,690,000 by 2020.

      As under 2. (Hardie, 2011).

Thus, the South African government is evidently focusing its policy efforts in the first phase of the NSWHP to 2014 on expanding the SWH market among high- (and middle-income) households, which can more easily afford to purchase the capital-intensive systems on an individual basis. This focus is meant to allow the domestic industry to scale up sufficiently so as to meet the mass rollout objectives for the low- and middle-income population segments in the second programme phase to 2020. As of mid-2011, the planned national SWH entity had not yet been instituted, threatening the achievement of up to 75% (i.e., the low- and middle-income market segments) of the envisaged 1 million installed systems by 2014.

However, market growth for glazed collectors since implementation of the NSWHP has not been smooth (Figure 6).

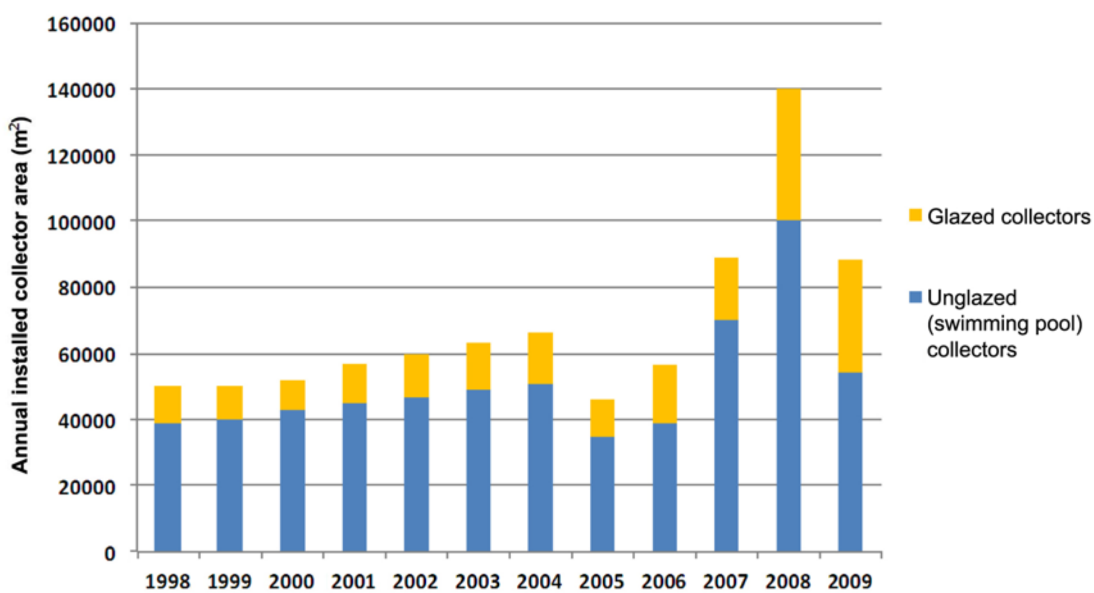
It is important to note that in the initial phases of the NSWHP (2008-2009) most SWH market growth occurred outside the Eskom rebate scheme. This trend is probably linked to the lengthy waiting period for testing SWH equipment to obtain approval to qualify for the Eskom subsidy scheme.

As Figure 6 shows, the entire glazed collector market more than doubled between 2007 and 2008 to 39,000 M^2 of new collector area, but then declined in 2009 to 34,000 M^2. This downward trend was probably due to a combination of the economic downturn and public mistrust of the inadequate quality of hardware (e.g., low-quality Chinese imports) and faulty installations not accredited under the Eskom rebate scheme.

The Eskom subsidy scheme did not have a significant impact when it was first introduced at the beginning of 2008 with a 25% capital cost ceiling, leading to an uptake of only 1,000 new systems under the NSWHP in 2008. Therefore, in early 2010 Eskom doubled the available rebates to stimulate market demand and allow for a five-year payback period for SWH systems, which falls within the average 4-8 year payback period for the conventional electric alternative (Edkins et al., 2009a). Depending on collector efficiency and the system's local content share, the rebates ranged from ZAR 3,000-12,000 (USD 435-1742), compared with a unit cost range of ZAR 15,000-35,000 (USD 2 177-5 060). The average rebate covered 35% of the capital cost and about 28% of the total installed cost of a SWH system (Hardie, 2011). With these increases in the capital cost incentive and improved administrative procedures for consumers, 60,000 new systems were installed under the Eskom rebate scheme in 2010. This marked increase in consumer demand and resulting budgetary pressure led in turn to Eskom's decision to reduce the available rebates for newly installed systems by an average of 10-25% from 30 April 2011 (Engineering News Online, 14 April 2011). In addition, rebate restrictions have now been imposed to avoid the promotion of oversized systems.

In terms of multilateral support, in late 2009 the World Bank-managed Climate Technology Fund (CTF) approved USD 500 million to support South Africa's renewable energy and energy efficiency objectives. Policy and regulatory support for SWH systems is an important component of the investment plan. For example, the CTF funds aim to help develop the administrative and financing capacity of municipal power distribution companies (MPDs), which, as bodies involved in the mass rollout of SWH systems in the NSWHP, will be vital players

Figure 6. SWH market development in South Africa, 1998-2009



Source: Edkins et al., 2010a; Weiss and Mauthner, 2011

in expanding household SWH use. Expected uses of CTF financing include low-interest loans to MPDs to support the bulk purchase of SWH systems, risk guarantees for customer payment defaults under ESCO leasing mechanisms, and low-interest loans to SWH suppliers to facilitate their initial market entry and expansion needs. Thus, these international cooperation funds are anticipated to help support the creation of a sustainable domestic industry capable of meeting the country's large-scale deployment objectives (CIF, 2009).

In its 2008 programme, the NSWHP targeted the amendment of the national building regulations, following on from existing municipal policy drives, to incorporate an energy efficiency obligation on new or refurbished buildings to cover at least 50% of hot water demand by energy-efficient technologies, including SWH systems. This regulatory pull would help generate a sustained demand for SWH systems, encouraging national suppliers to increase their production and installation capacities. However, the introduction of the energy-efficient building code has encountered delays and will only come into effect in November 2011.

The outlook for the NSWHP to achieve at least its short-term 2014 targets is uncertain. While the rebate scheme has a high likelihood of meeting the objective of 210,000 installations in high-income households based on the latest market trends, this is not the case for the mass rollout of low-cost systems to low- and middle-income consumers. Without as yet a dedicated SWH entity charged with managing this substantial logistical challenge, it is unlikely that the majority of the targeted 790,000 systems will be installed by 2014.

Barriers to SWH market penetration in South Africa

As the previous section indicated, continued challenges to sustained SWH market growth in South Africa comprise demand and supply barriers.

Demand-side barriers include:

- High upfront capital costs that need to be met in advance of the rebate being reclaimed. The average rebate payment period is eight weeks.
- High financing costs for consumers in the absence of low interest rate loans.
- Low and subsidised electricity rates below cost-recovery levels.
- Lack of awareness regarding the benefits of SWH system use and environmental aspects.
- Competition from incumbent electric boiler technology with high production volumes and low costs.

Supply-side barriers include:

- Quality issues: (i) lack of quality control and standards for systems not accredited under Eskom's rebate scheme; (ii) onerous, lengthy and high costs of compliance in terms of equipment standards and installation guidelines for suppliers and consumers to qualify for the Eskom rebate scheme.
- Low research and development (R&D) investment: because of low investor confidence in the credibility of the government's promotion strategy.
- Low economies of scale.
- Skills shortages, especially for SWH system installation, which is more labour-intensive than for electric water heaters and requires different skills.
- Unsupportive external environment (especially critical for small enterprises): e.g., restrictive employment legislation, high costs of regulatory compliance, high crime rates.

While it does not necessarily impede demand for SWH systems, sustained competition from low-cost imports (40% of the 2009 market) constitute a barrier to the establishment of a domestic industry, as the lack of investor confidence reduces the willingness to invest in the necessary capital structure (Hardie, 2011; Edkins et al. 2010a).

The outlook for the NSWHP to reach at least its short-term goals by 2014 are uncertain. While the Eskom capital-cost incentive scheme is likely to help sustain market growth to meet the objective for the high-income segment, the planned mass rollout of SWH systems is much less likely to scale up to the level needed to achieve the much higher number of system installations for low- and middle-income households. A fundamental obstacle is the continued absence of a dedicated organisation charged with initiating and managing this logistical challenge. Evidently, the achievement of the medium-term goals to 2020 is considerably more difficult to predict.

Table 4 assesses South Africa's experience with the NSWHP programme against the different evaluation criteria.

Conclusions and recommendations

When looking to introduce SWH technology options in their economies, developing countries can benefit from the international experience, policy lessons, technical advances and cost reductions resulting from large-scale market deployments of commercially mature SWH technologies in first-mover countries. Nevertheless, the introduction of new energy technologies is likely to be accompanied by deployment challenges that are specific to the national context. Thus, in order for the market penetration of a new technology to progress sustainably and in line with target objectives, policy support should be carefully adapted to national market circumstances and accompanied by concerted measures to develop and enhance the capacity of all the stakeholders involved, including suppliers, regulators, the public and the finance community.

Effective policy options to scale up SWH in developing countries

For a policy to be successful, it has to provide efficient and effective ways of increasing renewable energy capacity (cf. IEA 2008b). Solar thermal heat offers enormous potential in Africa for providing domestic hot water production and to some extent industrial process heat.

Table 4. Evaluation of South Africa's SWH policy promotion

Indicator	Score	Details
Administrative ease for the applicant	o	• The administrative procedures for the SWH system end-user to apply for the rebate are relatively straightforward, though the numerous installation requirements impose additional costs. • However, the waiting period for the direct financial transfer/rebate receipt combined with the absence of concessional loans for residential buyers, i.e. a high upfront investment cost, may dissuade a sizable share of the potential market.
Administrative ease for the implementation agency	-	The Eskom rebate scheme entails complex accreditation procedures to be managed by Eskom.
Institutional capacity	o	• Eskom is deepening its experience in managing the SWH capital-cost rebate scheme • However, in sharp contrast, the planned SWH 'champion' to manage the mass rollout of low-cost systems for the majority of the population has not even been created yet.
Public awareness and acceptance	o	• Government information campaigns are gradually improving public understanding of SWH systems. • However, overall public acceptance of SWH is still relatively low due to mistrust of technical quality linked to a continued large proportion of low-quality systems in the market, though they are not approved for the Eskom subsidy scheme.
Stringent quality assurance	o	• While the minimum accreditation standards set by the national standards bureau are suitably high, the delays due to insufficient testing facility resources are too burdensome for suppliers. • The lack of quality control for the large portion of systems not approved under the Eskom scheme is a severe problem, causing public mistrust and undermining the overall success of the NSWHP.
Private sector participation/market orientation	o	• Private-sector system suppliers form an integral part of the NSWHP and were consulted on the design of the policy framework. • However, the market orientation of the SWH promotion system is not evident, e.g. there are no financing products for system purchase using existing credit markets.
Credibility and predictability	-	• At its current status, the NSWHP is not very credible: the delivery mechanism (national SWH entity) to achieve the bulk of the 2014 target market has not yet been implemented, slowing down the development of a full domestic supply-chain. • The NSWHP support scheme (rebate scheme) is not very predictable: the Eskom rebate provisions are subject to unexpected (and not clearly communicated) changes depending on public budget constraints.

contd.

Sustainable impact on market development	**o**	• The outlook for the achievement of the NSWHP market objectives of 1 million SWH installed by 2014 and 5 million by 2020 is uncertain (see analysis in previous section). Nonetheless, there is a high likelihood of the high-income category target being achieved based on recent market growth trends. • The NSWHP has not (yet) implemented credible measures capable of gradually moving the SWH market towards self-sustainability
Capacity additions since inception	**o**	• Additional capacity installed linked to NSWHP incentives (Eskom rebate scheme): not publicly available • Total additional capacity installed since NSWHP inception: 73,489 m^2 (2008-2009) + 60,000 units (approx. 100,000 m2) in 2010 = approx. 173,000 m^2 (2008-2010) • Total cumulative capacity installed in South African market (end 2009): 309,682 m^2; (end 2010): approx. 410,000 m^2
Average annual market growth rate	**o**	• Since NSWHP inception (2008-2010): 20% average annual growth rate • In 2010: 32% annual market growth rate
Investment volume	**n/a**[30]	Data not publicly available
Carbon emission reductions	**n/a**	Data not publicly available
Domestic industry growth	**o**	2010: approx. 190 suppliers accredited by Eskom rebate scheme; total number of suppliers: approx. 400 2009: Available annual production capacity (domestic manufacturers and importers): 200,000 m^2
Employment creation	**o**	2009: 700 people employed mainly in small new businesses

Sources: author's own analysis; Hack, 2006; Weiss and Mauthner, 2011; Theobald and Cawood, 2009

South Africa's mixed experience with investment cost subsidies, as in several industrialised economies (cf. Steinbach et al., 2011), highlights the risk of unpredictable changes to subsidy levels due to the instrument's dependence on public budgets and the importance of streamlined administrative processes to attract end-users. When direct financial incentives are implemented, they should offer incentives by energy (kWh) or capacity (kW or M^2) rather than as a percentage of installed cost. This reduces the likelihood of market price distortions and the prevalence of oversized installations.

On the hand, regulatory incentives such as solar building obligations have proved to be very effective and should be considered in all African countries, given their vast solar resources. Nevertheless, a major drawback of renewable energy building obligations is the necessary monitoring to ensure that the building code is being observed.

Innovative financial policies, such as the PROSOL scheme in Tunisia, which is aimed at shifting the solar thermal market from a cash-based to a credit-based market, could be effective in other countries where private consumers lack the necessary capital to cover upfront system costs. The role of commercial financial institutions is key because it can place the financing of SWH systems on a competitive and sustainable footing (cf. Srinivasan, 2009). In addition, bank lending can give policy-makers the assurance that SWH systems are technically mature. The experiences of UNEP in designing and implementing the PROSOL project suggests that banks require a scale of a minimum of 10,000 loans to continue expanding their lending portfolio independently of the initial policy programme (Usher, 2010).

Besides the specific design of the main support instrument, a country's framework conditions also need to be conducive to encourage large-scale SWH penetration (IEA, 2008b). A key challenge in opening up the market for renewable heat in many developing (as well as industrialised) countries consists of raising awareness that heat demand is responsible for an important part of final energy demand, and is thus an important issue in realizing CO_2 emission reductions, energy security and fuel diversification. Tunisia has overcome this issue with targeted ongoing public information campaigns.

Concerted capacity-building is a fundamental element in establishing a sustainable market for SWH, which eventually becomes competitive without financial incentives. Educational and technical assistance (whether through national or international channels) should be offered to implementing agencies, system suppliers and installers.

The experiences of Tunisia and South Africa also show how international development cooperation, such as UNEP's backing of PROSOL in Tunisia and the World Bank's CTF financing support for the NSWHP in South Africa, can effectively complement and leverage but not replace concerted and monitored national policy efforts. Taking 'ownership' of a promotion system should help ensure that national stakeholders, especially the responsible implementing agencies, equipped with sufficient training, move towards the large-scale market objectives in a transparent, consistent and efficient manner.

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Annex 1

SWH technology overview

Solar energy is the most abundant energy resource on earth, with the total annual solar irradiance reaching the earth's surface (approximately 3,400,000 EJ[1] or 944,444,444 TWh[1]) exceeding the world's total annual primary energy demand in 2008 (514 EJ or 142,712 TWh) by a factor of more than 7,500 (Thirugnanasambandam et al., 2010; IEA, 2010a). Besides its abundance, solar energy is versatile: it can be harnessed through different conversion processes – providing electricity or useful heat – for a variety of end-use applications, at different scales, temperature levels and degrees of grid connection, e.g., water pumping, domestic hot water, swimming-pool heating, industrial processes (sterilisation, water desalination), and large-scale grid-connected power (IEA, 2008a; IEA, 2009).

Active solar heating technologies[1] use solar energy to provide heat. The components within a solar thermal system vary depending on the application, but always include a collector to capture the sun's radiation and a conversion system to transform the energy into a useful heat output. Advanced systems have storage and/or a back-up system that uses an alternate (often conventional) fuel, such as natural gas. Solar radiation is captured by the collector and then stored as thermal energy in a circulating fluid, e.g., refrigerant/water or antifreeze/air. The heated fluid cools an absorber and then transfers the thermal energy to the second part of the system (tank), where it is converted into a useful heat output and distributed with fans, pumps and pipes for a variety of end-uses (IEA, 2009).

SWH systems can be distinguished by two main characteristics:

- Active systems, which include circulation pumps and controls, or passive systems, which rely on natural convection to move the heat transfer fluid between the collector and the tank. Active systems are generally more expensive and more efficient than passive ones. However, the latter are often more robust and reliable, requiring less maintenance due to the absence of a pump and controller. Nevertheless, passive systems, e.g., thermosiphon[1] systems, are prone to freezing and overheating and are therefore more suited to moderate though sunny climates.
- Direct ('open loop') or indirect ('closed loop') systems. Direct systems circulate household water directly through the collectors to the tank, while indirect systems circulate a heat-transfer fluid (e.g., distilled water or diluted antifreeze) through the collectors and then use a heat exchanger to transfer the heat to household water. Because of their sophistication, indirect systems are more expensive but offer the advantage of freeze and overheating protection.

The temperature required for each end-use dictates the type of collector used to harness the thermal energy. Collectors can be designed to provide water- and space-heating at a household scale with low temperature requirements (20°-80°C), but the technology is also being increasingly employed at larger scale to provide hot water for commercial and industrial operations with medium temperature requirements (80°-250°C), as in the food sector in Austria and other countries, or linked to district heating installations. The main collector technologies include unglazed and glazed flat plate, vacuum or evacuated tubes. For residential and commercial water and space heating, glazed flat plate and evacuated tube collectors (which dominate the Chinese market) are the most popular. Unglazed systems are used for swimming-pool heating.

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Endnotes

1. Mtoe = million (10^6) tonnes of oil equivalent (toe).

2. The subscripts '$_{el}$' and '$_{th}$', e.g., GW_{el} and GW_{th}, refer respectively to electric power and thermal power produced.

3. These estimates are thought to represent approximately 90% of the actual installed global capacity, as some data gaps exist (Weiss and Mauthner, 2011).

4. The presented data were originally collected in square metres. A methodology agreed between international experts uses a conversion factor of 0.7 kW_{th}/M^2 to derive the nominal capacity from the installed solar collector area (Weiss and Mauthner, 2011).

5. It is important to note that in South Africa unglazed collectors make up the largest market share, e.g., 71% of total operational capacity (744 MW_{th}) in 2009. However, due to its status as a luxury good, the market for swimming-pool heating was significantly affected by the economic contraction in 2008-9, with a 46.1% decline in 2009 annual installations (Weiss and Mauthner, 2011).

6. By year-end 2010, Germany held a 44% share both of worldwide cumulative installed solar PV capacity and new capacity additions (REN, 2011).

7. Detailed cost ranges for current SWH systems are given in (IEA and IEA-RETD, 2007), while (IEA, 2011) provides projections for future evolution of SWH costs under different long-term scenarios.

8. The exchange rate used is USD 1 = CNY 6.45 (average exchange rate on 15 July 2011).

9. Solar obligations are a common regulatory instrument requiring solar energy to supply a minimum share of heat demand in new and renovated buildings.

10. For in-depth discussions of policy experiences and good practice for SWH market penetration in OECD countries, see (IEA and IEA-RETD, 2007) and (IEA-RETD, 2010). For a deeper analysis of European Union (EU) countries, refer to (Connor et al., 2009).

11. (Weiss and Mauthner, 2011).

12. For the purposes of this article, the term 'glazed' collector encompasses glazed flat-plate and evacuated tube collectors, which are used for hot water preparation and space heating, which is the focus of this study. In contrast, unglazed flat-plate collectors are used for swimming-pool heating.

13. The penetration of SWH systems in Tunisia is very low relative to other energy sources. This is evident from the fact that solar energy's contribution to final energy consumption in the residential, commercial and public-service sectors – which is dominated by hot water production and space heating – is too small even to be captured in energy statistics. In 2009, fossil fuels (oil products, such as liquid petroleum gas or LPG and natural gas) represented 41% of final energy consumption in these sectors, followed by (mostly traditional use of) biomass (in the residential sector only) (37%) and electricity (22%) (IEA, 2011a).

14. The penetration of SWH systems in South Africa is negligible relative to other energy sources. This is evident from the fact that solar energy's contribution to final energy consumption in the residential, commercial and public-service sectors – which is dominated by hot water production and space heating – is too small even to be captured in energy statistics. In 2009, traditional unsustainable use of biomass in the residential sector represents the overwhelming share of final energy consumption across these end-use sectors (38%), followed by coal (31%), (predominantly coal-fired) electricity (25%) and natural gas (6%) (IEA, 2011a).

15. The estimate of installed collector area uses a conservative assumption that the average overall collector area of a SWH system for a four-person household is about 2.5 M^2. This assumption reflects two opposite trends in South Africa: (i) that demand for evacuated tube systems (with larger collector sizes than flat-plate systems) is growing significantly (Theobald and Cawood, 2009), and (ii) that the national SWH support program targets a large share of basic SWH systems (with relatively small collector areas) for low-income households, especially to 2020 (Hardie, 2011).

16. From (IEA-RETD, 2010): 'Irradiation below 1200 kWh/M^2 was considered a low solar resource (L). Between 1200 kWh/M^2 and 1400 kWh/M^2 was considered a medium solar resource (M). Above 1400 kWh/M^2 was considered a high solar resource (H).'

17. From (IEA-RETD, 2010): 'A SWH system costing less than 10% of the GDP (PPP) per capita including installation was considered low cost (L). A SWH system costing between 10%-15% of the GDP (PPP) per capita including installation was considered medium cost (M). A SWH system costing more than 15% of the GDP (PPP) per capita including installation was considered high cost (H).'

18. (IEA, 2010b).

19. PPP stands for 'purchasing power parity': PPP 'measure[s] the amount of a given currency needed to buy the same basket of goods and services, traded and non-traded, as one unit of

the reference currency [in this article, USD]. By adjusting for differences in price levels, PPPs, in principle, can provide a more reliable indicator than market exchange rates of the true level of economic activity globally or regionally' (IEA, 2010b).

20. (UNDP, 2011).

21. The Global Competitiveness Index of the World Economic Forum assesses countries on their performance in twelve so-called 'pillars' that build competitiveness: institutions, infrastructure, macroeconomic stability, health and education, higher education and training, goods market efficiency, labour market efficiency, financial market sophistication, technological readiness, business sophistication, and innovation (World Economic Forum, 2011).

22. 'Under PROSOL, the loan duration was five years instead of the usual three-year term. As for interest rates, the commercial lending rate for similar loan products in Tunisia is 14%. Within PROSOL, banks agreed to a 7% reduction. Through the MEDREP Fund, UNEP provided a 7% interest buy-down for loans disbursed in the first 12 months and 3% for subsequent loans. This means the rate initially charged to customers was 0% and, after 12 months, 4%' (Menichetti and Touhami, 2007).

23. The exchange rate used is USD 1 = TND 1.39 (average exchange rate on 15 July 2011).

24. The AfDB defines 'middle class' as those with a daily expenditure of USD 4-20 per day. Tunisia ranks highest among all African countries in terms of the population share of its middle class. The relative size of middle-class population segments across Africa averages 13.4% (AfDB, 2010).

25. 'Split incentives' are a specific example of the so-called 'principal-agent' problem. 'Principal-agent' problems refer to the potential difficulties that arise when two parties engaged in a contract have different goals and different levels of information. A common example is referred to as the landlord-tenant problem, which problem occurs when the landlord provides energy-using appliances (such as a refrigerator or lighting systems), but the tenant pays the electricity bill. In this situation, there is little incentive for the landlord to choose the most energy-efficient appliances (IEA, 2007).

26. In 2008, new SWH installations (10,000) were dwarfed by the size of the conventional electric heating market (720 000) (CIF, 2009).

27. The Global Competitiveness Index of the World Economic Forum assesses countries on their performance in relation to twelve so-called 'pillars' that build competitiveness: institutions, infrastructure, macroeconomic stability, health and education, higher education and training, goods market efficiency, labour market efficiency, financial market sophistication, technological readiness, business sophistication, and innovation (World Economic Forum, 2011).

28. South Africa's official unemployment rate in 2010 was 24.9%.

29. The exchange rate used is USD 1 = ZAR 6.89 (average exchange rate on 15 July 2011).

30. Not applicable.

Small community in Srinagar, India
Photo: UNEP internal archive

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Enabling environment and policy principles for replicable technology transfer: Lessons from wind energy in India

Abstract

This article examines cross-border technology transfer between Indian and Danish/German firms in the wind energy industry between 1990 and 2005. The analysis shows the increasing technology gaps between the two sides during this time period, the fragmented and non-performance-oriented market mechanism, the small market size, the policy inconsistency, the institutional inadequacy caused by the power sector restructuring process, the persistent infrastructure deficiency, and the lack of proper oversights, which all contributed to the slowdown of technology transfer after the initial strong transfer trends. The weak demand-pull and supply-push domestic forces in India prevented replicable technology transfer from happening, as technology providers and collaborators looked elsewhere for more reliable market investment opportunities and suppliers.

The research shows the centrality of policy and capacity building to support continuous and replicable technology transfer. Such a policy and capacity-building framework would consist of the following: the creation of sizable and performance-oriented domestic markets using policy incentives specifically designed for the particular technology; robust project/technology quality requirements to deter incentive abuse; support for physical infrastructure development to accelerate the flow of necessary products, components and services; and financial and technical support for supply-chain and technology-specific capacity building at firm and industry levels. The spectrum of the last, e.g., support for capacity building from manufacturing via project execution to operation, depends on each country's and/or firm's choices on 'what to make' at home and 'what to buy' from outside. Policy decisions in this area require strong communications with industry players and other experts.

Financial and political policy sustainability and, overall long-term consistency of policy frameworks with sound adjustments are essential. Building strong monitoring and evaluation capacity, public-private partnerships, communication pathways, and technology- and industry-specific strategic thinking are requisite for both business and policy communities. Capacity building support from the international community also needs to focus on this area.

Introduction

This article examines private-sector wind energy technology transfers from Denmark and Germany to India between 1990 and 2005. The topic was chosen because the sector has a record of international private-sector partnerships between European and Indian companies. Special attention was paid to: 1) the roles and effects of government policy and institutional settings; and 2) enabling environment for technology transfer in order to learn lessons for how developing countries can build favourable environments for replicable technology transfer involving climate change mitigation technologies and catch-up industries.

The article is structured as follows. After this introduction, section 2 describes Indian policy on wind energy development. Section 3 examines the technologies that have been transferred to India from the technology frontier of Denmark/Germany. Section 4 investigates the causal factors which created the technology transfer results. Lastly, Section 5 summarises the lessons learned from these experiences and makes policy recommendations.

Indian wind energy policy and programmes

India began to be serious about wind energy development during the 1980s in order to establish an indigenous industry and exploit further its wind energy potential. Its efforts in the 1980s were mainly technology-push (development of indigenous turbine prototypes; demonstration programs from 1985) and wind data collection (wind resource assessment programme from 1983) at the federal level.

The situation changed significantly in the early 1990s. By the beginning of that decade, India had amassed an unsustainable level of public debt and was facing an unprecedented level of economic crisis. This led the country to embark on a massive economic reform programme in 1991. This Economic Reform of 1991[1] changed the wind energy policy picture greatly; as in other sectors, the federal Government of India (GOI) shifted the focus of wind energy policy to stronger private-sector involvement, extended public finance to private-sector wind-power projects and provided fiscal and financial incentives to encourage private investments. Investment assistance with soft loans and tax benefits for wind project investments started in 1992 at the federal level, although these tax benefits (rates and types of various taxes, tax holidays, rates of depreciation, etc.; see Annex 1) and the interest rates on soft loans changed quite frequently over the years.[2]

The direction of technology-push measures also changed from initial government-led demonstration projects and indigenous turbine development to the more market-driven approach adopted in 1992 focusing on technology commercialisation. From 1997, wind energy R&D efforts concentrated more on government–industry collaboration. The R&D Unit in the Centre for Wind Energy technology (C-WET) was established in 1999 to provide generic information and knowledge to innovate wind turbine components and subsystems suited for Indian-specific conditions. Meanwhile, the National Wind Resource Assessment Programme continued, constantly updating data and wind development potential by considering technical upgrades.

As for power generation project procedural regulations, the GOI abolished the clearance requirements of the Central Energy Authority (CEA) for any renewable energy projects from 1991 (Eased Industrial Clearance). In 1994 the MNES and Indian Renewable Energy Development Agency (IREDA) established joint-sector companies called 'Wind Energy Estates,' which set up wind farms in windy areas to provide fully developed plots for the installation of wind turbines by individual investors.[3] The first technology quality standards and certificates and project procedure guidelines were introduced in 1995 only after a large number of abuses of these incentives had been reported between 1992 and 1995.

Additionally, the GOI implemented many federal-level wind industry-related policy measures and regulations. The door to foreign investments was substantially widened in 1991, when the GOI began permitting financial collaboration, joint ventures and technical collaboration with foreign entities in many sectors, including wind. Another important policy change after 1991 was a new trade policy, in particular a change in custom duties. Between 1991 and 1994, the GOI trimmed tariff rates on imported power equipment, including wind turbine sets, from 400% to 20%, and custom duties on capital equipment fell to 25% (Bath 1998). Subsequently, however, the import duty rates for wind turbines and components changed quite frequently (see Annex 2). Import application procedures also remained complex until the 2000-01 fiscal year,[4] when Duty Exemption Certification (waiving the need to declare critical components) was extended to wind turbine erection and spare parts. Besides import duties, the 1993 tax rule made wind turbines exempt from excise duty and sales tax. The rule changed in 1998: while the first parts of wind turbines and rotor blades had no excise duty, both taxes were placed on spare parts in order to encourage high-quality manufacturing and assembly of the parts in the first place and avoid replacements (IWTMA 2002).

In addition to these federal policy incentives, various states began implementing wind policy incentives from 1992. Due to the federal structure of the Indian power sector, each state dictated the rates of power production incentives (feed-in tariffs) and the conditions for third party sales, banking and wheeling benefits. Many states also implemented state-level capital investment incentives. However, these incentives greatly differed among states. In September 1993, the Ministry of Non-conventional Energy Sources (MNES) issued the first federal guidelines for state-level promotional and fiscal incentives for wind project development to all states. Representative states implementing wind policy measures were Tamil Nadu, Gujarat, Maharashtra, Andhra Pradesh, Karnataka and Rajasthan (see Annex 3 for the diversity of states' policy measures).

Figure 1 summaries the policy instruments used to promote wind energy in India from 1990 to 2005.

Technology transfer results between Denmark/Germany and India

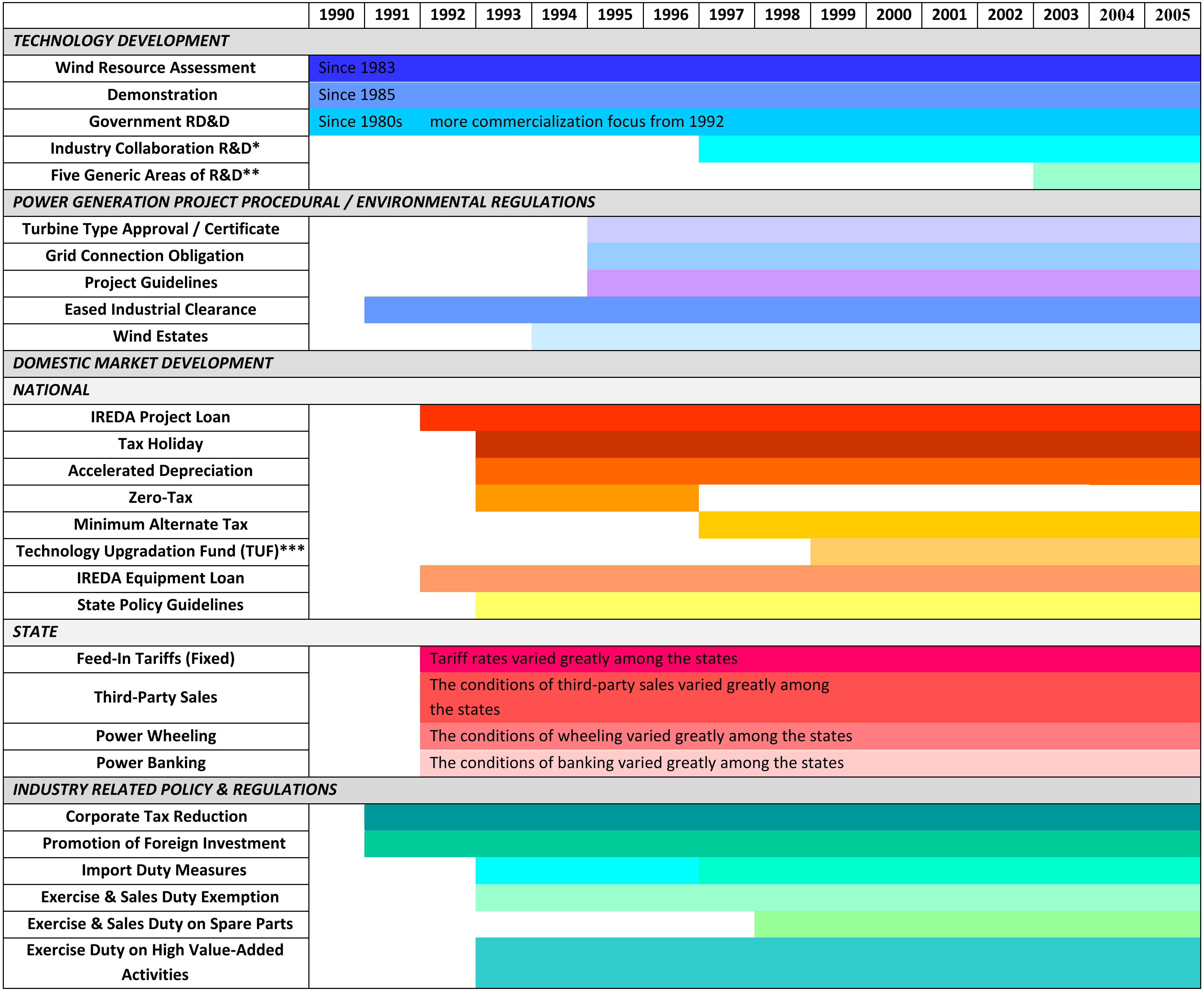
As a result of the above policy implementations, India experienced strong wind energy sector development and technological changes. This section examines the results in terms of private-sector technology transfers, which significantly contributed to the technological changes occurring in product introduction and manufacturing, project execution and innovation capabilities.

Product: Turbine capacity, technological features and turbine efficiency

Table 1 shows the wind turbines introduced by Danish and German manufacturers to India between 1993 and 2005 (data extrapolated from Consolidated Energy Consultants Ltd. 2005). In terms of turbine capacity, turbines of between 400kW and 600kW capacity had been introduced to the Indian market by the mid-1990s without much of the delay of their European market launch. However, these medium-capacity turbines never became mainstream in India. In addition, a number of turbines between 600kW and 999kW launched on the technology frontier market of Denmark and Germany between 1995 and 2005 were never introduced to India. By 2001, when the Indian manufacturer Suzlon introduced the first 1MW turbines to the Indian market, the major Danish and German manufacturers had already launched several MW-class turbines in the frontier market. By the end of 2005, when a 5MW capacity model had already been launched in the frontier market, India had introduced only four MW-class turbines (up to 2MW). Although not all the turbines launched in Denmark and Germany were necessarily suitable for the Indian market, the number of non-introduced turbines simply cannot be ignored. The Danish and German market also had much higher technology depreciation rates than the Indian market over the years: many wind turbine models which were no longer available in the frontier market were still installed in India in 2005. The average installed turbine capacity of Denmark and Germany compared with India's clearly illustrates the increasing gaps between 1995 and 2005 (Figure 2).

As for technological features, all wind turbines installed from 1993 to 1997 in India were stall-regulated, fixed-speed turbines, also the mainstream technology at the frontier at the time. Two fixed-speed turbines with dual winding technology were introduced to the Indian market by various manufacturers. However, the gaps in technological features began increasing during

Figure 1: Wind Energy Policy in India up to 2005



* R&D focuses more on providing generic information and knowledge to innovate components and sub-systems suitable for Indian-specific conditions, involving the industry, research institutions and laboratories, academic institutions and end-users.

** Five generic areas are: indigenous design and manufacture of all types of turbines by 2012; technology support to become net foreign exchange earner by 2012; performance improvement of existing turbines (Capacity Utilisation factor (CUF) from 17% to 25% by 2012); human resource development; and, research support for wind resource assessment and micro-siting.

*** The Technology Upgradation Fund (TUF) of the Ministry of Textiles offered a 5% reimbursement on the interest actually charged by financial institutions on sanctioned textile projects that include wind energy equipment for captive power generation by textile business entities. The scheme was available from April 1, 1999 to February 22, 2005.

Sources: (MNES 1995a; MNES 1995b; MNES 1996b; MNES 1997a; MNES 1997b; MNES 1999b; 1999; MNES 2000b MNES 2001b ; MNES 2002b; MNES 2002/2004/2006; MNES 2004, 2005) (Gupta 1995; TERI 2001); :(IREDA 2002a; IREDA 2002b and 2006; IREDA 2002c; Jagadeesh 2000; (Consolidated Energy Consultants Ltd. 2005; Rajsekhar, Van Hulle, and Jansen 1999); (IWTMA 2002; Khanna 1998; Wind Power Monthly 1996a; Wind Power Monthly 1997b; Wind Power Monthly 2003a; Sasi and Basu 2002; Wind Power Monthly 1997a; Wind Power Monthly 1997c; Wind Power Monthly 2000; Wind Power Monthly 2004);(Jagan 1995).

the mid-1990s; many important innovations at the frontier either did not arrive in India at all or were introduced with significant time delays, as the number of new turbines introduced decreased. While the increasing number of turbines introduced and installed in India after 1999 up to 2005 had pitch regulation (7 out of 18 introduced turbine models were pitch), fixed-speed turbines were still the majority (11 out of 18 were fixed-speed). Limited-range variable-speed turbines (shown as turbines with DFIG in Table 1), which occupied a large fraction of the market share at the frontier, had had a very limited number of installations in India by 2005.

The gaps in both turbine capacity and technological features created the large power generation efficiency gaps between the frontier and India due to the differences in aerodynamic efficiency and energy capture. Figure 2 illustrates the gaps by comparing turbine efficiency (turbine power generation efficiency), calculated by dividing yearly-generated wind electricity by the cumulative number of turbines.[5] It shows the staggering increase in the gaps in power generation efficiency between Denmark/Germany and India over the years, even taking weather and climate differences between the two areas and year-to-year weather variations into account. Between 1992 and 2003, turbine efficiency in Denmark and Germany increased 3.9-fold and 6.4-fold respectively, while efficiency growth in India remained only 1.6-fold. The turbine efficiency and capacity trends in the three countries show the similar gaps. The influences of the gaps in turbine capacity and variable speed operations on turbine efficiency were evident, as the turbines installed in Germany show the highest efficiency increase over the years.

Capability: Manufacturing, Project Execution and Innovation

The Indian wind industry indigenised small-capacity foreign-designed turbine-manufacturing technology at high level early on. By the end of March 1995, MNES estimated the indigenisation of manufacturing technology for up to 250kW capacity wind turbines as nearly 70% in terms of the number of components,

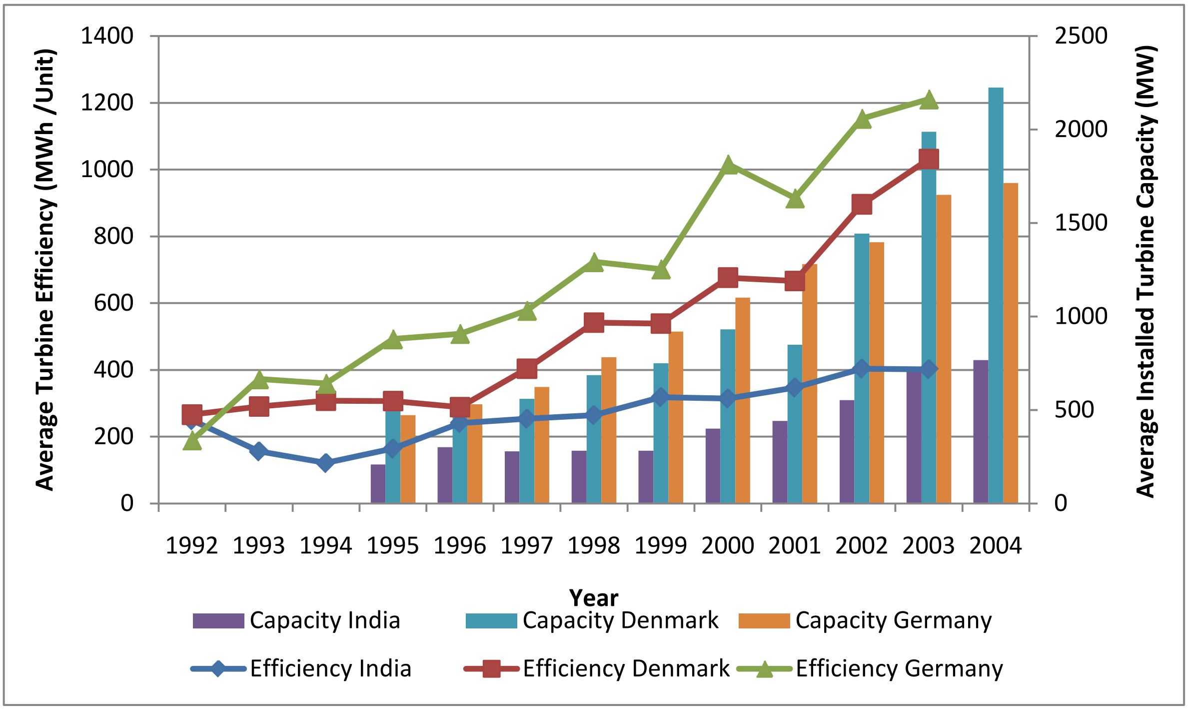
Table 1: Wind Turbines introduced by Danish Manufacturers 1993-2005

Manufacturer	Capacity	RD (m)	Power Control	Rotor Speed	Generator	Installation in India	European Launch
AMTL - Wind World	220kW* 250kW 500kW*	N/A 25 37	Stall	N/A 2-fixed 1-fixed	WRIG	1993 1994-1999 1996	N/A** 1991 1992
BHEL- Nordex	200kW 250kW	N/A 29.7	Stall	N/A 1-fixed	WRIG	1994-1996 1995-1999	N/A** 1994
C-WEL - DeWind	600kW*	46	Pitch	Variable	DFIG/CV	2001-2002	1997
Enercon India	230kW 330kW 600kW 800kW	30 33.4 44 48	Pitch	Variable	WRSG/ DD/CV	1995- 2005- 2001- 2005-	1995 2005 2001 2005
Enron/GE Wind (USA-Germany, subsidiary)	600kWa* 750kWi* 1.5MWs*	46 50 70.5	Active S Pitch Pitch	2-fixed Variable Variable	IG DFIG/CV DFIG/CV	2002 2002 2004-	1998 2001 1999
Flovel Tacke	250-80kW* 600kW*	26 43	Stall Stall	2-fixed Fixed	IG N/A	1996 1995	1990 1994
Grematch - Pegasus	250kW*	N/A	N/A	N/A	N/A	1995	N/A
NEG Micon (Subsidiary)	750kW 950-200kW 1.65MW	48.2 54.5 82	Stall Active S Active S	2-fixed 2-fixed 1-fixed	WRIG	1999- 2002- 2004-	1998 2001 2003
NEPC Micon	225-40kW 250kW 400-100kW 600kW*	29.8 29 31 42	Stall	2-fixed 1-fixed 2-fixed 2-fixed	WRIG	1993-1998 (1989), 1993-1998 1994-1998 1995	N/A** N/A** 1992 1994
NEPC - Norwin	750-180kW*	47	Active S	2-fixed	WRIG	2005-present	1998
Pioneer- Wincon	250kW 750kW*	29 48	Stall Semi- Pitch	1-fixed 2-fixed	WRIG	1995- 2002	1995 1998
REPL - Bonus	320kW	33	Stall	1-fixed	WRIG	1995 -1997	N/A**
Suzlon - Südwind	270kW* 350-100kW	N/A 33.4	Stall	N/A 2-fixed	WRIG	1996 1996 - 1997	1993 1996
Textool - Nordtank	300kW 550kW*	31 37	Stall	1-fixed	WRIG	(1991) 1996 1996	1985 1992
Vestas RRB	225-50kW 500kW	27 42/47	Pitch	2-fixed 1-fixed	WRIG	1993 – 1995 -	1988 1993
TTG - HSW	250-80kW	28.5	Stall	2-fixed	PEIG	1994-	1990

* The total installation number of these turbines was less than ten.
** No European record available for these makes. The numbers in parentheses indicate the year introduced by demonstration projects before 1993 in India.
Keys: DFIG = Doubly Fed Induction Generator, WRIG = Wound Rotor Induction Generator, DD = Direct Drive, WRSG = Wound Rotor Synchronous Generator, PEIG = Permanently Excited Induction Generator, CV = Converter, IGBT= Insulated Gate Bipolar Transistor

Source: extrapolated from Consolidated Energy Consultants Ltd. 2005

Figure 2: Average Turbine Capacity and Efficiency by Country



Note: Due to the differences in statistical years between Denmark/Germany and India, the Danish/German calendar year (January to December) is compared to the Indian fiscal year (April of the same calendar year to March of the next calendar year). For example, data for the Danish/German 1992 year is compared to the Indian 1992-1993 fiscal year. The comparison, however, is considered approximate enough.

Sources: Danish Wind Industry Association 2006; DEWI and ISET in BWE 2005; Consolidated Energy Consultants Ltd. 2005: DWIA, DEWI, BTM Consult ApS 2005b.

while blades, special bearings, etc. were still being imported (MNES 1995a). By 1997 the industry-wide rate grew nearly 80% (MNES 1997a). However, the indigenisation level of high-value and high-tech component manufacturing and their quality remained low. The dependence of high-tech power electronics and controllers on imports was never reduced, and med-tech mechanical engineering components made in India were still prone to failures. Many components of large-capacity turbines commercialised at the frontier since the mid-1990s were not introduced in India, with the exception of direct-drive WRSG with IGBT converter by Enercon, slip-ring generator application by Suzlon, and Glass Fiber Reinforced Epoxy (GFRE) blades and individual pitch mechanism by both firms. As for blade manufacturing capability, resin vacuum infusion and automation technologies related to vacuum infusion were indigenised in India through the manufacturing activities of LM Glasfiber India, Enercon India, and Suzlon. Manufacturing of 34m-length blades for 1.5MW turbines and 40m-length blades for 1.65MW turbines started in India in 2004 (MNES 2005), but manufacturing of other large blades for many multi-MW class turbines commercialised at the frontier were not introduced. In addition, the quality issues of components manufactured in India still persisted. Despite the approximately fifteen years of experience, still 20% of gearbox failures and breaking of blade tips were being recorded in 2003 (Wind Power Monthly 2003b). Overall, many of the gaps in mid-tech manufacturing capability between Denmark/German and India were not reduced, and the gaps in high-tech and complex component manufacturing capability for large-capacity turbines greatly increased.

In terms of wind power project execution, skills and know-how of project planning, site assessment, site development and micro-siting in India were low at the beginning and caused many project failures in the early and mid-1990s. However, these project execution capabilities advanced greatly since the mid-1990s through joint venture and license agreement collaborations. Progress in and the transfer of remote monitoring SCADA (Supervisory Control and Data Acquisition) products, as well as project development software tools such as WAsP and WindPRO for local wind-resource mapping, optimisation, and micro-siting, also helped the Indian industry to enhance these capabilities.

As for innovation capacity building, in general this had been slow. Government–industry R&D collaboration schemes developed by MNES in 1997 were seen as passive and limited by industry insiders, as they were not utilised widely (Shekhar, Kumar, and Shar 2001). In terms of in-house innovation capacity building by manufacturers, Enercon India and Suzlon built the R&D facilities in India, but their main R&D activities still remained in Europe. While innovation capability greatly advanced at the frontier with various high-technology developments since 1990, none of the significant innovations were carried out in India. The innovation capability gaps grew greatly between 1990 and 2005.

Overall, the increasing gaps between the frontier and India were seen in all of product technology, the manufacturing capability of med-tech/high-tech components, and innovation capability.

Causal factors of the increased technology gap

This section examines the causal factors of the increasing technology gaps illustrated in the previous section from the perspectives of the market, industry and infrastructure, and their relationships with policy.

Market-related factors

At the end of March 1989, India had only 10MW of total installed wind capacity, all in the form of government demonstration projects. With the introduction of market development policy measures in 1992, however, India began experiencing strong wind market growth. By the end of the 1995-96 fiscal year, installation grew very rapidly. The market slowed down dramatically from 1996-97 and the recovery was slow; annually installed capacity exceeded the 1994-95 level only in 2001-02. 2003-04 and 2004-05 saw the strongest installation, in record numbers (Figure 3).

The market fluctuation was seen not only at the national level but also at the state level. There was a strong disparity in wind energy development among the states too. Only a handful of states implemented state policy measures contributed to wind energy development. The first wave of development was concentrated mainly in Tamil Nadu and Gujarat between 1992-93 and 1995-96. Maharashtra was the main market between 1998-99 and 2001-02 when other state markets stagnated. The picture changed again from 2002-03, when Tamil Nadu, Rajasthan and Karnataka became the main wind development locations. The differences and fluctuations in growth patterns by state illustrate the strong market segmentation within India. Overall, Indian market demand in terms of size, location, and stability was highly uncertain.

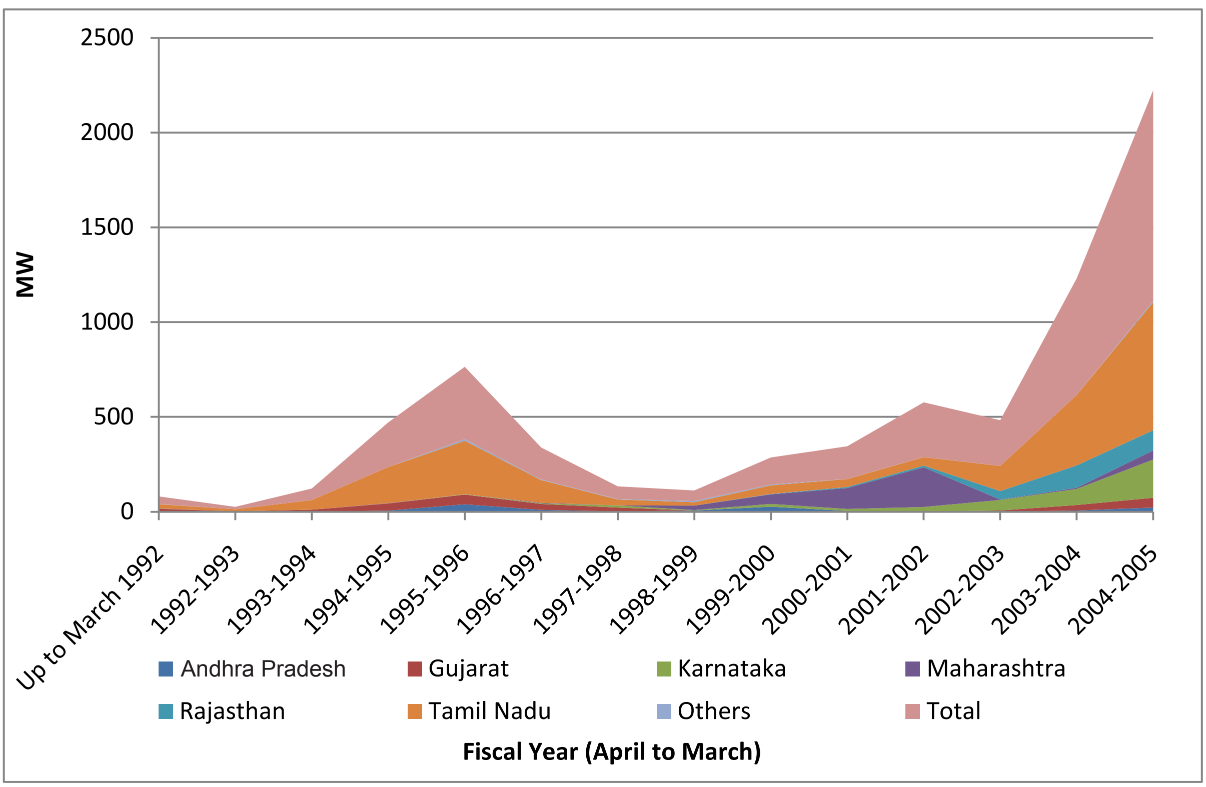
As for investor profiles, more than 98% of total installed capacity from 1992 to March 2005 was developed by industrial firms. According to MNES, 80% of wind power fed into the grid was used as captive consumption, being consumed by these investor-developers (industrial firms) themselves at a distance via wheeling, and 78% of wind-power buyers were energy-intensive manufacturing firms (Winrock International India 2003).

The fluctuations in the Indian market were mostly caused by the unstable policy and institutional environments. The first boom years occurred from 1992 to 1996 due to the combination of the generous 1993 tax rule incentives (the first-year 100% depreciation of capital equipment and zero-tax planning) and the

IREDA soft loans for wind projects. Foreign Direct Investment (FDI) stimulation from 1991 and the import duty reduction from 1993 supported the boom by bringing the required technologies from abroad. However, a peculiar aspect of the Indian wind market was the total irrelevance of wind power production incentives (feed-in-tariffs). This situation was created because the power-usage charges imposed on industrial customers by the State Electricity Boards (SEBs) was higher than the feed-in tariff payments. Traditionally the Indian SEBs used cross-subsidies which imposed far more expensive power-usage charges on industrial customers than on residential and agricultural customers, and this mechanism made industrial investors simply use wind power plants as their captive power consumption plants to avoid expensive power-usage charges, in addition to getting one-time tax benefits. Thus, the wind-power feed-in tariff incentives were totally irrelevant regarding the control of market development; Indian investment in wind energy simply gave industrial firms some short-term tax-planning and management tools.

The tax-saving practices without any project quality-assurance measures by the government also stimulated the questionable practice of gold-plating[6] by many investors. The first boom years were ended by the sudden policy changes of late 1995; the large reduction in tax benefits, the increased interest rates for IREDA loans, the higher import duties for wind turbine components from 1997, the extremely low performance level of wind energy plants during the first boom years and the great uncertainty involving the financial conditions of the SEBs, which started implementing unfavourable state wind-energy policies, all deterred investments, although the new federal project quality policy measures successfully eliminated the fraudulent investors. The market began experiencing strong growth again after the enactment of the 2003 Electricity Act, which streamlined and resolved many power sector issues.[7]

Figure 3: Annually Installed Capacity in MW by State in India



Source: MNES cited in (Consolidated Energy Consultants Ltd. 2005)

The success of the gradual transfer of the decision-making power from the SEBs to the State Electricity Regulatory Commissions (SERCs) as the result of the 1998 Reform Act,[8] the steady reduction of IREDA loan interest rates, Technology Upgradation Funds (TUF) and the gradual increase in turbine capacity and improvement to project execution technology also contributed to market recovery after 2000.

These market conditions, created by the complicated policy and institutional landscapes, greatly influenced technology transfer and development activities in India. Overall, the effects of market demands on project economic efficiency improvement, cost reductions and the introduction of low-wind-specific technology were fairly weak in India as a result of the greatly fluctuating market conditions. Despite the similarity of these demand characteristics with Denmark and Germany, they did not induce technological change through technology transfer after the mid-1990s.

The main cause for this was the small market size. In Europe, the regional market, especially the huge German market, strongly pulled technology development by the Danish and German manufacturers into the directions the market demanded. Conversely, with the recession from 1996-97 the Indian market simply lost such pulling-power to attract the introduction of newer and larger turbine models, which required larger investments as they cost more to manufacture and install. The prospect for economies of scale was also very limited in the small Indian market. Thus, a large market size and market certainty and continuity were lacking in India: even though many market demand characteristics were similar to those in the frontier market, without a sizable market and its own pulling power, technology upgrading through replicable technology transfer did not happen. The small market made all demands for technological improvement insignificant.

In addition, as described previously, Indian investment in wind was supported only by the industry's investor-developers, whose primary drive was not to make viable wind projects but to manage taxes and escape from the unreasonably high power-usage charges imposed on them. This contributed to the consistently low Internal Rate of Returns (IRRs) and the weak demands for IRR improvements. Thus, the market was not oriented towards economic performance. Although the IREDA revolving fund and soft loans, the encouragement of FDI and the reduction in import duties greatly helped the creation of market, without any proper mechanisms to prevent the abuse of government incentives, the market's and investors' lack of interest in the performance of wind turbines which could greatly improve the IRR created extremely weak demand for technological improvement.

The abrupt policy changes during the mid-1990s added great political uncertainty to the already problematic market mechanism. The low economic performance of the wind projects built during the first boom years, the rising interest rates and the soured relationship between investors and SEBs caused by the SEBs' problematic finance and pricing strategies all contributed to deterring many further investments. The confusing process of India's power sector reform and restructuring, which allowed some privatisation to take place in private-sector power generation while leaving cross-subsidies in power-usage charges intact among various sectors because of the incomplete commercialisation and not targeting the recovery of capital, operational and maintenance costs, created the self-contradictory mechanisms of the SEB policy, and affecting wind energy market growth negatively in the process. Market adjustment was therefore slow, and market continuity and certainty were well beyond reach.

The three-year market setback since 1996 was devastating for India's wind energy technology upgrading through technology transfer, because there was simply no attractive market to pull the extensive technological progress made at the frontier during this period. Regional Asian market demands were also weak, doing nothing to help utilise or augment Indian manufacturing capacity by producing export orders. Even after 2000, when the market began improving, India was not considered a primary investment spot for technology upgrading, as the market was far smaller compared to the combined regional European markets. The enactment of the Electricity Act in June 2003, the continuous restructuring of the SEBs and the establishment of the SERCs had positive effects on the market recovery. However, insufficient demand-pull after 1996 created persistent and damaging effects on India's technology development and diffusion, as could still be seen in 2005.

Industry-related factors

The economic reforms since 1991 and the new wind energy policy triggered the strong expansion of the wind industry too. The Indian wind turbine industry was largely formed through business diversification of local firms through technical collaboration agreements (joint venture or license agreement) with the manufacturers on the technology frontier. The main trigger for these collaborations was the encouragement of FDI in 1991.

Table 2 shows the entry and exit of turbine manufacturer businesses in India, which clearly demonstrates that most of them had foreign technology collaborators. However, it also shows that the majority of these firms exited from the Indian market between 1996 and 1999, which corresponds to the severe three-year market slowdown. Only four technology collaborations established before 1996 [9] still survived in 2005. The new entries after 1997 include two subsidiaries, which were 100%-owned by foreign manufacturers (NEG Micon and GE Wind), and three independent firms, two of which (Suzlon and NEPC India) became independent after the dissolution of their original partnerships with the European technology providers and collaborators. NEG Micon India (subsidiary of NEG Micon) and Vestas RRB were both still in business separately in India as of the end of 2005, though their Danish partners merged into one firm (Vestas) at the end of 2004.

These industry transformations influenced the technology transfer results greatly. Technology transfer was active in the early to mid-1990s through technology collaborations. By 1998, however, many technology providers and collaborators had pulled out of the Indian market. The reasons varied from the market slowdown and financial, technical or ethical problems with Indian partners, to their own business exits at the frontier. The number of technology introductions consequently declined because of the reduction of technology providers and collaborators.

The slowdown in the introduction of updated technology was also seen in the surviving technology collaborations, and it was more problematic. The resistance to passing manufacturing and production licenses to Indian partners became obvious from the turbines above 500kW capacity after the mid 1990s. This tendency was stronger in divided ownership firms (joint ventures and license agreements) than in undivided ownership firms (100% foreign subsidiaries and an independent Indian ownership firm) (see Table 3). The increasingly tighter technology and cost management and controls due to the growing competition at the frontier and the Indian market slowdown reduced the strategic advantages of joint ventures and license agreements with Indian partners. In addition, persistent low-quality production in India offset the cost advantages derived from low cost labour for export; the Indian firms could not meet the demands for higher-quality high-tech export products. This further limited the opportunities to improve the quality of manufacturing in India and affected the chances of being part of global value chain and sourcing networks, thus creating a negative feedback loop.

Technology components innovated at the frontier also increasingly became difficult to introduce on an individual basis, as their system integration needs became higher and higher. Acquiring high-level technology requires high-level capability as well as cumulative experiences, but the technological capacity to attract more updated technology was weak in India. Thus, supply-push technology transfer was weak, as the Indian side did not build sufficient capacity to support the progressively more competitive global technology and cost management needs.

In terms of the role and effects of policy on supply-push technology transfer, various industry-related policy measures without proper supervision of firm operations and technology or project quality control contributed to the limited formation of manufacturing capacity, allowing many low-quality projects and technologies to prevail, and only a handful collaborations actually built manufacturing facilities with serious in-house quality control.

There was also a lack of more direct and specific technology-push policy to support manufacturers in building the higher capacity needed to become the export base, due to the limitations of government interventions to individual joint venture and license agreements. Most technological decisions were left to the mercy of foreign technology providers and collaborators, which strictly controlled which technologies should be introduced to and how they should be handled in India through restricted business practices and technology transfer agreements. Because such practices usually prohibited any Indian R&D and adjustments to technologies from the frontier, the government–industry R&D collaboration schemes drawn up by MNES for developing technologies to meet Indian-specific needs were simply unrealistic.

As for technological capacity building, the contradictory use of import duties aimed at simultaneous cost reductions and indigenous technology development ended up deterring both market investments and technology introduction by confusing both investors and manufacturers.[10] The conflicting use of manufacturing incentives was also evident in the use of excise duty: imposing a high excise duty on high-valued activities had negative impacts on the improvement of technological capacity building, though the duty differentiation between the first and second components did contribute to the improvement of manufacturing and assembly activities.[11] The lack of consistency in these import and manufacturing incentives confused the industry and ended up hindering both product introduction and the manufacturing capability building of higher-valued components.

Infrastructure-related factors

Some general infrastructure issues also influenced wind energy technology development and diffusion in India. One problem was its weak grid, which was especially connected with reactive power consumption.[12] The other issue was the general road and port infrastructure problems in the country, which hindered the transport and construction efforts required for wind turbine manufacturing and power project construction. These two issues were closely intertwined.

In general, wind energy technologies and technical solutions developed at the frontier show sufficient adequacy to control the negative effects of the low wind and weak grids in India. This was particularly true of pitch-controlled, variable speed turbines. However, the technology transfer results show that these technologies were of minor importance in India up to 2005. One of the important reasons hindering the introduction of these technologies was deficiencies in road and port infrastructure, which greatly limited the size of the turbines that can be transported and installed in India. As the insufficient infrastructure hindered the introduction of large-capacity high-tech turbines, the technologies that can address the problems related to the weak grids and low wind conditions were not brought to or diffused in India because they were parts of large-capacity turbine technologies. Regardless of the privatisation of the transport and logistical sectors since 1991, improvements were slow. Although the wind manufacturer-developers assumed the responsibility for developing the road infrastructure to reach the project sites and fortify power evacuation facilities wherever necessary,[13] the efforts of individual manufacturers had their limitations. MNES could not offer any significant support for logistical improvements (Twele 2005). The lack of support from MNES for improvements to the deficiencies in the transport infrastructure was not a surprise, given that the issues cannot be solved by one ministry and/or one industry alone. As for the Transmission and Distribution (T&D) deficiency, despite the principle that the SEBs should be responsible for upgrading facilities and fortifying weak grids, this was not done because of their severe financial difficulties. This issue also involves many other energy-related ministries and industries.

Policy supports necessary to systematically solve infrastructure deficiency problems require better coordination among various ministries and larger and continuous investments. These did not exist in India, affecting technology transfer greatly.

Table 2: Turbine Manufacturer Entry and Exit in India

Entry Year	Indian Firm	Foreign Collaborator	Exit Year
1985	BHEL	----	
1986	**Vestas RRB**	**Vestas (Denmark)**	
1987	NEPC Micon	Micon (Denmark)	**1999***
1993	AMTL	Wind World (Denmark)	*****
1994	**BHEL**	**Nordex (Denmark)**	**1999****
	Elecon	HMZ (Belgium)	**1998**
	TTG Industries	Husumer Schiffswerft (Germany)	*****
1995	ABAN Loyd	Kenetech (USA)	**1997**
	Das Lagerwey	Lagerwey (The Netherlands)	**2000**
	Enercon India	**Enercon (Germany)**	
	Flovel	Tacke (Germany)	**1997***
	Grematch CNC	Pegasus (Germany)	**1995**
	Himalaya	----	**1996**
	Windia	Nedwind (The Netherlands)	**1998**
	Pioneer Wincon	Wincon West Wind (Denmark)	
	REPL	Bonus (Denmark)	**1997**
	Sangeeth	Carter (USA)	**1997**
1996	JMP	Ecotecnia (Spain)	**1996**
	Rayalseema	Mitsubishi (Japan)	**1996**
	RES	AWT (USA)	*****
	Suzlon	Südwind (Germany)	**1996**
	Textool	Nordtank (Denmark)	**1996**
1997	Kirloskar	WEG (UK)	**1998**
	Suzlon	-----	
1998	**NEPC India**	-----	
1999	**NEG Micon (subsidiary)**	**NEG Micon (Denmark)**	
2000	**C-WEL**	-----	
2001	C-WEL	DeWind (Germany)	**2002**
2002	**Elecon**	**Turbowind (Belgium)**	
	GE Wind Energy (subsidiary)	**GE Wind Energy (USA)**	
2005	**Pioneer Asia**	**Gamesa (Spain)**	

Bold letters show firms active as of March 2005.

Entry year is defined as the year that the firm installed its first turbine, exit year as when the firm installed its last turbine in this table. Although the original source shows some other manufacturers on the list, this table only included those that installed turbines, locations and dates of which were verified by the data in the source.

* These collaborations already ended in the late 1990s or before the specified exit years. However, the turbines originally provided by the providers were continuously manufactured and offered in India independently by the Indian firms after their partnerships ended. Flovel ceased the installation of turbines altogether in 2001.

** Nordex and BHEL ended its first licensing agreement in 2002, but a new agreement was in place by 2003. However, no installation was made between 1999 and March 2005.

Source: extrapolated from Consolidated Energy Consultants Ltd. 2005

Table 3: Firm and Technology Ownership and Introduced Turbine Capacity by Surviving and New Manufacturers in India

Divided Firm/Technology Ownership (Joint venture/license agreement)			100% Firm/Technology Ownership (100% subsidiary/independent Indian firm)		
Turbine Make and Capacity	Introduction		Turbine Make and Capacity	Introduction	
	India	Europe		India	Europe
Small-Capacity (less than 500kW)					
Vestas RRB **225-50kW** (JV)	1993	1988	C-WEL **250kW** (I)	2000	
Pioneer Wincon **250kW** (JV)	1995	1995			
Enercon India **230kW** (JV)	1995	1996			
Enercon India **300kW** (JV)	2005	2005			
BHEL-Nordex **200kW** (LA)	1994	N/A			
BHEL-Nordex **250kW** (LA)	1995	1994			
Medium-Capacity (between 500kW and 1MW)					
Vestas RRB **500kW** (JV)	1995	1993	NEG Micon **750kW** (S)	1999	1998
Pioneer Wincon **755kW** (JV)	2002	1998	GE Wind **600kW**a (S)	2002	1998
Enercon India **600kW** (JV)	2001	2001	GE Wind **750kW** (S)	2002	2001
Enercon India **800kW** (JV)	2005	2005			
Pioneer Asia **850kW** (JV)	2005	2004			
NEPC-Norwin **750-180kW** (LA)	2005	1998			
C-WEL-DeWind **600kW** (N/A)	2001	1997			
Elecon-Turbowind **600kW** (N/A)	2002	N/A			
Large-Capacity (larger than 1MW)					
			NEG Micon **950-200kW** (S)	2002	2001
			NEG Micon **1.65MW** (S)	2004	2003
			GE Wind **1.5MW** (S)	2004	1999
			Suzlon **1MW-250kW** (I)	2001	2003
			Suzlon **1.25MW-250kW** (I)	2002	2003
			Suzlon **2MW-250kW** (I)	2005	2004
JV = Joint Venture, LA = License Agreement, S = Subsidiary, I = Independent					

Source: extrapolated from (Consolidated Energy Consultants Ltd. 2005)

Policy recommendations to create an enabling environment for replicable technology transfer

India's experiences with wind technology have some important lessons for how to encourage private-sector replicable technology transfers from developed to developing countries. The small market size, the non-performance-oriented market mechanism, the policy inconsistency, the institutional problems of the power sector, the lack of technological capabilities to meet the increasingly higher quality requirements of wind energy technology and the persistent infrastructure deficiencies in India, along with tighter technology controls by technology providers and collaborators, all contributed to the increasing technology gaps in both product and capabilities with the frontier after the mid-1990s.

Enabling environment for replicable technology transfer

In addition to the domestic factors mentioned above, external factors such as the rapidly increasing high-tech characteristics of wind energy technology systems and the fast structural transformations of the industry at the frontier made it difficult for India to cope with the various changes. Nonetheless, domestic factors were the more serious causes of the increasing technology gaps and the lack of replicable technology transfer, preventing economic efficiency and technological improvements. The lack of positive feedback from India to the frontier during the constant industry and technology transformation deterred replicable transfer when the Indian market slowed down, demonstrating that the process or history greatly influence whether technology transfer is replicated or not. FDI and the formation of technology partnerships alone do not automatically guarantee continuous technology upgrading and replicable technology transfer. Replicable technology transfer is process-oriented, demanding simultaneous and continuous demand-pull created by sizeable and performance-oriented markets and technology-push connected to technology-specific learning mechanisms and market trials. Policy is central to materializing these two forces.

Financial and policy sustainability, as well as overall and long-term consistency of policy frameworks with sound adjustments and sequencing, are essential to support such process-oriented technology transfers. In addition to the creation of general enabling environments such as macroeconomic policy frameworks, technology- or industry-specific policies and enabling environments are equally important because economics and industry characteristics and their transformations are strongly technology-specific. Strong monitoring and evaluation capacities by policy makers and good public-private partnerships and communications are critical in creating such an enabling environment.

The article recommends the following rather simple frameworks for creating a virtuous cycle of replicable technology transfers involving distributed energy technologies and devices such as wind.

Policy for sizable market and performance-oriented demands

In order to stimulate more efficient and updated technologies repeatedly through private-sector technology transfer activities, the sizeable and performance-oriented market demands which continuously pull such technologies are fundamental; the market demand characteristics are a necessary but not sufficient condition for inducing technological change, which also requires a strong market pull. The performance-oriented market cares about economic efficiencies, resulting in constant demands for higher quality technologies. Consistent but flexible policy measures tailored to each technology status and characteristics are central to the creation of such a market.

- Capital investment, fiscal and financial, and power production incentives can be all used wisely to create performance-oriented demands. Market growth should be controlled by these sector-specific policy measures, in order not to repeat the Indian wind economics situation, which was affected by a factor external to the wind industry, namely the high power-usage charges imposed on industrial consumers. Engaging in sunset clauses of capital investment and short-term fiscal measures is also important to make the market more performance-oriented.
- Market segmentation is strongly opposed to the creation of strong market pull. National, regional and international policy collaborations can be helpful in creating a sizable market, and this can be done without the geographical proximity of each market.
- Implementation of incentive abuse prevention measures from the beginning of market and industry creation is critical for the orderly, certain and continuous growth of both. Quality assurance measures such as technology certifications and standards and project guidelines contribute to technological capacity building and the industry's structural adjustment by eliminating low-quality firms too.
- A revolving fund such as the one used for the IREDA soft loans can be a cost-effective way of utilising international public lending to support private-sector development.
- Hasty and disorderly procedure and methods in respect of power sector reform and restructuring can pose larger costs later by creating self-contradictory mechanisms and political uncertainty, this negatively affecting private-sector investments.

Supply-push policy: Choice of 'what to make' and 'what to buy'

Technological capacity building and its relationship to technological characteristics are very important in managing supply-push technology transfers. However, national-level policy formulation in this area is delicate, as it requires flexible adjustment and the coordination of policy measures with the business strategies of domestic firms in light of the rapid transformations to the global industry and technology, while not distorting competition and free business activities, including technology agreements between technology providers/ collaborators and receivers. Although supply-push policy measures are often considered limited to generic RD&D supports, FDI policy, trade policy, corporate tax policy and manufacturing tax incentives can be used to support national technology and industry building. As seen in the Indian wind case, however, they do not guarantee replicable technology transfers and can even create contradictory effects.

One important key for such policy formation are decisions regarding 'what to make (provide domestically or internally)' and 'what to buy (procure from outside).' Such strategic decisions are made by business firms on daily basis in respect of the management of innovation, manufacturing, project execution, and service provision, etc. What national-level strategies on 'what-to-make' and 'what-to-buy' can do is help firm-level decision-making and encourage replicable technology transfers without intruding on firm-level business activities by providing generic and technology-specific training and policy and financial supports and incentives for chosen supply-chain activities and technological capacity building, thus creating technical and cost advantages which stimulate firm-level technology transfer and export activities. Although this is not an easy task, the potential benefits in many aspects of national capacity building are large. The policy-making procedures of such national strategies can help both firms and policy-makers develop the capability to pursue more tactical strategies and build comparative and competitive advantages through practical and mutual learning. They can also help distinct the role of the public and private sectors in each technology sector in a given timeframe clear. Coordination and frequent communications between industry players and policy-makers become essential. Early creations of industry associations can support such a process too. Technology- and industry-specific strategic decision-making is critical today for any public- and private-sector activities from the perspectives of resource allocations and the creation of comparative and competitive advantage. Capacity building supports from the international community need to focus on this area too.

Physical infrastructure deficiency

This article has also highlighted the importance of 'physical infrastructure' in accelerating the flow of the necessary products, components and services to encourage technology development and diffusion. Although the soft dimensions of enabling environments are more often discussed (IPCC 2000), the hard dimensions should be recognised too, as they can greatly influence the outcomes of technology transfers and business activities. While the development in physical infrastructure are considered generic, the certain requirements are often quite technology-specific (e.g., grid stability, transport/ logistical and construction requirements). Therefore, the political coordination and prioritisation which balances these generic and technology-specific needs are very important.

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Endnotes

1. As a result of industrial policy with heavy regulations and restrictions controlled by bureaucrats since Independence in 1947, Indian business had suffered from the lack of transparency in the business environment, stagnant private and foreign investments, heavy government spending on inefficient public enterprises and the lack of technological progress. The country suffered from inflation, high budgetary deficits and foreign debt, increasing government duties and taxes, and low GDP per capita. The limited attempts at liberalisation made in the 1980s were insufficient to overcome these economic problems. The fiscal imbalance diverted household savings to public consumption and reduced the resources available for private investment. Due to the restrictions on foreign investment and trade, India faced a balance of payments crisis in early 1991, its foreign exchange reserves reaching an all-time low. The GOI attempted a series of short-term policies to finance imports and meet its immediate debt service obligations, which included using its gold reserves to obtain foreign exchange, use the IMF's special drawing facilities and obtaining emergency assistance from Germany and Japan. Eventually, however, the GOI had no choice but to embark on a programme of more fundamental economic reforms and reduce the role of the government in economic development (Bajpai 2002; Bath 1998).

2. For example, the IRENA soft loans for wind power projects changed every year between 9.5% and 21% (Gupta 1995; IREDA 2002b and 2006; Jagadeesh 2000; Sasi and Basu 2002; Wind Power Monthly 1997a; Wind Power Monthly 1997c; Wind Power Monthly 2000; Wind Power Monthly 2004).

3. The joint sector companies acquire and lease the land, develop infrastructure and grid facilities, obtain the necessary clearances, and install, operate and maintain the wind turbines on behalf of the investors.

4. An Indian fiscal year starts in April of the same calendar year and ends in March of the next calendar year.

5. Turbine efficiency is usually calculated by yearly generated electricity divided by total rotor-swept area. However, this method of calculation has not been adopted here because the data regarding total rotor-swept areas of Germany and India over the years was not available. Yearly differences in wind and weather conditions have also not been normalised due to a lack of data.

6. Gold-plating practices put far more expensive price tags on the turbines used in wind power projects than fair market prices, in order to inflate the project capital costs and receive more tax benefits and loans from governments.

7. This Act changed some fundamental aspects of the electricity sector of India, including the following: 1) completely de-licensing power generation, except for interstate hydro projects, and allowing free entry to power generation for businesses; 2) freely permitting captive generation by removing all licensing and permissions; 3) providing all power generation plants with open access to the transmission grid, as well as rights to build transmission lines for a fee in order to wheel power for self-usage or for third-party sales; 4) obliging all state governments to separate transmission activity from SEBs and to establish state-owned State Transmission Utilities as well as SERCs, while providing state governments with the freedom to decide the sequences and phases of restructuring; 5) ordering SERCs to determine tariffs based on commercial principles and gradually eliminating cross-subsides; 6) permitting consumers to enter direct commercial relationships freely with generating companies or traders after open access is allowed; 7) introducing power trading; and 8) obliging GOI to formulate a National Electricity Plan and CEA to prepare the National Electricity Plan (Prayas 2003). As for renewable energy, the 2003 Act limits the role of state governments to formulating policies related to: 1) providing government lands at nominal cost for renewable energy projects; 2) providing subsidy for the cost of infrastructural development; and 3) providing the cost of electricity purchase by licensees from

renewable energy plants. Tariffs and charges are now decided not by state governments or SEBs but by SERCs. The predominant roles of SERCs are: 1) to determine tariffs for the generation, supply, transmission and wheeling of electricity within the state, as well as surcharges for open access to consuming power from a source other than a licensee; 2) to regulate electricity purchase and procurement distribution processes; 3) to facilitate the wheeling of electricity within the state; and 4) to promote electricity generation from renewable energy sources by providing suitable measures for grid connection and power sales to any person, as well as measures that specify a percentage of total consumption of electricity in the area of distribution licensees for the purchase of electricity from such sources (Consolidated Energy Consultants Ltd. 2005).

8. This 1998 Act was replaced by the 2003 Electricity Act.

9. This excludes TTG Industries, whose existence was unknown as of 2005.

10. Low duties targeted the easy import of components and cost reductions to encourage the market investment. Meanwhile, high duties were aimed at import restrictions on components which were desired to manufacture in India to increase domestic technological capability. Indian policy was very confusing because these opposed measures often targeted the same components. The duties were frequently changed, as the GOI itself was confused.

11. Putting more duties on replacement components encouraged manufacturers and developers to avoid costly replacements and to manufacture and assemble the first components correctly.

12. Reactive power is the consumption of power from the grid to create a magnetic field inside a Wound Rotor Induction Generator (WRIG) in order to start it. The problem is specific to wind power generation using WRIG at a low loading stage. Reactive power reduces transmission efficiency.

13. Actually the difference in marketing and development approach created discrepancies in installed turbine sizes among manufacturers. For example, one of the reasons that Suzlon led the pack in terms of turbine size was that the firm began the so-called 'Wind Park' approach (the firm develops a large tract of lands and infrastructure altogether and then sells a patch of the development and services to investors), thus solving many infrastructure-related problems and creating economies of scale.

Annex 1: Fiscal policy and incentives for wind energy in India

Schemes	Contents
1989 Tax Scheme on Wind Power Project	Tax breaks to deduct the entire cost of equipment in the first year from pre-tax profits
1993 Income Tax Rules	Five-year 100% tax holiday on income from sales of wind electricity 100% depreciation on investment in capital equipment related to wind power plants in the first year Zero-Tax planning (possible to avoid paying corporate tax on incomes of their registered companies and corporations) by combining various tax rebates and exemption and 100% accelerated depreciation
1997 Tax Rules	Introduction of Minimum Alternate Tax (MAT) on wind projects ▪ 12.9% MAT on book-value profits (return on equity) imposed on the companies that chose the 'zero-tax' planning, while 100% first-year depreciation continued. Lowering tax rate for the companies with higher book-value profits than investments on wind power projects ▪ Reduced marginal corporate tax rate (from 46% to 35% in April 1997, further to 30% in 1998)
April 1999 Tax Rules	11.4% MAT Rate
April 2000 Tax Rules	8.4% MAT Rate
April 2001 Tax Rules	Ten-year tax holiday on income from sales of wind electricity
2003 Tax Revision	80% of first year depreciation on and after 4/1/2003

Sources: Consolidated Energy Consultants Ltd. 2005; MNES 1995a; Rajsekhar, Van Hulle, and Jansen 1999

Annex 2: Import duties on wind turbine sets and components in India

<table>
<tr><th rowspan="2">Items</th><th colspan="6">Import Duty Rates</th></tr>
<tr><th>1993-3/1997</th><th>4/1997-3/1998***</th><th>4/1998-3/2002</th><th>4/2002-3/2003</th><th>4/2003-6/2004</th><th>7/2004-Present</th></tr>
<tr><td>Generators up to 30kW</td><td>25%</td><td>37.86%</td><td>29%</td><td rowspan="6">5%</td><td rowspan="2">5%</td><td rowspan="6">5%</td></tr>
<tr><td rowspan="2">Wind Turbine Parts/ Components*
Special bearing
Gearbox
Yaw components
Turbine controllers
Sensors
Brake hydraulics
Flexible coupling
Brake calipers</td><td rowspan="4">0%**</td><td rowspan="2">22%</td><td rowspan="2">9%</td></tr>
<tr><td>25%</td></tr>
<tr><td>Rotor blades*</td><td>12%</td><td>9%</td><td rowspan="3">5%</td></tr>
<tr><td>Rotor blade parts*</td><td>0%</td><td>9%</td></tr>
<tr><td>Raw materials for rotor blades</td><td>80%</td><td>0%</td><td>N/A</td></tr>
<tr><td colspan="7">Duties are total effective duties that combine basic duty and special duty.
* For both manufacturing and maintenance purposes
** Import duty exemption was up to ten components
*** A prerequisite for clearing imports will be a requirement for the importer to furnish a certificate to the customs authorities from an officer of the rank of deputy secretary and above at MNES. Since MNES clearance is required for each and every shipment, the whole procedure could be time-consuming and arduous.</td></tr>
</table>

Sources: IWTMA 2002; Khanna 1998; MNES 2002/2004/2006; Wind Power Monthly 1996a; Wind Power Monthly 1997b; Wind Power Monthly 2003a

Annex 3: State policy

Tamil Nadu

Tamil Nadu was the first state to draw up a support policy for wind energy, long before the MNES 1993 guidelines was issued. Tamil Nadu strongly promoted demonstration projects from the 1980s, and the accumulated experiences were reflected in their early state policy (Annex 2-a).

Gujarat

Gujarat was another state that started the demonstration projects in the 1980s that helped to formulate its state support policy. Gujarat completely withdrew the state policy in March 1998, following a slight policy modification in 1997. In June 2002, the state announced a new policy (Annex 2-b).

Maharashtra

Maharashtra first drew up its support policy in 1995. The state began implementing a new policy with the strong fiscal and financial incentives in December 1999, which ended in March 2002. The newest policy began in November 2003 (Annex 2-c).

Andhra Pradesh, Karnataka and Rajasthan

The states of Andhra Pradesh, Karnataka and Rajasthan have offered the following policy (Annex 2-d).

Annex 3-a: Support policy in Tamil Nadu

Time Period	Wheeling Charge	Banking	Feed-in Tariffs	Third-Party Sales
Pre 1993 – 3/1996*	2% of power generated	One year 2% charge	INR 2.00/kWh in 1994-95 INR 2.75/kWh in 1995-96	Allowed with 15% wheeling charge (1994-95)
4/1996 – 3/2001*		One Month 2% charge	INR 2.25/kWh in 1996-97 5% annual escalation based on 1996-96 tariff ***	Not allowed
4/2001 – Present **	5% of power generated	One financial year 5% charge	INR 2.70/kWh*** No escalation for five year	

* In addition, a capital subsidy of 10% of project cost with a ceiling of INR 15 lakhs was available until the 1996-97 fiscal year. Exemption of generation tax was available until the 2000-01 fiscal year. Penalties for reactive power charge of INR 0.1/KVARH (quantum of reactive power) started from June 1995. The charge was increased to INR 0.30/KVARH in June 1999, and again to INR 1/KVARH in April 2000.

** Infrastructure charges of INR 28.75/MW and application/processing fee of INR 11,000/application apply. In addition, from May 2002, reactive power charge of INR 0.30/KVARH if the ratio of reactive power drawn to kWh exported is 10% or less and INR 1/KVARH for more than 10%.

*** TNEB has been too financially strapped to keep the 5% annual increase between 1996 and March 2001 and the tariff of INR. 2.70/kWh after April 2001. Only INR 2.25/kWh has been paid in reality. TNEB claims the balance will be paid as and when the utility's financial health improves.

Sources: Consolidated Energy Consultants Ltd. 2005; MNES 1995a; MNES 1996a; MNES 1997a; MNES 1998; MNES 1999a; MNES 2000a; MNES 2001a; MNES 2002a; MNES 2003; MNES 2004; MNES 2005; Winrock International India 2003

Annex 3-b: Support policy in Gujarat

Time Period	Wheeling Charge	Banking	Feed-in Tariffs	Third-Party Sales
1994 – 1997*	2% of power generated	6 months	INR1.75/kWh No escalation	Not allowed
1997 – 3/1998**				
6/2002 – Present***	4% of power generated		INR 2.60/kWh INR 0.05 annual escalation based on 2002-03 tariff for ten years	

* Land was leased on a 15-year term, and sales tax and electricity duty were waived.

** Sales tax exemption and deferral were available up to 50% of investment.

*** Reactive power charge INR 0.1 per consumed power and application/processing fee of INR 50,000/MW are applied. Electricity duty exemption and exemption from power cut are available up to 30%.

Sources: Consolidated Energy Consultants Ltd. 2005; MNES 1995a; MNES 1996a; MNES 1997a; MNES 1998; MNES 1999a; MNES 2000a; MNES 2001a; MNES 2002a; MNES 2003; MNES 2004; MNES 2005

Annex 3-c: Support policy in Maharashtra

<table>
<tr><th>Time Period</th><th>Wheeling Charge</th><th>Banking</th><th>Feed-in Tariffs</th><th>Third-Party Sales</th></tr>
<tr><td>1995 – 12/1999</td><td>Allowed</td><td>Allowed* up to 20% of energy generated</td><td>INR 2.25/Kwh
5% annual escalation based on 1994-95 tariff</td><td rowspan="3">Allowed</td></tr>
<tr><td>12/1999** - 3/2002</td><td>2% of power generated</td><td>One Year</td><td>INR 2.25.KWh
5% annual escalation based on 1997-98 tariff</td></tr>
<tr><td>11/2003- Present ***</td><td>2% of power generated for wheeling plus 5% for T&D loss</td><td>One Year</td><td>INR 2.25.KWh
5% annual escalation based on 1994-95 tariff for Group1 and 2****
INR 3.50/kWh with INR 0.15/kWh annual increase for Group 3*****</td></tr>
</table>

* Banking was for three months in 1996-97 fiscal year and became one year after 1997.

** Although this policy itself was created in 1998, the state did not implement it until December 1999 when the new administration took office in the state. In addition to the above, a capital subsidy of 30% of project cost subject to maximum INR 20 lakh, and sale tax exemption up to 100% of investment were available.

*** Reactive power charge INR 0.25 per consumed power and application/processing fee of INR 50,000/MW. No electricity duty for five years for captive use and a green energy fund are available for 100% of cost of approach road and for 50% of power evacuation arrangement cost as subsidy. No interest loan is available for 50% of power evacuation arrangement cost.

**** 5% tariff escalation is set differently for the following three groups:

Group 1 (projects commissioned before 12/27/1999): annual increase of compound basis for the first ten years, no increase for the next three years, and then 5% increase for the next seven years.

Group 2 (project commissioned between 12/27/1999 and 3/31/2003): annual increase of for eight years. Then the producer needs to sell power in the open market. Increase to be simple rate.

*****Group 3 (project commissioned between 4/1/2003 and 3/31/2007): INR 3.50/kWh for the first year with INR 0.15/kWh annual increase for a period of 13 years.

Sources: Consolidated Energy Consultants Ltd. 2005; MEDA 2001a; MEDA 2001b; MEDA 2002; MNES 1995a; MNES 1996a; MNES 1997a; MNES 1998; MNES 1999a; MNES 2000a; MNES 2001a; MNES 2002a; MNES 2003; MNES 2004; MNES 2005

Annex 3-d: Support policy in Andhra Pradesh, Karnataka and Rajasthan

<table>
<tr><th>State</th><th>Time Period</th><th>Wheeling Charge</th><th>Banking</th><th>Feed-in Tariffs</th><th>Third-Party Sales</th></tr>
<tr><td rowspan="4">Andhra Pradesh</td><td>1994 – 3/1997*</td><td rowspan="3">2% of power generated</td><td>One Year 2% charge*</td><td>INR 2.25/Kwh</td><td rowspan="2">Allowed</td></tr>
<tr><td>4/1997 – 3/2000**</td><td rowspan="2">One Year</td><td rowspan="2">INR 2.25/Kwh
5% annual escalation based on 1997-98 tariffs (until 3/2000) and 1994-95 tariffs (from 4/2000)
INR 3.48/kWh in 2003-04</td></tr>
<tr><td>4/2000 - 3/2004***</td><td rowspan="2">Not allowed</td></tr>
<tr><td>4/2004 – Present ****</td><td>Vary between INR 46/kWh and 60/kWh</td><td>N/A</td><td>INR 3.37/kWh
No escalation</td></tr>
<tr><td colspan="6">* 8 months banking was allowed from August to March. Capital subsidy of 20% of project cost subject to max. INR 25 lakh and 20-year long land lease with free rent for the first five years.
** Capital subsidy of 20% of project cost subject to maximum INR 25 lakh.
*** Reactive power charge of INR 0.1 per consumed power.
****Reactive power charge of INR 0.1 per consumed power, infrastructure development charge of INR 10 lakh/MW, and application/processing fee of INR 5,000/MW are applied.</td></tr>
<tr><td rowspan="4">Karnataka</td><td>1994 – 3/1997*</td><td rowspan="2">2% of power generated</td><td>One year (July – June)*</td><td>INR 1.75/kWh in 1994-95</td><td rowspan="4">Allowed</td></tr>
<tr><td>4/1997 – 3/2000**</td><td>One year</td><td rowspan="2">INR 2.25/kWh
5% annual escalation base on 1994-95 tariffs</td></tr>
<tr><td>4/2000 – 12/2004***</td><td>20% of power generated</td><td>2% per month for one year</td></tr>
<tr><td>1/2005 – Present****</td><td>5% of power generated</td><td>2% charge</td><td>INR 3.40/kWh
No escalation for ten years</td></tr>
<tr><td colspan="6">* Banking had one month grace period. Land-lease for a period of 50 years, capital subsidy same as for other industries, and exemption of electricity duty for five years were available.
** Exemption of electricity duty for five years was available.
*** Capital subsidy of max INR 25 lakh, electricity duty exemption for five years, and reactive power charge of INR. 0.4 per consumed power were applicable. Feed-in-tariffs were INR 3.25/kWh and INR 3.10/kWh for projects commissioned before 8/31/2003 and from 9/1/2003 to 12/31/2004, respectively.
**** Application/processing fee of INR. 30,000/MW and electricity duty exemption for five years.</td></tr>
<tr><td rowspan="2">Rajasthan</td><td>4/1999 – 10/2004*</td><td>2% of power generated</td><td>One year</td><td>INR 2.75/kWh in 1999-01
INR 2.89/kWh in 2001-04
5% annual escalation base on 1999-00 tariffs</td><td rowspan="2">Allowed</td></tr>
<tr><td>10/2004 – Present**</td><td>10% of power generated</td><td>One calendar year</td><td>INR 2.91/kWh for the first year, then INR 0.05/kWh annual escalation until 10th year, then INR. 3.36/ kWh until 20th year</td></tr>
<tr><td colspan="6">* Exemption of electricity duty for five years was available.
** 50% exemption of electricity duty for seven years is available. Reactive power charge of INR 0.25 per consumed power and application/processing fee of INR. 50,000/MW are applied.</td></tr>
</table>

Sources: Consolidated Energy Consultants Ltd. 2005; MNES 1995a; MNES 1996a; MNES 1997a; MNES 1998; MNES 1999a; MNES 2000a; MNES 2001a; MNES 2002a; MNES 2003; MNES 2004; MNES 2005

Fuel Efficient Cookstoves - local production in Cambodia
Photo: Jasmine Hyman

 

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Developing enabling frameworks for the dissemination of clean-burning, fuel-efficient cookstoves

Abstract

Clean-burning, fuel-efficient cookstoves have been promoted as a means of reducing negative health and environmental impacts resulting from the burning of solid biomass fuels. International initiatives such as the Global Alliance for Clean Cookstoves reflect general consensus in the policy making community that investments in fuel-efficient cookstoves provide large returns to society in terms of health benefits, time savings and reduced pressure on forests and climate. However, with a few exceptions the adoption and long-term use of alternative stoves remains low. This article surveys the history of stove adoption and reflects on current models of stove dissemination to identify best practices in clean cookstove programme design and dissemination. The article summarises best practices from the history of cookstove intervention attempts and uses illustrative case studies to present best practice techniques to transform the cookstove challenge into an opportunity for a more effective scaling-up strategy.

Introduction

Distributing clean-burning, fuel-efficient cookstoves, whether through aid or low-cost distribution programmes, has recently risen up the global public agenda since the establishment of the 'Global Clean Cookstove Alliance' (GACC) in September 2010. The GACC is a private-public partnership including the United Nations Foundation, the United States' Environmental Protection Agency and the Shell Foundation, among others (United Nations Foundation 2011; Smith 2010). UNEP is an official implementer of the Alliance and is actively working with over 250 other organisations towards a '100 by 20' target in which 100 million homes adopt clean and efficient stoves and fuels by 2020.

The potential benefits of shifting from current cooking technologies to clean-burning, fuel-efficient cookstoves include reduced exposure to harmful indoor air pollution, decreased pressure on wood resources for firewood and charcoal, reduced workloads for women and children (the traditional collectors of firewood in many cultures), lower monthly expenditure on fuel, and reduced burns and injuries in the home. There are also benefits for the global environment in the form of reduced emissions of greenhouse gases (GHG) and black carbon (soot).[1]

However, in order to meet the 100 by 20 goal, we must examine the past. Interest in stove interventions dates back to the 1970s, when concerns were centered mainly on forest conservation. The justification for interventions in household energy broadened over the years to incorporate concerns about public health and climate change, with forest conservation taking a lesser role. Through these shifts, it became apparent that, despite potentially large social and environmental benefits, successful stove dissemination was not easy to achieve. This article reviews the benefits of clean-burning cookstoves, examines the links between local cooking habits and global climate change, and then examines ways in which the international community can support the widespread dissemination of efficient cookstoves in line with developmental and environmental goals. The discussion outlines key experiences from the past, current financing opportunities for the development practitioner, and issues related to stove adoption and gender dynamics that are also the key to a cookstove project's success on the ground. The purpose of this article is to familiarise the reader with current knowledge on cooking-stove promotion and diffusion, and to point out best practices for fuel-efficient cookstove programme design, dissemination and local level adoption.

Why clean-burning, fuel-efficient cookstoves?

Today, between a third and a half of the world's population rely on solid fuels for the majority of their energy needs. Solid fuels include a range of unprocessed biomass like firewood, crop residues and dung, as well as processed fuels like briquettes and charcoal. In some places, fossil coal is also used for household cooking and heating. Coal use is most prevalent in China, but also occurs in some parts of India, southern Africa and Latin America (ICF Macro 2011).

Numerous negative consequences arise as a result of reliance on solid fuels. Cooking represents the largest use of energy in the household, and most cooking appliances tend to be relatively inefficient both in the way they combust fuel and in how they transfer the heat from the stove to the food. Many families cook indoors, either seasonally or year-round. Inefficient combustion releases harmful pollutants, which concentrate in the kitchen, leading to pollution levels far in excess of international standards (Smith, Edwards et al. 2007). As a result, the WHO estimates that smoke from solid fuels contributes to nearly 3% of the global burden of disease (Smith, Mehta et al. 2004), rivaling malaria and tuberculosis as a source of illness and death in developing regions. Many pollutants also act as heat-trapping greenhouse gases (GHGs) (Bailis 2005; Smith, Uma et al. 2000). Finally, in some locations wood is harvested unsustainably, leading to a net loss in tree cover, which further exacerbates climate change and contributes to environmental degradation.

Additional negative impacts on household members are associated with the collection and preparation of solid fuels. In some places, fuel is collected by women and children who often trek long distances, harvest wood using simple hand tools and carry heavy loads of fuel, which all create a considerable physical burden (Bryceson and Howe 1993). Fuel collection has also been associated with an elevated risk of sexual assault in some regions (Gaye 2007). The potential impacts from cookstove interventions therefore range from reduced pressures on global environmental resources to enhanced livelihoods, health and working conditions in developing country households.

Climate change and cooking stoves: How are they related?

Clean-burning, fuel-efficient cookstoves can contribute to climate change mitigation through two pathways. First, by reducing the demand for wood, stove adoption can relieve pressure on forest resources. On average, stoves currently used to generate carbon emission reductions in the Clean Development Mechanism (CDM) reduce wood fuel consumption by more than 50 percent relative to the stoves they replace (see below for more information about stoves in the CDM). Annually, deforestation constitutes 15-20% of global greenhouse emissions (IPCC 2007). Thus, in places around the developing world where wood fuel demand drives deforestation, clean-burning, fuel-efficient cookstoves can slow or reverse the loss of forest cover and reduce CO_2 emissions by avoiding unsustainable tree harvesting.

However, the exact contribution of wood fuel demand to deforestation is not known. Linkages between wood fuel utilisation and deforestation are complex. While it is possible to measure and document wood savings in households that adopt clean-burning, fuel-efficient cookstoves (PCIA 2011), measuring impacts on forest cover is more difficult, and well-documented cases leading to reduced rates of deforestation are elusive (Ghilardi, Guerrero et al. 2007). This remains an area of active research.

The second way that clean-burning, fuel-efficient stoves contribute to climate change mitigation is by improving combustion. Perfect combustion of hydrocarbon fuels releases only CO_2 and water vapor. However, traditional cookstoves typically have poor combustion and emit methane (CH4), carbon monoxide (CO), non-methane hydrocarbons (NMHCs) and aerosols (Smith, Uma et al. 2000). These additional pollutants have a significantly higher global warming potential than CO_2 (IPCC 2007; MacCarty, Ogle et al. 2008). Well-designed stoves can improve airflow and/or raise temperatures in the combustion area, thereby burning more cleanly and reducing emissions of non-CO_2 pollutants.

In order to compare the climate impacts of cookstoves accurately, fuel processing also needs to be considered. This is most relevant for charcoal because the emissions that occur when wood is turned into charcoal via traditional technologies like earthen kilns can exceed the emissions that occur when charcoal is burned to cook food (Pennise, Smith et al. 2001). Thus, when efficient charcoal stoves are introduced and lead to reduced fuel consumption, emissions decrease at the point of production as well as the point of use.

Thus, clean-burning, fuel-efficient stoves can contribute to climate change mitigation by lowering emissions of non-CO_2 pollutants and reducing wood consumption in cases where wood fuel harvesting leads to deforestation. Importantly, the pollutants that are reduced or avoided by improving combustion also present health risks (particularly aerosols and CO). Promoting stoves as a climate change mitigation strategy therefore leads to improved indoor air quality and associated health benefits.

Approaches to cookstove dissemination over the years

Stove dissemination programmes of various types are currently being implemented in dozens of countries (Legros, Havet et al. 2009). The GACC is perhaps the highest profile stove programme to have been implemented to date. To understand how the Alliance's ambitious goal of 100 million stoves may be achieved, it is instructive to look at the lessons learned throughout the recent history of stove dissemination.

Cookstoves for forest conservation

Although there was some activity in earlier decades, most would place the origin of cookstove interventions in the 1970s. The history of stove dissemination mirrors the history of development priorities over the decades. The first stove projects focused on stopping deforestation. In the 1970s, woodfuel demand was directly blamed for deforestation in developing countries (de Montalembert and Clement 1983; Eckholm 1975; FAO 1978), but over time more nuanced analyses emerged demonstrating that changes in forest cover are often driven by other pressures like timber extraction and demand for pasture or cropland (Leach and Mearns 1988; Leach and Mearns 1996). Further, stoves of that era relied on questionable design principles, and projects had little user input in the design process and suffered from poor monitoring and evaluation (Barnes, Openshaw et al. 1994). Finally, enthusiasm for stove adoption among target populations was often quite low. As a result of these difficulties and the questionable link between wood fuel users and deforestation, early donor interest in cookstoves waned. However, important lessons had been learned: while wood scarcity is a real problem, in many cases wood fuel users cannot be directly 'blamed' for deforestation. Further, successful cookstove interventions require a collaborative approach with the target community in order to ensure that the new technology is both technically and culturally appropriate.

Cookstoves to reduce indoor air pollution

As these realisations sunk in, research was emerging about the health impacts caused by exposure to smoke from the indoor use of solid fuels (Smith 1993). By the late 1990s donors began to prioritise public health, thus opening new funding channels for cookstove programmes. However, this was also a period when donors began to disfavour subsidies and other non-commercial approaches to development assistance and instead began to promote commercial models (Bailis, Cowan et al. 2009). This created particular challenges for alternative stoves. On one hand stoves are durable household goods, and such goods have always been sold in unsubsidised markets around the world. On the other hand cookstoves are upheld as tools for public health interventions, environmental conservation and, more recently, carbon emissions reductions. Each of these problems is linked in some way to a 'public good': public health, ecosystem services and climate change mitigation. Public goods are typically not provided through commercial approaches and may require financial assistance from the government, NGOs or international donors. However, in the case of stoves, by the 1990s such assistance lost popularity.[2]

Cookstoves for climate change mitigation

In the lead-up to the ratification of the Kyoto Protocol to the United Nations Framework Convention on Climate Change in 2005, stoves gained traction for their potential to mitigate climate change (Ezzati, Bailis et al. 2004; Smith and Haigler 2008). This attention has spilled over into mainstream media outlets (Martha Stewart Living 2010; Rosenthal 2009) and has opened up new channels of funding.

In addition, two other aspects in recent climate change mitigation discussions have added to the interest in cookstoves. First, the reduction of emissions from deforestation and degradation (REDD) has brought attention back to the complex links between wood fuel dependence and deforestation (Angelsen, Brockhaus et al. 2009, especially Chapter 19). Secondly, cookstoves have been identified as major sources of 'black carbon' (BC) aerosols, which are potent warming agents (Hansen and Nazarenko 2004). Research on the atmospheric impact of BC aerosols revealed an additional channel through which stoves could mitigate climate change (Ramanathan and Carmichael 2008).

The largest international experiment in new energy finance is the CDM, created under the Kyoto Protocol. The CDM enables developed countries to fund reductions in greenhouse gas emissions in developing countries. Stoves are now being deployed in dozens of carbon offset schemes across the developing world. Emissions reductions for each adopted stove range from 1 to 3 tons of CO_2 equivalent per year (tCO2e/yr). Offsets generate revenue for project developers that can potentially reduce the costs of the stove for the end user and enable the stove producers to achieve financial sustainability, even without development assistance.

In addition to bringing much-needed finance to stove projects, carbon markets have also introduced closer scrutiny to monitoring and evaluation. In the past, most projects were evaluated based on the number of stoves sold or installed without attention being paid to whether and how the stoves were actually used (Ruiz-Mercado, Masera et al.). Now, in order to receive payments for carbon credits, stove projects must follow specific monitoring methodologies and undergo third-party verification. While this proves burdensome for implementation, it is critical to ensure environmental efficacy and provides essential insight into the fate of the stoves after they arrive in the kitchen.

One cookstove project in Mali provides an example of the difference a small amount of carbon finance can make. The project, which sells fuel-efficient charcoal 'SEWA' stoves, uses carbon finance to reduce the stove's cost by 30 percent (from a retail price of USD 7.50 to roughly USD 5.30). Though USD 2.20 seems negligible, average monthly income in is Mali less than USD 100 per household, and this financial assistance has been helpful for stove dissemination (The Gold Standard 2008). Text Box 1 describes a similar project in Peru.

Thus the 1990s brought about another lesson for the cookstove community: while fully subsidised diffusion programmes are unattractive to donors, partial subsidies and assistance can help bridge the abyss between traditional and alternative cooking technologies.

Complexities of stove adoption

Outside China, uptake of fuel-efficient stoves has been slow. Despite decades of interventions, adoption rates remain low. This leads to a natural question: under what circumstances do people adopt new stoves? In order to change cooking technologies, stove users must perceive that the stove carries benefits that outweigh the costs and risks associated with adoption. For stove users, the benefits of adoption can take many forms. These include primary policy objectives like cleaner indoor air and reduced wood consumption. However, research has shown that smoke reduction is not always a top priority for users (Mobarak, Dwivedi et al. 2011; Troncoso, Castillo et al. 2007). Other dimensions, which do not factor into social or environmental policy objectives, are also crucial: for example, ease of use, reduced cooking times and flexibility in being able to burn multiple types or sizes of fuel may also be important. Reduced smoke in the kitchen may also be desirable for reasons other than health. Troncoso and colleagues (2007) report that aesthetic issues like soot-free pots, pans and kitchen walls were very highly valued by stove adopters in central Mexico.[3]

The costs of adoption include any monetary or in-kind expenditure that the stove user pays or contributes to the stove provider.[4] However, other costs may also be relevant. Some cookstoves can only burn small sticks and twigs, which may require users to spend additional time preparing fuel. Moreover, users may perceive some risk in adopting a new stove technology. For example, the stove may alter the taste of certain foods, it may break or be incompatible with cooking utensils, maintenance may be too burdensome, and spare parts may not be readily available, or the stove may fail to perform as advertised.

Regional variations in stove programmes

Roughly 160 stove programmes are currently active (REN21 2010). The IPCC's 'Special Report on Renewable Energy Sources' (Chum, Faaij et al. 2011) uses data from the UNDP and WHO to estimate that 820 million people, or 'around 30% of the 2.7 billion that rely on traditional biomass' use 'some kind of improved stove for cooking' (Ch. 2, p. 55). Since typical households have four to five individuals, between 160 and 200 million 'improved' stoves are probably in use worldwide. The authors' own analysis of UNDP/WHO data finds ~200 million stoves in use.

Of course, wide regional disparities exist. Currently, 75% of non-traditional stoves in use globally are in China, where over 70 percent of the solid fuel-using population has adopted some type of new stove (Legros, Havet et al. 2009). India, with a similar number of people reliant on solid fuels, follows a distant second, with 13.5 million non-traditional stoves, just eight percent of solid fuel users (Legros, Havet et al. 2009). Other regions, like Sub-Saharan Africa and South Asian countries, where biomass reliance exceeds 80% of the population, stoves have reached just 4-5 million households, which is fewer than 10% percent of solid fuel users in each region (Legros, Havet et al. 2009). It is difficult to explain the wide disparity between non-traditional stove adoption in China and the slower uptake elsewhere; however, Text Box 2 discusses some of the dimensions of China's stove programme that led to its success.

Summing up, over the past three decades, experiences indicate that many factors complicate efforts to achieve the widespread adoption of clean-burning, fuel-efficient cookstoves. Design difficulties, a lack of prioritisation and cash restraints among target populations, and difficulties with the monitoring and verification of long-term adoption rank among the most problematic issues. Yet the challenge is well worth the attention of the international community given the magnitude of stove-related problems and the cost-effectiveness of successful stove interventions. The next section of the article examines more closely how widely cookstove dissemination can be achieved worldwide.

Current models of stove dissemination: The challenge of scaling up

Stove dissemination, whether one prioritises forests, public health, climate or all three of the potential benefits, requires careful programme design to overcome a series of challenges. The successful diffusion of efficient cookstoves cannot follow a single recipe. Instead stove programs must find the right combination of elements from a multi-course menu. This section examines the factors that programme designers must consider.

Sensitivity to factors related to gender and social norms

Importantly, there is a gender dimension to the costs and benefits of stove adoption that may be underappreciated (Clancy 2002; Skutsch 2005). For example, in many households around the world, expenditure decisions are made primarily by male household heads (Hart 1997), while responsibility for cooking and the impacts associated with exposure to indoor air pollution fall primarily on women. Although clean-burning cookstoves may reduce harmful emissions, the men who control budgets do not directly experience these benefits. Fuel-efficient stoves also reduce fuel consumption, but in many cases women and children collect fuel wood at no monetary cost, so that men may undervalue the time saved. In contrast, when fuel is purchased, the benefits of adopting fuel-saving technology may be more obvious.

Numerous context-specific factors come into play when a family is presented with a choice to purchase a fuel-efficient stove (or even accept a stove offered to them for free). Some stove users may consider reduced fuel consumption an attractive attribute while others may not be concerned with fuel consumption but value cleaner kitchen environments, and yet others may demand fuel-flexibility because of seasonal variation in the types of fuel available to them. Moreover, there may be no agreement within the household about the relative importance of each dimension described above. In addition, the opinions of family members may not be static. Instead, opinions may evolve as individuals observe friends, neighbours and 'local thought leaders' who adopt (or do not adopt) cookstoves, or they may be influenced by marketing messages conveyed by stove promoters. Achieving the widespread adoption of clean cookstoves among the hundreds of millions of households worldwide requires an understanding of these complex social factors. Partnering with local organisations, women's groups and local leaders can help the practitioner transform this challenge into an opportunity for a more locally tailored and effective scale-up strategy.

Business models to meet local conditions

In order to achieve widespread stove adoption, stove dissemination needs to occur on an unprecedented scale. As discussed above, over 700 million households worldwide use solid fuels without clean-burning, fuel-efficient stove. Reaching these households poses a challenge. In order to achieve the scale necessary, thousands of new businesses will need to be established in stove construction and supply, as well as in retail sales. Business start-ups are difficult under any circumstances, particularly when the majority of consumers are poor rural families. Many of the countries in which solid fuel users reside are not business-friendly. A recent World Bank study ranks Sub-Saharan Africa and South Asia, where the majority of people in need of stoves reside, as the most difficult regions in which to conduct business (World Bank 2010).[5]

Several stove programmes have reduced these challenges by developing lightweight stove designs that are fabricated in a centralised factory and shipped around the world (Aitken, Watson et al. 2010; Adkins, Tyler et al. 2010). This strategy reduces the need to establish multiple businesses in areas of the world with difficult business environments. It also facilitates quality control and allows stove producers to take advantage of economies of scale. However, for regions where large in-built stoves are the norm, like Central America, mass production of light-weight portable stoves is unlikely to succeed. Still, in these cases some degree of centralised production is possible. For example, several stove promoters in Central America have established centralised facilities, which make mass-produced components like grills, grates, chimneys and fireboxes (Proyecto Mirador 2011; Álvarez, Palma et al. 2004). While this approach requires facilities to be established in places with difficult business environments, they also have the advantage that they create employment and build local capacity. Similarly, small-scale, highly decentralised production can also be successful, as in the case of the well-known Kenyan ceramic jiko (KCJ), a simple low-cost charcoal stove that is mass-produced by informal artisans (metal and ceramics workers) across Kenya. The design was popularised with donor support in the 1980s and 1990s and has now been replicated across Sub-Saharan Africa (Bailis, Cowan et al. 2009).

Finance

The costs of cookstove projects range from the design of the new technology to the investments required to transport the stoves, educate consumers, deliver the stoves, monitor long-term use and, if necessary, repair or replace poorly functioning stoves. Financial models range from NGO-led efforts that provide users with 100% subsidised stoves to purely commercial sales in which the users pay the full costs and the suppliers earn a profit. Many stove programmes exist somewhere between these two extremes, offering stoves at partially subsidised prices. An increasing number use carbon finance as a means to lower purchase costs for the target population while also recouping the initial capital investment (Burridge, Goetz et al. 2011).

A commonality present in most cookstove initiatives is that the majority of solid fuel users are poor rural families who tend to be cash-constrained and lack access to credit. Fuel-efficient stoves may cost as little as USD 5 for a simple metal charcoal stove (Kinyanjui 2010) to over USD 100 for some of the robustly built 'plancha' stoves being promoted in Central America (Álvarez, Palma et al. 2004). However, even at the lower end of this range, the cost may be a barrier to adoption among the poorest families, while the upper end of this range would be a stretch for most rural families. Thus, whether the objective is to make fuel-efficient stoves more affordable to all potential users, or simply to allow the poorest families to access what better-off families can already afford, mechanisms to reduce the initial price of stoves are essential for widespread adoption. This can be accomplished through several mechanisms, including corporate finance, direct subsidies, microfinance and finance through the generation and sale of carbon offsets.

Corporate Finance

A small number of large corporations have led stove dissemination efforts. For example, Bosch-Siemens, BP and Philips have invested in developing and marketing alternative stoves. In these cases, corporations with large amounts of capital and substantial in-house capacity for research, product design and marketing have been able to bring a stove from concept through to commercialisation (Roth 2011; B/S/H 2011).[6]

Subsidies

There are active debates about the degree to which clean-burning, fuel-efficient stoves should be subsidised (Bailis, Cowan et al. 2009; Barnes, Openshaw et al. 1994). Many think that subsidies of some form are justifiable on health grounds. Research has shown that clean-burning, fuel-efficient stoves are an extremely cost-effective public-health investment. The WHO estimates that efforts to reduce illness and death from exposure to wood smoke in Sub-Saharan Africa through clean cookstove dissemination would cost between USD 500 and 700 per healthy year gained. In contrast, interventions that attempt to improve health in the region by promoting clean-burning fossil fuels like kerosene or LPG would cost between USD 1,000 and USD 11,000 per healthy year gained (Mehta and Shahpar 2004). In fact, stoves are likely to be as cost-effective as other low-cost interventions that reduce the burden of disease from common diseases in developing regions like malaria and tuberculosis, which are typically subsidised in order to reach the poorest and most vulnerable populations (Bailis, Cowan et al. 2009). Moreover, other analysts have estimated additional non-market benefits of interventions such as timesaving for stove adopters resulting from reduced illness and less time spent collecting fuel, as well as reduced environmental damage. Taking these benefits together with health improvements yields very large cost-benefit ratios for cookstove projects, ranging from three to six in Malawi (Habermehl 2008) and China (Smith and Haigler 2008), nine to eleven in Mexico (García-Frapolli, Schilmann et al. 2010), thirteen in Zimbabwe (Mutamba and Gwata 2003), and 25 to 29 in Uganda (Habermehl 2007). However, most of the benefits are not monetised and are unlikely to materialise without outside intervention, which suggests that long-term subsidies may be justified (Adler 2010).

Stove subsidies come in many forms. In addition to directly reducing the final price of the stove to consumers, subsidies may also target stove developers themselves in the form of start-up grants or concessionary loans (Gaul 2009). This is particularly useful at the early stages of stove development. Stoves, like any type of new consumer good, must undergo research, field-testing and multiple design stages. The concept of health benefits through the reduction of smoke from solid fuels must also be marketed to consumers, as well as any other benefits of clean cookstove adoption (faster cooking times, lower fuel consumption, etc.). Many stove developers began as non-governmental organisations, which may have trouble financing these activities in the early stages of product development.[7]

Microfinance schemes

Another method to overcome the high costs of cookstoves for consumers is to couple micro-finance with stove dissemination (Adler 2010). Since its inception, microfinance has become a popular means of providing small quantities of credit to poor rural families with little access to formal credit markets.[8]

In the past, some stove promoters have attempted to offer their own forms of micro-finance, but this has proved difficult, as they seldom have the ability to assess risk or the capacity to take action in the case of a default (Bailis, Cowan et al. 2009). More recently the situation has changed, as many MFIs have loosened their lending policies and now lend for purchases of consumer goods (McIntosh, Villaran et al. 2011), including loans for energy services (Rao, Miller et al. 2009). To finance stoves, the Shell Foundation, a major donor, has courted MFIs in order to encourage their participation in the sector (Microfinance Focus 2009). In addition, individual stove promoters are forming partnerships with MFIs (Microfinance Africa 2011). Grameen Shakti, an offshoot of the Grameen Bank, the pioneering Bangladeshi MFI, began lending for purchases of non-traditional stoves in 2006, when they financed the purchase of 400 stoves. By 2010, the organisation had financed nearly 150,000 stoves (Grameen Shakti 2011).

Another option is pairing microfinance with carbon finance, as was done by the Nepal National Biodigester Program in Chitwan province (Sundar and Shakya). Since micro-lenders generally favour loans for income-generating activities over loans for consumer goods, pairing microfinance schemes with carbon finance options can also help project designers overcome financial barriers.

Carbon Finance

As briefly mentioned above, carbon finance represents another means of reducing upfront stove costs. Carbon credits place value on the emissions reductions achieved by shifting from traditional to clean-burning cookstoves. Funds generated by selling credits can be used to reduce the cost of the stove. Rather than relying on government subsidies or donor aid, stove promoters can sell emissions reductions as a source of finance. One of the benefits of finance generated through carbon credits is that the cookstove project can achieve long-term financial sustainability without relying on donor or government support.

Carbon offsets from cookstoves exist in both regulated and voluntary markets. The regulated markets are dominated by the Clean Development Mechanism (CDM), which has a lengthy verification process that can pose barriers for project developers. The voluntary market presents an alternative to the CDM. Regulations vary in voluntary markets: some market segments allow less burdensome verification processes than the CDM, while others, like the Gold Standard, are arguably more strict (The Gold Standard 2011).

At the time of writing, there were nineteen cookstove projects in the CDM pipeline (Fenhann 2011). Voluntary markets are not as well documented as the CDM, so the total number of cookstove projects participating in voluntary carbon markets is not clear. Nevertheless, over thirty projects seeking voluntary Gold Standard certification have also been identified (The Gold Standard 2011). A recent analysis from REN21 (2010) noted that 160 projects are currently active worldwide. If correct, this implies that roughly 30% of stove projects are engaged with carbon markets through the CDM and/or Gold Standard.

On average, the cookstoves being promoted by projects in the CDM pipeline are estimated to reduce fuel consumption by about 60% relative to the traditional stoves they will replace, resulting in annual GHG emissions reductions of 2.4 tCO_2e per stove.[9] Historically, offsets in the CDM have sold for USD 11-14 (Kossoy and Ambrosi 2010). If stove projects sold offsets at that price, then each stove would earn USD 30-38 per year. Assuming half of this is required to cover the significant transaction costs of establishing a CDM project (Michaelowa and Jotzo 2005), then USD 15-19 per year remain to cover the costs of the stoves. Most stoves last two to three years, and some are built to last seven years or more (Burridge, Goetz et al. 2011). Thus the sale of carbon offsets can substantially reduce the cost of most stoves.

Conclusions

The '100 by 20' challenge is timely, reflecting widespread understanding within the international development community that investments in clean-burning cookstoves provide large returns to society, largely in the form of non-monetary benefits like health, time savings and reduced environmental impacts. While the scale of the problem presents numerous challenges, policy-makers can draw on decades of prior experience to prepare the field for higher levels of stove adoption and stove-programme durability, even in the face of changing economic conditions and complex cultural settings.

This article has summarised current knowledge on cookstoves in terms of the science, historical victories and failures, and current options for financing diffusion projects. While each fuel-efficient cookstove intervention must be designed for the development needs of the particular target community, general best practices can be used to help guide the policy-maker in programme design:

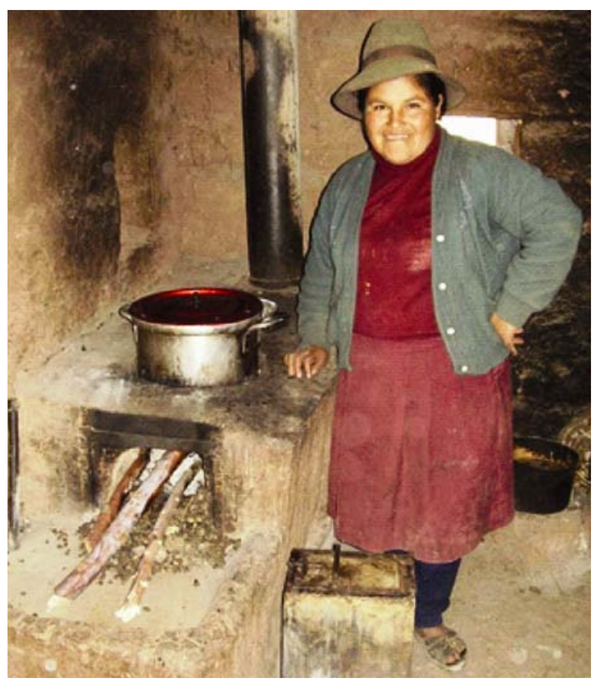
1. Achieving the widespread adoption of clean cookstoves is challenging, requiring an understanding of complex social factors. Cookstove programmes that are partnered with local organisations, women's groups and local leaders can transform this challenge into an opportunity for a more effective scaling-up strategy.
2. The environmental and health benefits associated with reduced emissions are 'goods' that may not be fully valued by the target community. It is therefore sensible for policy-makers to identify the characteristics of alternative stoves that would be valued, such as faster cooking times or cleaner kitchens, and to incorporate them into stove design and marketing.
3. In a similar vein, cultural factors may be the key to the success of the cookstove programme. Fuel-efficient technologies must not only cook more cleanly and reduce carbon emissions, but cultural norms – such as flavour, the ability to accommodate traditional pot sizes and portability – can be key indicators as to whether or not a particular cookstove programme will succeed in a given context.
4. Gender and power dynamics within the community and the household may influence stove dissemination. Early investment in stakeholder consultations and village-level surveys can help project developers identify household decision-making process regarding the choice whether or not to adopt a new stove.
5. It should be recognised that subsidies in some form, either direct to the end user or at some intermediate stage(s) of the project, may be essential until the dissemination programme 'takes root' in the community and financial self-sustainability can be achieved.
6. Carbon finance, microfinance and private-public partnerships may complement subsidies

Text Box 1: Notes from the field: The Q'ori Qoncha Cookstove Program in Peru

Currently in rural Peru, the terra cotta fogón is used for domestic cooking. A fogón is a lidded pot placed on the ground and heated by a wood fire. According to the Catholic University of Peru, approximately two million Peruvian homes use a fogón to cook with wood fuel. The fogón has no chimney and thus fills the home with smoke. Women and children are principally impacted as they spend the most time in the kitchen, and they often suffer from serious health problems. Furthermore, the fogón does not cook the food evenly or completely, nor does it sterilise water, causing digestive health risks for the entire household.

The Q'ori Qoncha Cookstove Program in Peru was initiated by the French social initiative 'Microsol' and carbon consultants from the myclimate organisation, together with local Peruvian NGO 'ADRA Perú – Agencia Adventista para el Desarollo y Recursos Asistenciales', ProPERU Service Corps and the 'Instituto Trabajo y Familia' in 2008. The Gold Standard Foundation, a certification scheme for carbon emission reduction projects endorsed by over sixty environmental groups worldwide, registered the program in 2010. According to an independent verification report by Tuv Nord in May 2011, the Q'ori Qoncha program has installed 26,070 fuel-efficient cookstoves in the Peruvian regions of Cusco and La Libertad, resulting in improved living conditions and livelihoods for the households involved, as well as the reduction of 44,409 tons of carbon dioxide from the global atmosphere.

The stoves are locally produced from clay, fine mud and adobe. In addition to the environmental and health benefits, the program also creates new skilled jobs, as locals produce and maintain the stoves. According to one recipient of a cookstove in Lima, 'Our lives changed. The advantages go far beyond the wood savings' (The Gold Standard 2008; Tuv Nord 2011).

Left: A traditional fogon on an open fire; note that there is no channel for smoke evacuation.
Right: A fuel-efficient cookstove with chimney. The black walls remain from the days of the old fogon, but smoke is part of the past [2008, The Gold Standard]

Text Box 2: Past successes: China's National Improved Stove Program (NISP)

China's massive National Improved Stove Program (NISP) ran from the early 1980s until the late 1990s in three distinct phases. The program began with strong government backing, but was run as a decentralised program, with decisions being made largely at the county level. Moreover, each phase involved a shift toward increasing commercialisation, as described below (Sinton, Smith et al. 2004; Smith 1993):

- Phase 1 (1983–1990): Counties received funding to promote fuel-efficient stoves. The central government supplied a small fraction and county governments provided additional funds, but consumers paid the largest proportion of the stoves' costs. NISP was not designed to target the poor, but some counties subsidised stoves to poor households.
- Phase 2 (1990–1995): Consumer subsidies were rapidly scaled back as part of a commercialisation strategy. However, businesses assistance was still available in the form of tax breaks and favourable loans.
- Phase 3 (1995–2002): Government support largely shifted to providing technical advice. However, the government also played an important role in setting standards and offering certification to ensure consumer confidence in the new designs.

Over twenty years of activity, NISP created a strong infrastructure consisting of private enterprises, R&D facilities and state agencies that are equipped to develop and market efficient solid fuel stoves throughout many of China's rural areas.

or replace them entirely. In places where MFIs are already well established, it may be relatively straightforward to expand their lending instruments to include clean-burning stoves, particularly as improved stoves become more 'mainstream'. Similarly, MFIs may be helpful in establishing stove enterprises: design labs, manufacturing facilities and retail outlets.

While there is no 'one size fits all' solution for bringing clean-burning, fuel-efficient cookstoves to the rural and urban poor, the clear political commitment and international focus has created an enabling environment, setting the stage for meaningful progress.

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End Notes

1. This list includes the full range of possible benefits arising as a result of a shift from burning solid fuels in open fires or stoves characterised by poor combustion vented directly into the indoor environment with clean-burning, fuel-efficient stoves. We must note, however, that not all stoves promoted as cleaner and more efficient alternatives deliver all of these benefits. Moreover, a wide range of stoves are characterised as 'improved', with the implication that they deliver this full suite of benefits, but in reality they do not (Smith and Dutta 2011). For this reason, we avoid the term 'improved' and use 'clean-burning, fuel-efficient' in its place.
2. Subsidies are not straightforward. Previous analyses of stove adoption have acknowledged their importance while also stressing the need to phase them out after a short time (see Barnes, Openshaw et al. 1994, for example). We explore this tension in Section
3. Though it is beyond the scope of this article, stove design is essential to achieving these qualities: ease of use, reduced cooking times and flexibility, as well as reduced emissions and fuel consumption (see Bryden, Still et al. 2006, for a detailed discussion).
4. In Central America, improved stoves are typically large appliances built directly into the kitchen. There, stove promoters may require in-kind contributions of sand, cement or bricks as a partial payment for the stove (Proyecto Mirador 2011).
5. However, the report also notes that many countries in Sub-Saharan Africa are undertaking numerous reforms to become more open to business. In contrast, countries in South Asia are lagging behind relative to other regions.
6. The Protos cooker by Bosch-Siemens uses plant oil rather than solid biomass. Nevertheless, it is a good example of a stove developed by a large corporation with considerable in-house capacity for research, product design and marketing (B/S/H 2011).
7. Others, like the large corporations that have developed improved stoves, face fewer challenges in this regard.
8. There is a vast literature on microfinance, which is beyond the scope of this chapter. For examples relevant to public health, see (Leatherman and Dunford 2010; Pronyk, Hargreaves et al. 2007) and access to energy services, see (Ezzati, Bailis et al. 2004; Zerriffi 2011).
9. This is the unweighted average annual GHG reduction claimed per stove based on data in Project Design Documents (PDDs) for nine CDM projects and eleven Programs of Activity (PoAs) listed as being in the CDM pipeline as of August 2011 (Fenhann 2011).

Wind turbines in the foothills
Photo: UNEP internal archive

  

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An enabling framework for wind power in Colombia: What are the lessons from Latin America?

Abstract

This article discusses the existing framework for enabling wind power in Colombia. Although the Colombian framework does not specifically target wind power, it provides tax reductions for renewables. So far, such policy has favoured conventional technologies (including hydro), at the expense of renewable energy technologies. Other Latin American countries including Brazil, Mexico, Chile and Costa Rica have achieved fast deployment of wind energy technologies by combining feed in tariffs with other incentives such as portfolio standards and tax reduction. The Brazilian case is an example of how adequate incentives can add wind energy technologies to a power system that relies mostly on hydro sources. Based on this evidence, we propose a policy for promoting renewables in Colombia by using schemes that combine feed-in tariffs and portfolio standards to make initial progress by 2020.

Introduction

This article examines the existing environment for power generation in Colombia and identifies policy requirements for increasing the share of Renewable Energy Technologies (RETs), specifically wind power. As high capital costs are one of the main barriers to investing in wind power, we focus on the regulatory incentives for investment in power generation.

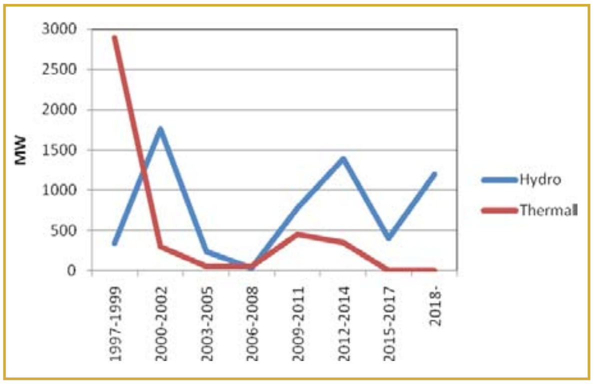
Colombia's hydroelectricity potential is among the highest in the world (WEC, 2004). Energy policy in Colombia has aimed at developing these resources: by 2010, hydro power's share of total generation capacity was 63%, and it supplied between 70% and 80% of the demand connected to the transmission grid (XM, 2010). Although this policy has had positive results in terms of costs and efficiency of supply (Larsen et al., 2004), the high dependence on hydro power makes the system vulnerable to climatic variations (UPME, 2009; Larsen et al., 2004). Thermal generation, with a 33% share of total installed capacity, balances the fluctuations of hydropower generation. In a dry year, when hydropower cannot operate at full capacity, thermal power plants generate up to 50% of total demand, whereas in average rainy conditions, thermoelectricity dispatch might be as low as 15-20% of the total (UPME, 2009; XM, 2010).

During the last fifteen years, gas-powered plants have been the preferred option to back up power generation during periods of peak demand and during the dry season in Colombia. More than 1400 MW of gas-fired generation capacity has been built since 1994, making up 28% of installed generation capacity in 2010, and accounting for 84% of thermal capacity (UPME, 2009). Combined-cycle gas turbines (CCGT) have shorter lead times and lower capital costs than large hydro plants; this, along with the incentives given to thermal plants between 1997 and 2005, made CCGT a commercially attractive option for increasing the reliability of power supply in Colombia.

Regulatory incentives for remunerating capacity expansions that increase security of supply and the reliability of the interconnected system date from 1994. These incentives have been modified and adjusted to the changing conditions of the Colombian market (Larsen et al., 2004; Dyner et al., 2007). By definition, this mechanism is technology-neutral, meaning that any technology that ensures 'firm' (i.e., stable) energy supplies can receive monetary payments. As Figure 1 shows, between 1997 and 2007, the incentives initially favoured thermal technologies for increasing generation capacity, but ever since 2000 these have favoured hydro technologies. Note that the only wind farm in place did not receive capacity payments and was built using different incentives.

To summarise, hydroelectricity forms the basis of power generation in Colombia, and because water inflows are variable, CCGTs provide security of supply. However, as Figure 1 shows, incentives for firm capacity have favoured hydro-based power, a seasonally-dependent technology. The dominance of hydro power has a direct impact on the profitability of thermal plants, whose high operating costs make thermal generation economically infeasible during periods with high availability of water. With this structure, the electricity sector in Colombia has a relatively low carbon footprint, and the main reason for seeking a larger share of RETs is technology diversification and, as discussed above, security of supply.

Figure 1. New generation capacity between 1997 and 2010 and expected additions to 2018 (results from auctions).



The potential for RETs deployment in Colombia is high but has not been fully estimated. Water sources suitable for small hydro plants (less than 20 MW) are abundant, as is solar radiation. More research is needed to assess the wind potential of the whole country, but the coastal region of La Guajira, where Jepírachi, the only wind farm, is located, has proven potential for generating commercial wind power as high as 18 GW, according to Vergara et al. (2010). Because the capital costs of wind power are relatively high compared to other options, policy-makers in Colombia tend to consider it a viable option to generate energy in off-grid zones, rather than a technology that can contribute to power supply in the interconnected power sector (UPME, 2009). Nevertheless, evidence from the only wind power project in Colombia suggests that wind power technology can increase the reliability of power supply in the dry seasons. In particular, wind flow variations in La Guajira, Colombia, balance seasonal and hourly variations of water flows, and effectively increase the availability of energy (ESMAP, 2009).

Experiences from around the world indicate that wind power can be successfully added to the primary energy mix, provided that there is an enabling framework that lowers entry barriers, especially the high capital costs (IEA, 2009). In 2002 Colombia created a general framework for promoting Renewable Energy Technologies (RETs). This framework includes incentives for research on RETs and tax exemptions for suppliers that use RETs and obtain carbon certificates. Between 2004 and 2010, the Colombian enabling framework promoted only one wind farm with a capacity of 19.5 MW (0.015% of total 13440 MW capacity). This is a poor result compared to other countries in Latin America.

The existing framework for promoting renewable and wind power generation consists of the following initiatives:

- Law 697 of 2001 and Decree 3683 of 2003, which:
    1. Incorporate renewables and energy efficiency as part of the goals to be met by energy policy and create institutions to support their development,
    2. Propose research funding for energy efficiency, and
    3. Include renewable options for non-interconnected regions.
- Law 788 of 2002, which establishes:

    A fifteen-year tax-exemption period for power generated from wind or biomass energy. To benefit from this tax-exemption scheme, generators must obtain carbon emission certificates, which are an additional source of income, and 50% of this income must be invested locally in social benefit programs.

This policy for RETs has been insufficient to trigger a large-scale development of wind power in Colombia. By 2010, the only wind farm in place was Jepírachi. Despite the significant potential for developing renewable energy sources, only 1.2% (105 MW) of proposed new generation projects are non-hydro renewable. Although other wind projects are under consideration, the indicative plan for power generation and transmission expansion registers only the 20 MW Jouktai wind farm, which is to be located in La Guajira (ESMAP, 2009; UPME, 2009).

The Colombian framework fails to promote wind power mainly because the incentives it provides (tax cuts) are not targeted at lowering entry barriers for renewables. The high capital costs of wind power, a market structure based on hydro technologies and high industry concentration (four utilities account for 82.39% of hydro capacity; UPME, 2009) create a negative environment for investing in wind farms.

As discussed earlier, regulatory incentives (capacity and reliability charges) have favoured expansion based on medium to large-scale hydro plants at the expense of other technologies, particularly renewables (Larsen et al., 2004). Reliability charges can be allocated regardless of technology and could in principle remunerate the capital costs of wind energy. In their current form, however, reliability charges do not provide a method of forecasting the power generated by intermittent sources other than that available for hydro sources. The contribution of hydroelectricity to power supply can be forecast from long historic time series which are not available for wind, solar or other renewable energy technologies. Thus, it is not possible to make a reliable estimate of the contribution of wind power technologies to total energy supply during years of extreme weather conditions. A lack of wind generation data is common to many wind farms, but average assessments of capacity can be used for remunerating immature wind farms, as the New York Independent System Operator (NYISO), the Pennsylvania-Jersey-Maryland market (PJM) and Spain do. (Botero et al., 2010).

As there are limited incentives for technological innovation, utilities are reluctant to diversify their technology portfolios. Barriers to renewable energy technologies are likely to persist in the short to medium term. Wind power costs, however, are expected to decrease, which will provide an opportunity to develop Colombia's wind resources. From the 1980s to the 2000s worldwide, wind power capacity grew at annual rates above 20% (IEA, 2004); turbine sizes increased and capacity costs generally decreased (Wiser and Bolinger, 2009). Capital and equipment shortages in the 2000s put pressure on wind capacity costs, but in the long term it is expected that the industry will move along a learning curve, thus reducing its capital costs (Wiser and Bolinger, 2009).

The case of the Jepírachi wind farm, which this article discusses in detail, illustrates the challenges of Colombia's renewables, and also shows the potential for the deployment of wind power technologies on a larger scale. Having examined the Colombian framework for promoting RETs, we then look at policies in Latin American countries, focusing on those whose power sector structure is similar to that of Colombia's. Based on this analysis, we examine the potential for the Ministry of Mines to set wind generation goals of 3% for 2015 and 6% by 2019. Finally, this proposal is contrasted with the current proposal by Vergara et al., (2010) to make reliability payments to intermittent sources by calculating their contribution to the ability of the interconnected system to meet demand during extremely dry seasons (firmness).

Assessment and development of wind resources in Colombia

As of 2010, the only wind farm operating in Colombia is located in La Guajira province, a region in the north-east of the country. This onshore wind farm has fifteen units of 1.3 MW each for a total nominal power of 19.5 MW. This farm, the first one built in Colombia, was commissioned in 2004 and it is connected to the national grid by a 110 kV transmission line. Minimum wind speed for the windmills is 4 m/s and the average wind speed is 9.25 m/s (EPM, 2008; Pinilla and Trujillo, 2009). This wind regime is rated among the best in South America, comparable only to the Patagonia region (ESMAP, 2010). The farm was built by Empresas Públicas de Medellín (EPM), a public utility, the second largest power generator of the country and the only vertically integrated utility. Jepírachi is part of EPM's R&D programme on wind energy, whose purpose is to learn about the operation of wind farms in Colombia, and which includes:

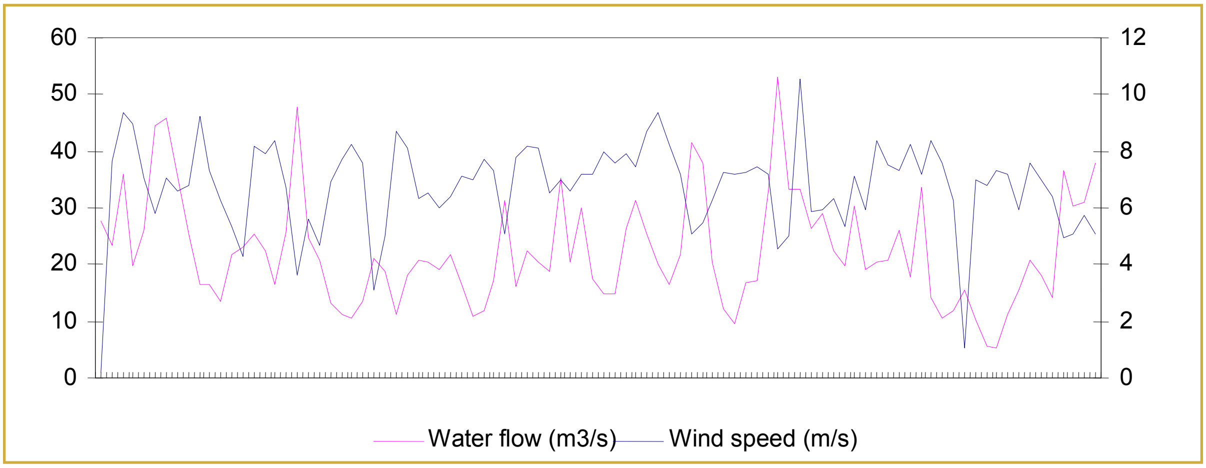
1. Evaluation of wind regimes
2. Study of tax incentives and the enabling framework for RETs, and
3. A pilot plant to transfer and innovate wind energy technology

EPM started this R&D programme after examining medium to long-term trends for power generation in Colombia. The Guajira is a semi-tropical desert, and the operating challenges of the pilot plant have shown the need to adapt wind power technology to the Caribbean conditions (Pinilla and Trujillo, 2009).

GTZ, the World Bank and the Universidad Nacional de Colombia advised EPM during the formulation of the project, whose capital investment was $21 million dollars (EPM, 2004). The plant is located in the Uribia municipality, in the territory of the indigenous Wayúu community. This is an arid area, with long summers, frequent droughts and no surface water. Water comes from wells and desalination plants. As a part of its social and environmental plant, EPM built a desalination plant that provides the Wayúu community with clean water. Carbon credits are 10% of the Jepírachi's revenues, the rest coming from energy sales.

The output and performance data for the Jepírachi plant confirm that year-round winds in the Guajira region confirm the high potential for energy generation (see Figure 2). However, as winds speeds do vary, the performance of wind power is evaluated in terms of its capacity factor and availability. Capacity, or plant factors, are a measure of the productivity of a power plant, calculated as the amount of energy that the plant produces over a given time period divided by the amount of energy that would have been produced if the plant had been running at full capacity during the same time period (DOE, 2008). Availability is defined as the number of hours of energy production divided by the number of hours that wind speed is between the operating limits of the turbine (Pinilla and Trujillo 2009). Pinilla and Trujillo (2009) report that capacity factors for turbines in Jepírachi are similar to those for other turbines, averaging 38% with 96% availability, whereas production is higher than typical values in the literature (1750 kWh/M^2-year per turbine).

Figure 2. Complementarities between water regimes in the northwest of Colombia and wind regimes in La Guajira, Colombia.



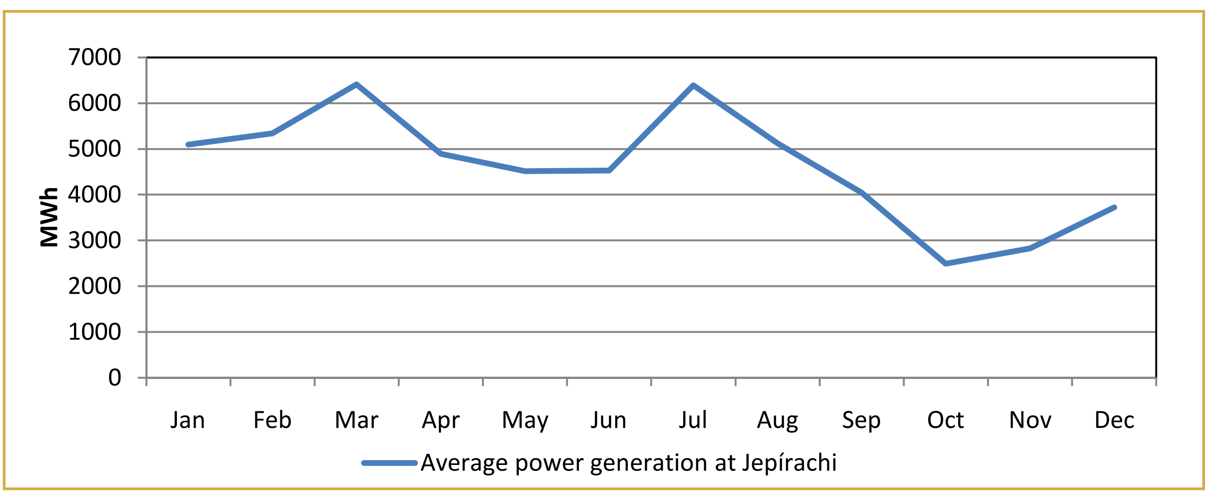
Source: COLCIENCIAS-EPM-Universidad Nacional de Colombia, 2003.

As Figure 2 shows, wind peaks in La Guajira coincide with low water flows in the northwest of Colombia. To a large extent, wind resources complement water resources and the complementarities between water flow and wind speed are higher during the first months of the year, when water is scarce. Figure 2 shows how energy produced in Jepírachi is higher during the first six months of the year, and it is lower during the second semester.

In addition to the complementarities between water and wind regimes, daily variability of wind can also improve the performance of the interconnected system because wind power could displace some water resources in the low-demand hours (Vergara et al., 2010).

Being the first operational wind farm in Colombia, Jepírachi has provided valuable data and knowledge

Figure 3. Average power generation at Jepírachi. Adapted from Vergara et al., 2010



that may support efforts to expand wind power generation in Colombia. In particular, and unlike other projects, this has been well accepted by the Wayúu community and is a reference for the future of wind power in La Guajira (Valencia, 2009). There are technical challenges in adapting wind generation technology to the conditions of the Caribbean (Pinilla and Trujillo), but the plant's performance is likely to improve as EPM learns to operate the technology in the harsh climate of La Guajira. Current performance data prove that the high-speed, low-turbulence winds of Guajira province could generate more than 100 GWh per year (Pérez and Osorio, 2002), and a couple of projects have been proposed to develop such potential, as shown in Table 1.

From this policy perspective, during the early stages of technology adoption, innovation and learning are the main benefits of adopting RETs. In the long run, these technologies increase the robustness of Colombia's power system by complementing its hydro energy sources. As the previous discussion shows, the Colombian power market needs clear, direct and effective regulation of renewables to promote wind power. This becomes even more evident if one examines the policies for renewables in similar countries. The next section analyses the enabling frameworks for wind energy in Latin America and relates these frameworks to the Colombian case in order to propose changes to the existing policy.

Table 1. Wind power capacity expansions built and under construction in Colombia as of 2010

Project	Capacity (MW)	Location	Company	Stage
Jouktai	20	Uribia, Guajira	Wayuu S.A. / ISAGEN	Advised by the Netherlands. Environmental license issued in 2010*
Ipapure**	200	Ipapure (Uribia, Guajira)	N.A.	In 2008 EPM asked for bids for a pre-feasibility study for a 200MW plant in Ipapure (Uribia) and Bahía Hondita (Maicao)***.

** Source: ISAGEN (2010)*
*** Source: ESMAP (2009)*
**** Source EPM (2008)*

Against this background, the main challenges in expanding wind power in Colombia have less to do with technology or with resources than with policy and the regulatory framework. In this sense, in a market dominated by hydropower technologies, investors are unlikely to pursue individual RET projects unless there is a comprehensive enabling framework, set at the national level, which provides clear incentives targeted at specific technologies. As hydropower has a low carbon footprint and low operating costs, the main reason for creating such a comprehensive RET policy is to enable a variety of technologies to enter the market, thus diversifying primary energy supply.

Wind power policy in Latin America

The initially slow penetration of renewable power in Latin America (LA) has changed since the mid-2000s, and for many countries, including Brazil, Mexico, Chile and Costa Rica, wind power capacity is growing at average rates higher than 25%. Policies to promote RETs in LA are diverse. Mexico and Brazil have devised comprehensive programs to increase their share of renewables, including wind power, on both small and large scales. These programs rely on incentives such as tax breaks and feed-in tariffs for wind power plants operating in a competitive power market. Feed-in tariffs guarantee a minimum price for renewable energy which is usually higher than the retail electricity price, and which is sustained over a long time frame. With small markets and a centralised market structure with vertical integration, Costa Rica and Nicaragua have reached the highest shares of wind power in the region (5 and 4.5% respectively; see Table 2). Chile is now implementing a different strategy through a RET portfolio standard. A renewable energy portfolio standard mandates electricity retailers to source a portion of their supply from renewable facilities (IEA, 2010). Because all suppliers must comply with the mandate, this policy internalises environmental costs, without targeting a specific renewable energy technology (Kydes, 2007).

As shown in Table 2, for some countries surveyed in LA wind power capacity is already higher than 1%, and many countries are committed to ambitious expansion plans. We now discuss some of these cases in detail. Note that, in most of these countries, carbon emissions from power generation are low.

Mexico

Mexico's installed electricity generation capacity is nearly 75% thermal and 19% hydro (SENER, 2009). In 2007, Mexico approved a plan for developing the use of large-scale renewable energy (PERGE plan). The World Bank supports the PERGE plan, which includes an assessment of wind power potential and the building of the La Venta III wind power farm (101.4 MW). This initiative was complemented by the enactment of the Law for Renewable Energy Use and Financing of Energy Transition (LAERFTE) in 2008. LAERFTE defines the programs and strategies for promoting RETs. The current goal for wind power is to reach 4.34% of installed capacity by 2012 and to generate between 1.74 and 2.91% of power from wind (SENER, 2009). The construction of transmission lines connecting the wind-rich Isthmus of Tehuantepec to the national grid is also one of the programs created by LAERFTE. To address the intermittence of wind energy and to integrate wind power technologies with the grid, the regulatory

Table 2. Wind power capacity in Latin America, 2009 or 2010

	Installed capacity, MW	Approved and planned expansion, MW	Potential wind power capacity, GW	Percentage of total generating capacity
Argentina*	60	794	200	0.23%
Brazil*	931	3140	143	0.89%
Chile*	172	2000	40	1.29%
Colombia*	19,5	27,5	18	0,15%
Costa Rica*	120,1	100,5	0.6	5,34%
Cuba	7,2		N.A.	0,14%
Curazao	9	24	N.A.	5,17%
Ecuador	2,4	15	N.A.	0,06%
Mexico*	519	2300	71	1.03%
Nicaragua	40	215	2	4,53%
Uruguay*	20,5	150	2	0,93%

Sources: Programa de Energía Eólica en Uruguay http://www.energiaeolica.gub.uy/index.php and LAWEA http://www.lawea.org/YearBook/2009-2010/EspanolFinal/index.html

** data for 2010*

commission has drawn up interconnection and transmission contracts for renewables (Reglamento ley energías renovables, 2009; Contrato de interconexión, 2010), aimed at stabilising wind producers' income.

In addition, other laws provide incentives like deducting 100% of capital investment in equipment and machinery for renewable generation from taxes (Ley del Impuesto sobre la Renta Art. 40 Fracción XII, 2008). Finally, small-scale wind power generation is one of the technologies included in the programme for rural electrification (Proyecto de Servicios Integrales de Energía), which is funded by the World Bank and which aims to reach 2500 rural communities by 2012.

Brazil

Brazil's installed capacity is 79% hydro and 18.5% thermal. In 2002 Brazil created the PROINFA programme, aiming to reach a 20% share of renewable energy sources in power generation by 2020 (Lei 10.438, 2002; Lei 10.762, 2003). This comprehensive policy has provisions for technology transfer and for developing domestic technology, as well as incentives for small producers. In the case of Brazil, electricity generated by wind, small hydro, and biomass plants is sold to Eletrobrás, the state-owned electricity utility, in twenty-year contracts at a regulated price. In the first stage of the programme (until 2013), a renewable energy price is set to reflect technology costs, and for wind power, the price is guaranteed to be at least 90% of the average end-use tariff. For the second stage of the programme, renewable energy is to be paid at the average cost of new hydro plants, which is lower than the average cost of new wind plants (Lei 10.438, 2002). To increase the competitiveness of wind energy, in 2009 regulators held separate capacity auctions for wind power, approving more than seventy wind projects with a combined capacity of 1.8 GW (ANEEL, 2010).

Uruguay

Uruguay's wind energy programme is financed by the Global Environmental Facility (GEF) through UNDP and it is executed by the energy and nuclear technology division of the Ministry of Mines and Energy. The objective of this programme is to develop a policy framework for wind power, to acquire relevant information for wind projects and to remove technological barriers through technology transfer and development (MIEM, 2008).

Hydroelectricity accounts for 70% of total power generation capacity in Uruguay, the remaining capacity being thermal. However, renewables are making progress in this country: a) by 2009, two 10 MW wind farms were already in place; and b) Decrees 77/2006, and 397/2007 mandate the state-owned utility UTE to award contracts for building 60 MW of non-conventional renewable sources, while 28.45 MW of wind power were awarded to three different projects currently under development (DNTN, 2009).

Decree 77 of 2006 and Decree 397 of 2007 allow UTE to buy at least 50% of generated power if the installed capacity is greater than 10 MW, and 100% if there are long-term contracts for renewable energy. Wind power is always dispatched, as it has low marginal costs and is exempt from transmission charges. Wind power generators have long-term power sales agreements with UTE, which do not allow generators to sell to third parties, though they can sell excess generation in the spot market. To increase the share of wind energy and to diversify the primary energy matrix, UTE is authorised to contract up to 150 MW of wind power capacity. New generators enjoy corporate tax breaks, and domestic equipment makers are exempt from other taxes.

Chile

Chile's installed capacity is 62% thermal and 37% hydro. Three companies, Endesa, Colbun and AES, have a 53% share of generation capacity. Chile's renewable energy law (20.257), enacted in 2008, mandates generators with a capacity larger than 200 MW to include sales of at least 5% of their total from renewable sources. This fraction is to increase by 0.5% annually between 2015 and 2024 until 10% of energy demand is supplied from renewables. Generators that do not meet the renewables' requirement pay a monetary penalty. To date, this policy has promoted 170 MW of wind power (LAWEA, 2009).

Costa Rica

The Instituto Costarricense de Electricidad (ICE) is a public monopoly that controls power generation, transmission and distribution in Costa Rica. Laws 7200 of 1990 and 7508 of 1995 allow private investment in the generation of up to 15% of installed capacity and set incentives for renewables. Building, Operation and Transfer (BOT) contracts and power sales agreements to ICE are the main incentives used to promote investment in renewable, mostly wind and geothermal energy. These mechanisms have successfully increased wind power capacity in Costa Rica from 16.5 MW in 1996 to about 120 MW in 2010. Approximately 80% of this capacity belongs to private concessionaires and 20% to ICE (ICE, 2010). The existing wind projects have support from the Clean Development Mechanism (CDM), and two of them (Chorotega and Vera Blanca) are part of World Bank's Prototype Carbon Funds. About 100 MW of wind power is due to be auctioned in the near future under BOT contracts.

Nicaragua

Law 532 of 2005 aimed to increase the share of renewables in the predominantly thermal energy system. This law sets tax incentives for renewable energy, and it also mandates distribution companies to contract a portion of their energy from new RETs. These contracts are for a minimum of ten years and subject to a regulated price. Generators that do not have contracts with distributors may sell their energy in the market place at prices initially set between 5.5 and 6.5 USD ¢/kWh. In addition to these incentives (portfolio standard and feed-in tariff), wind power generators in Nicaragua receive CDM support.

In general, RET policies in Latin America emulate the success of those developed in the EU and the US, and there are no noticeable innovations. As in most of the world, Latin American wind power policies combine tax incentives with feed-in tariffs and in some cases portfolio standards. Although wind power policies in Latin America are relatively new, they have produced good results, particularly in Brazil, Mexico, Chile and Costa Rica. Relevant lessons for Colombia and may be summarised as follows:

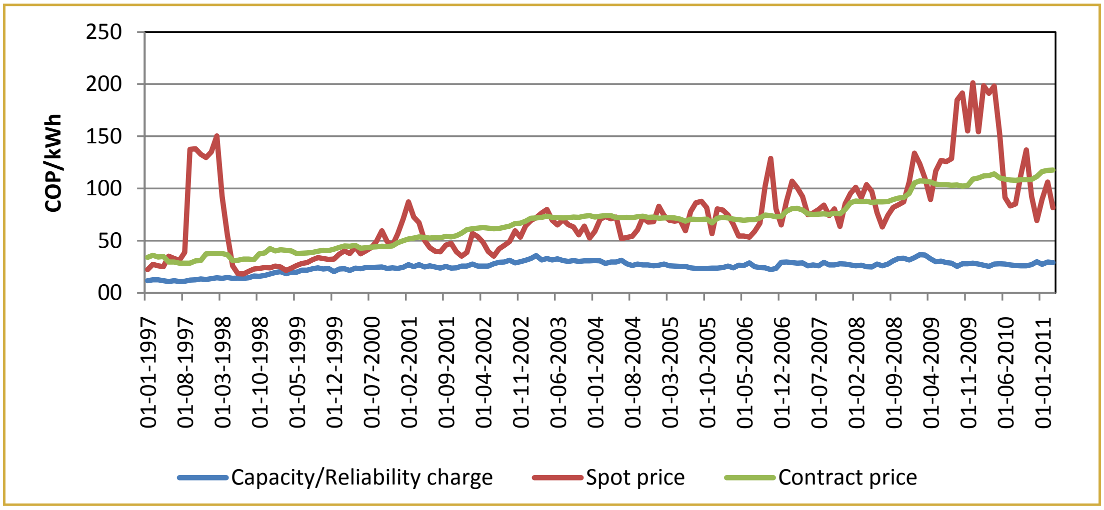
- RET policies need clear goals, targets and dates to achieve them.
- If hydroelectricity dominates power generation, enabling frameworks for RETs should provide incentives targeted at specific technologies, such as the separate wind auctions held in Brazil, as well as feed-in tariffs.
- Carbon funds and other international financial mechanisms are useful for increasing the Internal Rate of Return of wind power projects. However, to reach a higher share of wind power generation, countries need to integrate these technologies with the grid. The Mexican interconnection contracts for wind energy are a good example of how to achieve such integration.

The next section examines and compares different policy alternatives to increase wind power share in Colombia. We propose and discuss a goal of reaching a wind share of 3% of generation capacity by 2015 and 6% by 2019.

An enabling framework for wind power in Colombia

In the absence of a feed-in tariff, CDM and energy sales are the main sources of revenue for wind power in Colombia. Unlike thermo- and hydro-electricity, wind power technologies have no access to the capacity and reliability charges paid in Colombia. Between 1997 and 2006 these charges contributed 49% to the average generator's income, and although they are decreasing, they still represent 28% of its revenues (Figure 4).

Figure 4. Evolution of income sources for power generators in Colombia between 1997 and 2011. In 2010 1 USD = 1887 COP.



Successful wind energy policies set generation targets and dates, along with the mechanisms to meet them. Targets in developing countries range from 3% to 10% of renewable energy share in generation. From experiences in comparable countries, a 3% share of wind generation capacity by 2015 and 6% by 2019 are attainable goals, and would have an almost negligible effect on the system's finances. Many countries combine financial and production incentives to reduce market and capital risks for new wind power capacity (Zuluaga and Dyner, 2007). This article next compares feed-in tariffs, portfolio standards, reliability charges and subsidies mechanisms in terms of their information needs, costs and fiscal impact, effectiveness in lifting market barriers, ease of monitoring and enforcing, and flexibility within changing economic and market conditions (Table 3).

A recent analysis of market barriers for wind power in Colombia identifies three main instruments to lowering entry barriers for renewable energy (Vergara et al., 2010): 1) strengthening access to and increasing participation in the CDM; 2) targeting subsidies such as exemptions to income tax as well as to systems' charges; and 3) introducing reliability charges (Table 3) and taxes on polluting technologies. As we discuss next, although these three instruments enable the development of wind power, a more comprehensive policy is required to increase its market share in Colombia.

Two of the three instruments proposed by Vergara et al. (2010), CDM and tax exemptions, are already in place in Colombia. CDM forms part of Colombia's national environmental policy and is a source of revenue for the Jepírachi wind farm, which also enjoyed tax exemptions on capital. However, these are completely insufficient revenues compare with the capacity charge mechanism that is available to hydro and thermo electricity, making clean technologies uncompetitive. Two of the main utilities in Colombia, EPM and ISAGEN, have shown an interest in investing in wind power, but only as part of their R&D initiatives aimed at making progress along their learning curves regarding diversification, with a specific focus on its adaptation to local and Colombian market conditions (ISAGEN, 2010).

Taxing polluting technologies and modifying current market rules to include wind power have not been tried yet, but their usefulness within the Colombian context is unclear. Carbon taxing, for instance, would have little effect on energy prices because the base load power is hydro, which is enough to satisfy demand in

Table 3. Comparison of policy instruments for promoting renewable energy

Policy Instrument	Information needs	Costs	Effectiveness	Ease of monitoring and enforcing	Flexibility
Feed-in tariffs	Low	Shared with customers	High. Decrease levelized energy costs from 2% to 30%*	High, established by regulatory commission	High, tariffs can be periodically reviewed and modified
Portfolio Standard	Low	Shared with customers	High. Used by 9 of 20 IEA – wind members*	Established by regulator. Needs a market for green certificates	Low, targets are set for a given period of time
Subsidies	Low	Fiscal impact, need to be included in government budget	Decrease levelized cost of energy from 2% to 20%*	Allocation and targeting of subsidies is difficult, often causing inefficiencies	Low, subsidies set for a fixed period of time
Reliability / capacity charges	High	High costs of auctions. Costs shared with customers	N/A	Low, need additional investment for metering	Periodically reviewed and modified, according to performance. Revisions are expensive.

** www.iea-retd.org*

most periods. This suggests that, with a large hydro baseline, a more direct mechanism is needed to stimulate investment in renewable energy technologies.

According to Vergara et al. (2010), the reliability charge previously discussed can be modified to include wind projects in the corresponding auctions. Vergara et al. (2010) argue that a capacity charge designed for wind power might be as effective as direct incentives such as the renewable portfolio standard. In the short term, however, this mechanism is difficult to implement because there is no information for calculating the firm energy contribution from wind power.

Furthermore, regardless of how these capacity and reliability charges are implemented, the Colombian experience suggests that market mechanisms alone are insufficient to promote alternative power because of the existing entry barriers. More importantly, incentives and instruments are means to reach the goals of policy, and should be designed and implemented after these goals have clearly been set. Note that, even though reliability and capacity charges might be periodically reviewed and modified, this may be relatively costly to achieve. However, previous arguments, particularly the one relating to the unavailability of long time series on wind flows, clearly reject this alternative.

It is clear that electricity regulators and policy-makers need relevant data when considering increasing investment in clean energy. Not every policy has the same information requirements. Information availability influences the ease of monitoring and enforcing policy. These leave room for considering all the options in Table 3, except for the changes to the Colombian reliability charges, which have already been rejected.

Unlike other instruments in Table 3, feed-in tariffs can directly target specific technologies and are effective mechanisms for recovering the high capital costs of wind power technology. In addition, feed-in tariffs are flexible. A flexible instrument can easily be adapted to changing market and economic conditions. Feed-in tariffs, for instance, might be in line with wholesale market prices and may only need to be adjusted by a producer price index.

By definition, portfolio standards are less flexible than feed-in tariffs and must be sustained over longer periods of time. Changes in portfolio standards need to be discussed and announced in advance, to avoid regulatory uncertainty. Portfolio standards, however, are highly effective, and because utilities are overseen and regulated, they can be monitored and enforced with ease.

The previous section indicates that the most successful Latin American policies for increasing the share of RETs in power generation make use of feed-in tariffs. By far, feed-in tariffs have been the most widely used and successful regulatory option to promote renewables and wind energy worldwide, as nearly 45% of global wind generation capacity (53 GW in 2008) has been installed using this mechanism (REN21, 2010; IEA, 2010).

Renewable portfolio standards have also been successfully applied in LA to increase the market share of renewable energy. This mechanism promotes renewable generation and internalises the environmental costs, while allowing the market to develop and utilise the most economic technologies (Kydes, 2007). Portfolio standards are a part of the renewables policy in Australia, Canada, Italy, Japan, Korea, Portugal, Sweden, the UK and the US (IEA, 2009), and they are usually combined with other environmental policies.

Based on lessons learned from Latin America and elsewhere, we propose an effective framework for promoting RETs in Colombia by combining feed-in tariffs with renewable portfolio standards. The first step in this direction is to define a policy with both measurable goals and the mechanisms to reach them. A target of 3% of renewables would add about 400 MW of wind power capacity by 2015, and to reach a 6% by 2020, an extra 450 MW would be needed. An effective mechanism to achieve this goal is to mandate generators with capacities larger than 500 MW to source 3% of their dispatch from renewable energy in exchange of a feed-in tariff, while other generators can participate voluntarily. For other independent producers, new renewable power capacity can be allocated by auctioning 20 MW modules to be remunerated through a feed-in tariff. This scheme would complement existing instruments, namely supply subsidies and CDM support, while providing stronger incentives for investment.

Conclusions

To a large extent, Colombia's limited success in promoting wind power reflects the absence of a policy programme specifically targeted to increasing the share of renewable energy within the portfolio of power generation. The World Bank (Vergara et al., 2010) proposes to adjust the current reliability charge to increase investment in wind power generation. Although appealing, this approach is not adequate, as: a) it places high requirements on wind power for information, which is currently not available; and b) it is not as effective as other proven mechanisms around the world. The experience in other countries is that, independently of the market structure and size, the early adoption of wind power benefits from two basic mechanisms: feed-in tariffs and portfolio standards (Zuluaga and Dyner, 2007). Moreover, policies that seek to accelerate learning by doing and technology adoption, like the Brazilian PROINFA programme, are adequate to lower entry barriers in countries with a large hydroelectricity component, such as Colombia.

Latin America, and particularly Colombia, has a good opportunity to deploy wind power technologies that now offer relatively cheap and modular generation units. From the perspective of regional integration, this is a strategic opportunity for Colombia, which needs a much higher electricity supply to contribute to the requirements of Central American countries and to complement Ecuador's and Peru's supply.

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Section II: Enabling frameworks addressing multiple technologies

Solar PV used to power village communications
Photo: UNEP internal archive

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FIT for use everywhere? Assessing experiences with renewable energy feed-in tariffs

Abstract

This article aims to provide a summary to governments and stakeholders in developing countries on the function, strengths and potential drawbacks of 'feed-in tariffs' (FITs) as one possible market incentive to increase the share of grid - and mini-grid - connected renewable electricity generation. It is important that FITs are not seen as a 'silver bullet', but rather as one policy option to complement others aimed at overcoming the barriers to significant and sustained investment in low-carbon energy. Despite the long-term rise in fossil fuel prices, the fact remains that most grid-connected renewable energy technologies (RETs) require financial support in order to compete with electricity generated from conventional primary energy sources, principally coal, natural gas and large-scale hydro-energy. In many countries, a lack of clear and stable revenue support for renewable energy (RE) has simply deterred investors from backing RE projects.

For developing countries, many of which have significant renewable energy resources, harnessing this 'freely available' energy is one way to offset domestic energy shortages, reduce import bills for hydrocarbons and expand energy access, especially in rural areas. In this article, an explanation is given of how FITs work followed by a discussion of their relative success in promoting RETs in OECD economies, taking into account broader aspects of the country and policy contexts. The rest of the article focuses on how FITs can be adapted for developing countries, considering their main benefits, potential costs and drawbacks.

Introduction

'Feed-in Tariffs' (FITs) provide a minimum guaranteed price paid by utilities to all generators of electricity from renewable energy, supplying, or 'feeding into' the grid. The exact value of tariff support is set by the government, usually for a fixed time period, and tends to vary according to the type of generation technology.[1] The cost of feed-in tariffs is normally assumed by electricity utilities and then passed on to, i.e., divided among, all consumers. As such, FITs are a form of cross-subsidy designed to encourage investment in clean and low-carbon electricity generation, without placing a cap or quota on the amount of RE generation (Couture and Gagnon, 2010; Haas et al., 2011). However, they are unlike conventional subsidies in that they are intended to spur market and technological development, driving cost reductions in the process. Opinion is divided over the long-term fate of FITs, as it is hoped that renewable technologies will be able to operate in the market without price support in the future. Importantly, FITs provide financial support only to electricity generated and delivered to the grid, as opposed to subsidies for the initial capital investment.

Basic FITs are conceptually very simple and easy to administer, which partly explains their popularity and success in accelerating the deployment of RETs. Approximately 75% of global installed solar PV capacity and 45% of wind power receive some degree of supply-side tariff support (Rickerson et al., 2010). While FITs are best known for their role in supporting investment in RETs in Europe, there is in fact a diverse and growing range of experiences across the world, from which it is possible to draw some lessons.

In many OECD countries with mature electricity markets, the use of FITs has led to widespread RET deployment, as in Germany, Denmark and Spain, which have Europe's largest shares of renewable energy generation – particularly grid-connected wind energy (Reiche and Bechberger, 2004). In Germany the first FIT was introduced in 1991, and by 2008 feed-in support totalled €2.5 billion. While 17% of German electricity generation is met by renewable sources (BMU, 2011), average financial support in 2009 was €0.13 per kWh, which equated to €3.83 per household per month, or 6% of the average electricity bill.[2]

Crucially, and in order to incentivise constant efficiency improvements and innovations, per-unit FITs are normally lowered every year (at a predetermined and fixed rate), which brings them closer to average conventional generation costs. This is known as tariff 'degression'. As such, FITs have helped push down the per-unit cost of electricity generated by RETs by encouraging technical innovation and economies of scale. In the case of Germany, annual degression in the FIT paid for new RE generation were originally set at 1% for biomass, 1.5% for wind power and 5% for solar PV, which has the highest per-unit tariff. However the degression rate has been increased in recent years, most notably for solar PV, which, as of 2011, has a 13% degression rate (IEA, 2011). Nevertheless, FITs typically provide investors with a guaranteed revenue stream for 10-20 years, as long as the installation remains operational. FITs have therefore proved successful in reducing the financial risk of investing in RETs, as compared to other policies such as tradable permits.[3]

However, once RETs take up a larger share of the generation market place, FITs can become expensive and harder to justify, especially where governments claim to be strictly endorsing the principles of electricity market liberalisation and/or placing a higher value on cheap energy in the short term. Therefore, it is important to bear in mind that FITs are only an interim policy, designed to accelerate the development and diffusion of RETs. Experience shows that diffusion will push technologies along the innovation cost curve towards market competitiveness with conventional energy sources, the environmental impacts of which should be internalised or priced in. On the other hand, in many developing countries, such as Uganda, which has a high dependency on diesel generation, the per-unit cost of mature RETs such as hydro and wind power is already lower than electricity generated from the fossil fuel base-load, which is itself on an upward price trend due to the increasing scarcity of easily accessible oil, gas and coal, as well as their climate and pollution externalities.

The most common features of FIT laws are the following:

- Utilities are obliged to purchase electricity supplied to the grid from RE sources generated specifically for that purpose (as distinguished from net-metering).
- The value of the electricity purchased (the FIT) is set by the government at a fixed rate each year, which normally declines in value over time so as to reward first movers and reflect technology cost reductions.
- The value of the FIT differs depending on the type, size and location of RE technology used, with higher rates paid to the least competitive technologies.
- Generators are usually responsible for paying for grid connection to the nearest connection point (shallow connection charges), whereas the grid operator bears the cost of grid extensions. Otherwise, in a deep connection charge system, the RE generator is normally responsible for the grid connection and all associated transmission upgrades.
- FIT contracts are signed between generators and utilities, typically for 10-20 years.

History and design of FITs in OECD countries

FITs have been successful in promoting investment in RE generation in many developed countries, mainly because they minimise the long-term financial risks surrounding individual projects. The world's first FIT was legislated in California in 1978 under the federal Public Utility Regulatory Policies Act (PURPA), which, in a context of high and rising oil prices, set the value of tariff support to reflect the avoided long run marginal cost of electricity, i.e., the anticipated cost of generating an extra kWh of electricity (Butler and Neuhoff, 2004). This, combined with an Investment Tax Credit implemented in 1979, underpinned the Californian 'wind rush' when approximately 15,000 wind turbines with a combined capacity of 1,200MW were installed during the early 1980s. However, the policy was withdrawn in 1985 (by which time oil prices had fallen to near pre-1973 levels) amid accusations that the financial support was too expensive and provided unrealistic rates of return for renewable energy investors. This experience in itself provided lessons for policy-makers seeking to legislate ambitious support for renewable energy.

Arguably the most successful FIT has been in Germany, where the policy was first introduced in 1991, initially with variable support linked to consumer energy prices. However, following a drop in energy prices during the late 1990s, the German FIT was fixed in 2000 (at different levels depending on the energy technology), which had the effect of greatly increasing investment in renewable energy capacity, particularly in wind and solar PV. While Germany's decision to fix FIT support was a significant boost to the RE industry, many studies conclude that other policies, as well as the wider market structure, were equally important, including the country's decision to phase out nuclear power (Jacobsson and Lauber, 2006).

In Germany, installed wind-power capacity increased from a total of 56MW in 1990 to 14,600MW in 2003, by which time wind power was already supplying 6% of Germany's total electricity demand (UNEP, 2007). In 2010, Germany's total installed wind capacity stood at more than 27,000 MW. In Denmark, a FIT underpinned rapid investment in wind power between 1980 and 2002, which, by 2007, accounted for 19.8% of domestic electricity supply and approximately 25% of installed capacity (Danish Energy Agency, 2009).

In the UK, plans to introduce a FIT were added to the government's Energy Bill in October 2008 after years of having resisted the introduction of direct tariff support, with the policy coming into effect in April 2010. This was a major departure from reliance on a micro-generation grant scheme and the 'Renewables Obligation' (RO), a quota-based mechanism that the UK has used to expand renewable energy supplies gradually since 2002. Although the RO has enabled a doubling of renewable electricity generation in the UK since 2002, this is unimpressive given the country's low starting point of around 2%. Indeed, it was partly the success of FITs in other countries that led the UK government to conduct a policy U-turn.

However, this was not done without a major policy campaign spearheaded by a coalition of NGOs and industry groups.

The specific value of FIT support is usually based on the type of RE technology, with the aim of 'levelling the playing field'. As such, FIT support, measured as € per kWh, is usually set higher for technologies like solar PV, which remain furthest from market competitiveness, i.e., are more expensive per kWh of electricity generation. Conversely wind power, which is often the most cost competitive, tends to receive a lower level of FIT support. In order to accelerate cost reductions through market expansion, it is important to match the relatively high tariff support for expensive RET such as solar PV, with a relatively steep rate of tariff degression, thus creating strong incentives to invest sooner rather than later (Auer et al., 2009).

In addition to technology-based criteria for establishing FIT values, the policy can also be calculated on a resource basis in an attempt to level the playing field further by preventing the developers of wind projects from capturing large rents in areas of high wind resources. This was done in Germany, where the value of tariff support provided for wind farms in windy locations was set at the same level as low-wind resource locations, but declined at a faster annual rate thereafter. However, a resource-based differentiation in tariff support can be difficult and time-consuming to calculate and administer, and the argument is often made that 'first movers' deserve to be rewarded (assuming they locate their wind farms in the windiest locations) for taking a risk with a lesser-established technology, and where costs tends to fall along with market expansion.

While support in the form of a high FIT has doubtless boosted the market for solar PV in Germany,[4] it was not the only policy. The provision of direct installation subsidies, such as the 100,000 Roofs Photovoltaic Programme, which provided a total subsidy of 35%, was equally if not more important in Germany (Stryi-Hipp, 2009). The relative success of FITs also depends upon various non-market factors such as the ease of processing RE development applications, i.e., the degree of bureaucracy in each country, as well as wider social obstacles such as a strong 'NIMBY'[5] effect.

Some countries, such as the Czech Republic, Denmark, the Netherlands, Slovenia and Spain operate a 'premium' FIT, whereby developers can choose between selling their renewably generated electricity at price set at marginal X% above the market price, which tends to fluctuate, or opt for a (higher) fixed tariff support. In these cases, both the fixed and premium tariffs are reviewed by the government each year to reflect changes in energy prices and technology costs, while RE project developers are free to change between regimes. This flexible system is designed to protect both project developers and consumers by ensuring that losses and excess profits are avoided (Mallon, 2006).

Mendonça et al. (2009) argue that FITs are an inherently more inclusive financial mechanism to support RETs when compared to the tax credits scheme used in the United States. Taking the example of the development of wind energy in Denmark, they state that '..it was driven from the bottom-up, with enthusiasts influencing the political process in such a way that Government then engaged in providing the enabling conditions to boost the development of the sector, through economic incentives and favourable ownership restrictions' (p. 384). Taken together, Mendonça et al. argue that this institutional organisation in Denmark, and the process of creating a strong domestic political agenda to support RETs (in particular wind energy), was the product of what Danish academic Frede Hvelplund terms 'innovative democracy'. Specifically, this is understood as a process whereby stakeholders were actively engaged at all stages and levels of policy formation and where the development of community-owned wind farms spread the investment costs, and the income benefits, of wind energy down to the household level. This ensured both a high level of community 'buy in', as well as strong and longer term rural support for on-shore wind energy, the lack of which has been a major barrier in the UK, for example.

FITs are rarely used alone in support of renewable energy. In both Germany and Denmark, a combination of investment subsidies for individual projects (worth as much as 30% during the early days of promoting wind energy in Denmark), tax exemptions, soft loans and publicly funded R&D also played a major role. While these additional direct and indirect financial incentives for investing in RET were relatively expensive, it should be remembered that the costs of RETs per MW installed capacity have fallen dramatically since the 1970s, in large part thanks to the pioneering industry support and development that was achieved in countries like Denmark.

Criticisms and shortcomings of FITs in OECD countries

While FITs have been very successful in many EU countries, if judged in terms of RE capacity installed, they have some drawbacks and detractors. According to 'standard' neo-classical theory, as a form of cross-subsidy FITs should act as a drag on domestic economic growth, productivity and competitiveness. In reality, the direct economic impact of FITs is almost negligible, at least in high-income countries. In part, this is due to the relatively small component that electricity comprises for most household and business expenditure (indeed the share of electricity has steadily declined as an input factor among OECD countries since 1990). In 'pioneer' countries such as Denmark and Germany, tariff support for renewable energy also helped nurture a new multi-billion euro industry and created thousands of manufacturing and engineering jobs, though these are 'one-off' benefits that can only be captured by such pioneering states.

Taken at face value, fixed-rate FITs do not create competitive pressure between electricity producers since investors are able to calculate, with a higher degree of certainty, their rate of return based on the long-term structure of tariff support, i.e., they have a guaranteed fixed income. This can be compared to the policy of providing premium payments, or bonuses, on top of the market (i.e., variable) price of electricity, which in theory provides operators with a greater incentive to reduce their costs in order to maximise project returns. However, this assumes that the premium is not set too high, in which case it can lead to excess profits if the market price of electricity increases significantly, as was the experience in Spain. In an attempt to manage the cost of financial support to RE generators, Spain introduced floor and ceiling prices to its system of feed-in premiums in 2007.

Consequently, FITs as a generic policy are often criticised by free-market and fossil-fuel lobby groups as an expensive means to support investment in RE generation, and specifically because the cost of tariff support may become unsustainable once the share of RE generation becomes significant. As such, free-market advocates often argue that, by providing fixed payment levels, FITs are both inefficient and have a distortive effect on energy markets. In the EU, this has led some analysts to conclude that, if the cost of FITs were to rise significantly, they would undermine the Union's wider policy agenda of creating a single, liberalised European energy market (Sijm, 2002).

However, given the years of experience gained with FITs within many EU member states and the steady rise of RE installed capacity across the EU, energy policy debate has begun to centre on proposals to harmonise the support provided to RE. The European Commission favours 'well-adapted' FITs as the 'most efficient and effective support schemes for promoting renewable electricity' (Commission of the European Communities, 2008), a position supported by various academic studies, including Haas et al., 2011. Indeed, in July 2010, the European Energy Commissioner Günther Oettinger called for a harmonisation of FITs between EU Member States (Euractiv, 2010). As well as seeking to optimise net support for RE across the 27-Member State bloc, such policy harmonisation stands to reduce market distortions in anticipation of a region-wide energy trading system.

To a large extent, the success of FITs depends upon the stability and certainty they provide for investors. As such, too many changes made to FIT values can have a detrimental effect on the market by eroding investor confidence. In Europe, since 2008 the stability of some FIT regimes has been undermined by economic recession and government austerity. Although they are not directly financed by government budgets, FITs do contribute to a higher net tax burden for the economy, which has made them the target of governments wishing to reduce economy-wide costs, despite the greater long-term benefits of minimizing dependence on imported fossil fuels. Indeed, it is easy for governments to target FITs amid an economic recession, and in countries such as Spain that have a relatively high FIT bill, pressure to streamline the economy is also coming from the European Central Bank and international credit rating agencies.

FITs have also been the victim of their own success in many European countries, such as Spain and Italy, where investment in solar PV projects have greatly exceeded expectations, thus exacerbating political pressures to reduce the levelised cost of FITs among all ratepayers. In 2011 the UK government announced it would conduct a review of its FIT law, less than a year after it came into effect, which is highly likely to damage the country's nascent solar power industry. Such policy change can greatly undermine investor confidence in the stability of FITs. However, even if necessary economic incentives are introduced via a well-designed, clear and stable FIT, the rapid deployment of RETs (whether small or large-scale) can be hindered by unfavourable planning regulations, import taxation etc., depending on the circumstances in each country.

The pre-requisites and characteristics of successful FITs are as follows:

- Eligible RETs should be clearly defined, and include 'dispatchable' base-load generation technologies such as biomass, hydro and geothermal, as well as variable RETs such as wind and solar PV in order to encourage a diversified energy portfolio.
- Countries should conduct or commission in-depth renewable energy resource assessments and mapping and impact assessments, so that investors (be they public or private) know which RETs and locations are optimal.
- Tariffs should be technology-specific and based on the cost of generation, as opposed to final consumer prices or 'avoided' costs, so as to provide a clear and stable internal rate of return to investors (typically between 7-10%), while avoiding the risk of windfall profits at the expense of consumers.
- Apply a hybrid rate of tariff decline, i.e., where the annual rate of decline in tariff support has a fixed baseline, with the option to reduce tariffs for new projects further if and when major cost reductions are achieved for a specific technology.
- Especially in developing countries, FIT policies should be developed in conjunction with wider macro-economic policy-making and calculations so as to understand their likely impacts on the economy and development goals.

Sources: Couture and Gagnon, 2010; Mendonça and Jacobs, 2009; Haas et al., 2004; Haas et al., 2011.

Designing FITs for developing countries

Despite the success of FITs in various OECD countries, particularly in Europe, there are some basic reasons why they may have to be adapted to work in developing countries. Of fundamental importance is the fact that most developing countries have a smaller proportion of consumers connected to the grid, often less than 25% in sub-Saharan Africa, meaning that FITs will not in themselves help address the need to expand energy access. Indeed, they may even undermine policies to increase access to electricity in areas where demand can be met by lower-cost centralised thermal generation, especially in urban areas (though energy security and fuel-mix diversification are common concerns that reduce the cost benefits of conventional thermal generation). In countries where there is an abundance and high use of low-cost primary energy for electricity, such as with coal in South Africa, the cost of FITs will need to be relatively high in order to level the playing field between competing technologies. This is likely to make FITs politically unpopular, and in the case of South Africa, in 2011 the National Energy Regulator (NERSA) launched a review of the country's 2009 FIT with a remit to reduce tariff support by as much as 42% for solar PV.[6]

Secondly, businesses and households in developing countries that do consume electricity generally spend a higher proportion of their income on it, meaning that any marginal tariff increase will have a greater economic impact. As such, the funding mechanism for FITs may have to be structured differently in developing countries, for example, with financing from international donors or centralised national funds, instead of by consumers. However, in countries that provide subsidies for fossil fuels, the net macro-economic cost of financing FITs could be zero or negative if these are phased out during the time period of FIT support.

There is also a risk that centralised financing for FITs could undermine their economic and administrative simplicity, i.e., their strengths, and move them towards a more traditional form of industrial subsidy that is exposed to greater political interference and uncertainty. Alternatively, in order to help minimise the costs to consumers, FITs can be designed with a nationally appropriate cap placed on the percentage of installed capacity from RETs. While this is far from 'ideal', it does at least allow for a controlled expansion of the local renewable energy industry, which is more likely to develop without future support once the initial cost and experience barriers have been broken down (IEA, 2010; Mendonça and Jacobs, 2009).

In the context of developing countries, many of which still operate state-owned and/or monopolistic electricity utilities, it is useful to remember that FITs do not depend upon a wider framework of market liberalisation, although such a framework is likely to provide greater security for investors. The important basic elements of FITs are that they combine guaranteed tariff support, purchase obligations and regulated grid access, which, if not tampered with by governments, provide a stable investment framework for a diversity of independent power producers. This means that investors will look closely at the stability of the public utility in order to assess the security of power purchase agreements, adding to the argument for focusing commercial investments on low-cost RETs such as hydro and biomass in developing countries.

There are also societal factors that stand to challenge the successful application of FITs, given that they have to be adapted to a particular set of national circumstances. For example, Mendonça et al. (2009) maintain that the conditions necessary to achieve the 'innovative democracy' that enabled the rapid deployment of RETs in Denmark are more likely to be found in industrialised and democratic societies, though they do not make sweeping statements to exclude all developing countries. It appears to be a moot point whether this process can be reverse-engineered in countries that do not have a strong culture of bottom-up and/or truly democratic decision-making.

In some developing countries, RETs are already cost competitive with conventional energy, especially where there is a high dependence upon small and medium-sized diesel generators. Where this is the case, the introduction of a relatively low FIT is likely to stabilise, and even reduce, the market price of electricity, especially when fuels are imported and continue to follow a long-run price increase. In these circumstances, the free-market response would be to argue that a FIT is unnecessary, since price signals alone would trigger investment in RETs. In theory yes, but in reality investors and governments alike tend to 'stick to what they know', even if there are clear short - and long - term costs in doing so. Given that FITs not only provide tariff support but also allow IPPs to connect to the grid, they can act as a 'package' enabling RETs to overcome the technological lock-in of conventional energy supplies. Nonetheless, it is evident that in most countries free-market price signals alone will not achieve the levels of deployment of renewable energy required to decarbonise our energy systems, hence the need for long-term bankable incentives.

There is increasing evidence for and arguments in support of applying FITs to mini-grids, especially in developing countries (DBCCA, 2011; Solano-Peralta et al., 2009). Developing business models for FIT application to mini-grids is especially relevant for geographically large developing countries with low levels of energy access. This could serve as an important economic bridge between the use of decentralised off-grid RETs used in mostly remote and isolated locations, and the high cost of connecting communities that have a low demand load, located relatively far from the grid. However, given the small size of the systems, it is not clear whether RETs would really 'feed in' (i.e., contribute to) the mini-grid, or simply dominate them. In the latter case there is a risk that, in applying FITs to mini-grids, they would end up operating as a direct subsidy paid to remunerate RE generators, as opposed to providing support at the margins to enable RETs to compete with conventional energy technologies.

Following the COP15 in Copenhagen, the United Nations Secretary General's Advisory Group on Energy and Climate Change (AGECC) requested Deutsche Bank Climate Change Advisors (DBCCA) to develop the idea of a public-private Global Energy Transfer Feed-in Tariff (GET FiT). The GET FiT concept is primarily designed to mitigate investment risk for RE projects in developing countries by passing the bill for FIT support on to donor agencies. DBCCA analyse FITs only from the perspective of investors, whose main criterion is to gauge the extent to which a particular policy framework is likely to achieve Transparency, Longevity and Certainty (TLC). This is a simple yet comprehensive approach to understanding policy 'best practice', though one focused on 'de-risking' business models and attracting mainly private investment in RE projects in developing countries.

Rickerson et al. (2010) focus on Tanzania as a case study of a developing country that is attempting to implement a politically viable and investor-friendly FIT. Applying the measures of TLC to the Tanzanian government's 2009 Small Power Producer (SPP) law, they conclude that the framework, which includes an initial FIT of US$0.077/kWh, is sufficient to attract investment in the 'low-hanging fruit' of RE projects such as small hydro and biomass, but not enough to promote wind or solar power projects.[7] Rickerson et al. maintain that the key shortcoming in the design of the Tanzanian FIT is that the value is calculated on the basis of avoided costs, not technology-specific generation costs, which would provide greater certainty for investors who need to calculate a project's internal rate of return. At the same time, the Tanzanian SPP is praised for its transparency and for covering payments for projects connected to both grid and rural mini-grids. This is particularly significant in a country where less than 20% of the population have access to electricity.

Finally, the GET FiT concept maintains that FITs will not be successful in developing countries unless local financing is secured in RE projects, even though financial markets in developing countries (especially in sub-Saharan Africa) often lack diversity and flexibility and generally regard RE projects as high risk. Rickerson et al. argue that local financing can be secured by the provision of technical assistance to local lenders aimed at minimising fears regarding investment in alternative energy projects, and by sharing the financial risk with foreign investors and donor agencies. However, it is not yet clear how the necessary international funds can be secured in the long term to provide the financing for FITs that investors (whether local or foreign) are likely to demand. The problem of long-term financing is currently being addressed by the GET FiT initiative, including the possibility of tapping into bond markets, backed up by long-term annual commitments from donor agencies. Nonetheless, this centralised approach to financing FITs is inherently more risky in terms of longevity and certainty, especially since the cycles of donor financing do not currently fit this model.

Conclusions

Many studies have concluded that RETs are a viable means to increase access to electricity in developing countries, as well as helping to reduce emissions of greenhouse gases. Yet it is not always obvious how to reconcile a desired expansion of access to affordable electricity with an increase in the installed capacity of RETs that generally have higher per kWh up-front capital costs than fossil fuel generation. Nevertheless, when combined with grid expansion (and possibly mini-grids), FIT-backed renewable energy can also achieve co-benefits by facilitating wider investment in rural areas, e.g., with community electrification and generation programmes. This requires FITs to be implemented in conjunction with other rural development programmes. However, implementing a FIT alone does not guarantee that investments in renewable energy projects will follow, and it is important to remember that their success in many OECD countries has also been bolstered by other financial support mechanisms.

Further, FITs should be regarded as just one element in wider efforts to create an 'enabling framework' for investment in renewable energy, albeit a central element and one that can go a long way in helping to 'de-risk' RE projects in both developed and developing countries. However, in understanding the relative success of FITs the devil lies in the detail. There exist a wide variety of FITs across countries, all of which have a specific set of national circumstances. Good, location-specific design and implementation is key.

Although FITs aim to reduce economic barriers and create a level playing field for a variety of electricity generation technologies, they are ultimately an expression of political will and, as a form of price-setting regulation, cannot easily keep pace with technological progress or reflect cost reductions. This process requires regular monitoring in order to control costs, maintain industry stability, keep CO_2 reductions and RE expansion targets on track, and maintain and enhance public support. The growth of a national RE industry and the creation of new business and job opportunities will inevitably bolster this support. Alternatively, countries can opt for tenders for a specific capacity volume, which imposes a ceiling and floor price for RE generation, thus creating a hybrid incentive mechanism that blends a price target with a quantity objective. This kind of performance-based incentive is similarly effective as FITs and appeals to countries with different economic models and cultures, e.g., Chile with its strict market orientation.

By providing fixed income support for RE generation, FITs will always be the target of free-market critics eager to brand such interventions 'inefficient and expensive'. However, this accusation is often unfounded and/or exaggerated and fails to appreciate the far larger costs associated with conventional energy systems. For example, little or no mainstream recognition is generally given to the higher external (non-market) costs of conventional fossil-fuel electricity generation, principally their CO_2 emissions, contribution to air pollution and the simple fact that they are finite resources.

While the electricity sector in many countries is no longer in receipt of direct subsidies following a wave of privatisation and liberalisation policies (promoted, in the case of developing countries, by the IFIs during the 1990s and 2000s), the value of historical state subsidies, direct and indirect, provided to conventional fossil fuel-based and nuclear electricity generation runs into hundreds of billions of dollars – a history that has helped ensure the current low prices through technological development.

In conclusion, FITs can help investors overcome some of the strictly financial barriers to investing in RE projects. However, for effective scaling-up of investment in RE, there also needs to be concerted efforts to overcome the non-financial barriers, including low levels of stakeholder participation in decision-making processes and community ownership of individual projects. Although it is unwise to generalise, a particular risk in implementing a FIT in developing countries is that utility prices, including energy, are an easy target for political manipulation by governments keen to be seen as tackling poverty and providing politically popular welfare benefits. Even if strong and stable political support is provided for FITs, they may fall victim to cut-backs at times of economic constraint, as has happened in various OECD countries, including the UK, Spain and Italy.

On the plus side, FITs are conceptually simple and democratic, which makes them an appealing policy tool to help create a viable enabling framework for significant investment in renewable energy. While they have had most experience and success in developed countries, FITs can be considered by governments and NGOs in less developed countries where there is plenty of scope to innovate and adapt the basic elements of tariff support to suit local circumstances. However, in order to optimise the broader development benefits resulting from the scaling up of RETs, coupled with reduced environmental impacts, due consideration should be given right at the planning stage to institutional capacity and resource and impact assessments.

UNEP in support of feed-in tariffs

FITs are the most commonly used, yet only one out of many policy tools available to increase renewable energy deployment, and if chosen, should complement and support existing energy policy portfolios. Lessons drawn from existing FIT frameworks in mostly developed but also in some developing countries can help address the knowledge gaps in developing countries. Thus, the United Nations Environment Programme (UNEP) has initiated a project on the design and implementation of FITs in developing countries, as part of its broader remit to promote low-carbon growth and in the context of transition towards a green economy. The project has started, with the first activity being a study to improve understanding of the factors that determine the success or failure of FIT policies in developing countries, with a view to providing during a subsequent phase targeted advice and capacity building to countries that either plan to introduce a FIT or reform existing ones. Outputs of this work will include a 'Law Drafters Guide', intended to guide policy makers though the essential and optional elements involved in designing regulatory instruments for the effective introduction of an FIT, as well as a detailed study on the available financing options, and their economic impacts, for developing countries.

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Endnotes

1. FITs should be distinguished from net-metering policies, which allow for usually small-scale generators of RE electricity to consume their energy on site, while remaining customers are connected to the grid. Although net-metering policies enable generators to supply the grid when their supply exceeds demand, the price paid for this electricity is normally equal to the market spot rate, i.e., unsubsidised and sometimes even zero.
2. However, according to the Germany Ministry of Environment (BMU), the cost of FIT support is rising rapidly in Germany, largely due to the explosion of growth in higher-cost Solar PV installations. BMU estimates that the average cost of FITs will be more than 10 EUR per household per month (equivalent to 14% of the bill) in 2011. (Reference: BMU, April 2011, 'what effect does the promotion of renewable energies have on the domestic price of electricity?' (Welche Wirkung hat die Förderung der erneuerbaren Energien auf den Haushalts-Strompreis?). www.erneuerbare-energien.de/files/pdfs/allgemein/application/pdf/hintergrund_ee_umlage_bf.pdf .
3. This conclusion has been reached by a number of authoritative studies, including the 2006 Stern Review into the economics of climate change mitigation. Stern reports that 'comparisons between deployment support through tradable quotas and feed-in tariff price support suggest that feed-in mechanisms achieve larger deployment at lower costs.'
4. At almost 17,000 MW, Germany's installed solar PV generation capacity accounted for more than 50% of the global total in 2010, most of which is grid-connected.
5. NIMBY: 'Not In My Back Yard'.
6. However, in the case of South Africa, the key barrier to the success of FIT is that Eskom (the state-owned electricity utility) is the sole buyer of electricity and has no obligation to buy FIT-supported renewable electricity (Pegels, 2009).
7. Examples of low-cost RE projects could include those identified by the Poverty Alleviation through Cleaner Energy from Agro-industries in Africa (PACEAA) project in East Africa. Funded by the European Commission's COOPENER programme, the project addressed the issue of rural electrification as a means of alleviating poverty, in particular by using electricity from agro-industries. www.paceaa.org/ .

Transmission lines in South Africa
Photo: URC internal archive

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Pitfalls of policy implementation: The case of the South African feed-in tariff

Abstract

The carbon intensity of the South African economy is among the highest in the world: the amount of CO_2 emitted per million international dollars generated reaches almost twice the world average. The first steps have been taken by the South African government to tackle the challenge of decarbonisation, such as the introduction of a renewable energy feed-in tariff (REFIT) in 2009. However, REFIT is a showcase for potential pitfalls in the implementation of renewable energy support policies: a stalemate lasting two years after the introduction of REFIT ended with the abandonment of the scheme in favour of a competitive bidding process in 2011. This paper seeks to analyse the underlying reasons for this and to offer recommendations for similar situations in the future.

The paper identifies three main barriers to the implementation of REFIT: 1) social priorities other than the deployment of renewable energy technologies, 2) a lack of coordination and capacity at the policy-making level, and 3) strong lobby groups with interests in fossil fuel technologies. These barriers not only exist in South Africa, but in most other developing countries. Therefore, many of the recommendations for South Africa can be transferred to other country contexts, such as:

- *informing the public about climate change and stressing the positive side-effects of renewable energy technologies, thereby building public support*
- *making use of international mechanisms to build political momentum*
- *forming clean-energy coalitions with powerful groups in society*
- *communicating support rules as early and clearly as possible, and keeping later adjustments to the rules predictable to maintain investment certainty*
- *establishing inter-ministerial groups with oversight authority to enhance political coordination*
- *supporting established energy suppliers in their discovery of renewable energy tariffs (RETs) as a new business field*
- *strengthening the position and capacity of renewable energy newcomers.*

Should South Africa support renewable energy technologies?

Since the Fourth Assessment Report of the Intergovernmental Panel on Climate change (IPCC) in 2007, there has been a widespread consensus that climate change is one of this century's most serious problems. However, while the strongest impacts are only expected to start in several decades time, bold and – most importantly – global action to prevent the worst has yet to be taken today. Most national policies do not yet reflect this fact.

Even though the total contribution of South Africa to global CO_2 emissions is still moderate (about 1 per cent in 2007), its per capita emission rate of 7.6 tonnes of CO_2 in 2007 was above the global average of 4.6 tonnes and more than nine times higher than the sub-Saharan average of 0.8 tonnes. The amount of CO_2 emitted per million international dollars generated is almost twice the world average (World Resources Institute 2010).[1]

Most South African emissions come from the use of coal, which is the main source of electricity production (IEA 2010b). South African electricity demand is currently at about 240 TWh per year (Statistics South Africa 2011a). Electricity production stands at about 260 TWh, coming from an installed capacity of about 41 MW. Most of the electricity is provided by Eskom, the South African state-owned electricity utility. Demand is expected to increase by 4 per cent annually and to double by 2025. Bearing in mind the need to decarbonise, renewable energy technologies (RETs) will have to play a prominent role in added capacity, especially as capacity can be added quickly with wind power or solar photovoltaics, easing Eskom's narrow electricity supply reserve margin of less than 10 per cent.

Furthermore, RETs could contribute to solving some of South Africa's most pressing social and economic issues. The development of a nascent industry could lead to substantial job creation, at least in the longer term. At 24 per cent, the South African unemployment rate is high (Statistics South Africa 2011b). The potential of strong renewable energy support to create new jobs has been proved in other countries: the gross employment effect in the German renewable energy sector, as an example, was estimated at 340,000 jobs in 2010. Admittedly, the German job creation experience cannot be transferred one-to-one to South Africa. Germany enjoyed a first-mover advantage in technologies such as wind energy, which cannot be replicated by countries that follow her. While the South African government does see job-creation opportunities in the manufacture of RETs, it cautions that at least in the short term 'employment expectations should not be unduly raised' (Department of Minerals and Energy 2003, 40). Furthermore, the proactive German support strategy was comparatively costly. The additional costs caused by the German feed-in tariff were EUR 4.65 billion in 2008, rising to EUR 8 billion in 2010 (Wuppertal Institute 2011). These costs are, inter alia, caused by the success of the support scheme in stimulating the growth of solar photovoltaic installations. In addition, Germany's relatively poor solar resource base necessitates a high level of support per kWh produced.

In contrast, the South African renewable energy resource base is excellent – particularly solar energy. The total area of high radiation in South Africa amounts to approximately 194,000 sq. km, including the Northern Cape, one of the best solar resource areas in the world (Eskom 2002). The technical potential of 2,700 sq. km, or 1.4 per cent of the area, could meet total projected South African electricity demand in 2025 (Eskom 2002; du Marchie van Voorthuysen 2006, 6). This would correspond to the scale of solar energy projects planned in the DESERTEC project in northern Africa (Desertec Foundation 2011).

Admittedly, benefitting from the vast South African solar resources is not within the realm of 'low-hanging fruits'. Utilising the potential through renewable energy generation would require large investments not only in generation utilities, but also in transmission lines from the areas of high radiation to the main electricity consumer centres. However, given the scale of the low-carbon development challenge, just reaping the 'low-hanging' fruits will not suffice.

Is a feed-in tariff appropriate to support renewable energy technologies?

To be appropriate, a support measure needs to be effective and efficient. Many countries, mostly in the OECD, have proved the effectiveness of feed-in tariffs. Designed in ways that guarantee reasonable profits over a long-term planning horizon and accompanied by enabling conditions such as lean application processes, they can significantly stimulate renewable energy growth (Haselip 2011). This has been shown by markets as diverse as solar energy in Germany and wind energy in China.

To be efficient, tariff rates have to be designed carefully. They must be high enough to stimulate investment, but should not generate excessive profits. As high resource endowments make renewable energy projects more profitable, tariff rates can be adapted regionally. Also, tariff degression over time can account for decreasing marginal costs. Ultimately, RETs are expected to reach grid parity – that is, become competitive with fossil fuels.

South Africa not only has a good renewable energy resource potential, but also a good financial, technological and industrial capacity base. This will be conducive to the long-term development of a renewable energy industry.[2] However, local companies will clearly need support in the initial stage. To maximise benefits for local industry, some countries have linked renewable energy support to local content requirements. As an example, support is only granted if a certain share of equipment and installations is purchased from domestic suppliers. China practised this strategy successfully: until early 2010, it required wind turbines installed in the country to have at least 70% 'domestic content' in terms of the value of incorporated materials and components. However, this requirement is no longer necessary, as today virtually all turbine installations are Chinese-produced. The requirement was therefore abolished in early 2010 (Altenburg et al. 2010).

In contrast to price-based mechanisms such as feed-in tariffs, quantity-based mechanisms can be used to support RETs. Some countries introduced renewable energy quotas, where electricity consumers, suppliers or producers are obliged to source a certain percentage of their electricity from renewable energy. To increase efficiency, this system is often complemented by a green certificate scheme. Under ideal conditions, price-based and quantity-based mechanisms are equally efficient (Weitzman 1974). However, under imperfect real-world conditions, quota systems have had less impact (European Commission 2008; Butler / Neuhoff 2008). One reason may be that they provide less investment certainty. If there are few actors in the market, price fluctuations can be high. Once the quota has been reached or even exceeded, prices for renewable electricity decrease and threaten the profitability of projects. This results in additional risk, which is priced at a premium by the private sector and acts as an unnecessary obstacle to investment.

With their long-term, stable investment framework, feed-in tariffs seem to be among the most effective and efficient support measures available today. Designed carefully, they can at the same time contribute to lowering emissions, stabilising electricity supply and creating 'green' jobs at reasonable costs. However, the South African experience shows that often the devil is in the detail.

The South African feed-in tariff: From REFIT to REBID

When the South African feed-in tariff (REFIT) first emerged, the national energy regulator NERSA planned for rather low tariff rates subject to annual degression. Each technology was eligible for a different tariff, since the costs of electricity production differ in each case. The differentiated tariff system was to allow project developers to recover the full cost of their projects plus a reasonable return. However, developers did not see any scope for profitable projects on the basis of the low REFIT rates. Furthermore, with rates guaranteed for fifteen years, the time-span for investment planning was short compared to the capital life-spans of renewable energy investments of 25–30 years assumed in NERSA's initial calculation.

NERSA then invited and received a number of comments on the REFIT from stakeholders and the public in the form of submissions and public hearings. Renewable energy project developers and their associations used these forums to voice their concerns about the profitability of projects. After deliberations in early 2009, NERSA took the final decision on tariffs and contract length (see Table 1). The tariffs were raised considerably – wind energy support doubled, CSP support tripled – which was well received by investors and environmental organisations (Pegels 2010). Furthermore, the period for which tariffs were guaranteed was extended from 15 to 20 years to enhance investment certainty. The South African feed-in tariff thus had a very promising start.

However, despite the attractive rates, no projects have been implemented on the basis of the REFIT. This does not result from any lack of investor interest: according to the South African Wind Energy Association, wind project developers alone have invested about ZAR 400 million (EUR 41 million) into the development of project proposals (Naidoo 2011).

Instead, the uncertain regulatory environment has been the bottleneck. Since its introduction, the REFIT has experienced considerable implementation issues. Although tariff rates were set in 2009, project developers could not enter into contracts with Eskom, the single buyer determined by the government, as they had to wait for the issuing of standardised power purchase agreements. After two years of standstill, the South African energy regulator NERSA issued a consultation paper on a tariff review (NERSA 2011). These reviews had initially been announced to take place on an annual basis for the first five years. Adjusted tariffs were to be applied only to new projects to safeguard investors' long-term planning horizons (NERSA 2009a). However, tariffs remained unchanged in 2010 and thus continued to be the planning basis for project developers. The reductions proposed by NERSA in March 2011 were considerable and took project developers by surprise: some tariffs were cut by more than 40 per cent (see Table 1).

In addition to the size of the cuts, project-developers criticised the timing of the announcement, which prevented the imminent release of a request for proposals for the first 1025 MW of renewable energy projects. More than the reduction of expected profits, developers and investors deplored the loss of investment certainty and trust.

Table 1: 2009 versus 2011 REFIT rates

Technology	REFIT 2009 ZAR c/kWh (EUR c/kWh)	REFIT 2011 ZAR c/kWh	Percentage change 2011/2009 (%)
Wind	125 (12.8)	93.8	-24.9
Landfill gas	90 (9.2)	53.9	-40.1
Small Hydro	94 (9.6)	67.1	-28.6
CSP, trough with storage (6 hrs./day)	210 (21.5)	183.6	-12.6
CSP, trough w/o storage	314 (32.2)	193.8	-38.8
CSP tower with storage (6 hrs./day)	231 (23.7)	139.9	-39.4
Large-scale grid connected PV (≥1 MW)	394 (40.4)	231.1	-41.3
Biomass solid	118 (12.1)	106	-10.1
Biogas	96 (9.8)	83.7	-12.9

Source: NERSA 2011; NERSA 2009a; NERSA 2009b

Shortly thereafter, statements by the National Treasury questioning the legality of the REFIT policy itself intensified uncertainty. The comments were based on the legal requirements relating to public-sector procurement in South Africa: the Constitution of 1996 states that organs of state need to purchase goods or services in a fair, equitable, transparent, competitive and cost-effective manner. Referring to the fixed tariffs, the National Treasury questioned REFIT's competitiveness and cost-effectiveness. In July 2011, Energy Minister Dipuo Peters determined that price competition will indeed be part of the first renewable energy procurement round. Even though project-developers remained hopeful, NERSA concurred with the inclusion of price competition into the procurement process shortly thereafter.

In early August 2011, the Department of Energy eventually released details of the process, together with a request for proposals from renewable energy project-developers. The subsequent selection process involves two sets of criteria. Qualification criteria include economic development, legal, land acquisition and use, environmental, financial and technical elements. Project-developers who pass all thresholds of the qualification are further assessed on the basis of two evaluation criteria, economic development and price, weighed 30 per cent and 70 per cent respectively. The submitted price needs to be below a given ceiling approximating to the 2009 REFIT rates. REFIT, as introduced in 2009, was then abandoned in favour of a competitive bidding process.

In international comparison, bidding processes and quotas have a less positive track record than renewable energy feed-in tariffs. Several countries, such as Ireland, Italy and the United Kingdom, have abandoned or at least complemented their competitive bids with feed-in tariffs (Ecofys et al. 2009). South African policy-makers therefore opted for the less proven scheme. In addition, the opaque process and stepwise deterioration of purchasing conditions could have led to considerable confusion and a loss of trust among investors. Fortunately, the interest of project-developers seems to have remained high. In the first two months after the release of the request for proposals, more than 300 project-developers representing 27 GW of potential capacity expressed their interest in bidding (Creamer 2011c). However, policy-makers must avoid further confusion in the implementation of the support scheme. It is therefore conducive to analyse the underlying reasons for the cumbersome conversion from REFIT to REBID.

Why so cumbersome?

The South African REFIT process highlights some of the potential pitfalls in the effective support of RETs worldwide. Steering coal-based economies towards low-carbon development is an extremely complex task – and an unfamiliar one. Having focused on energy access for the past fifteen years, South Africa's policy-makers now have to add the requirements of low-carbon development to their considerations. At the same time, they cannot lose sight of the continuous developmental challenge. They share this challenge with numerous other developing countries, where issues other than climate change mitigation are more pressing and take precedence over renewable energy support – at least when this support involves additional costs. Some of the issues South Africa faces are highlighted below, followed by a discussion of the barriers to effective renewable energy policy implementation located in the economic and political economy spheres.

Differing social priorities

The issues prevalent in many developing countries that RETs might help to solve – such as a lack of electricity access, high unemployment rates and electricity demand exceeding supply – at the same time hinder renewable energy support policies. In areas where the extension of the national grid has long been promised, people may not accept renewable off-grid solutions. Some South African rural communities, for example, see electricity stand-alone systems as 'second-class' electricity (IEA 2010a). This narrows the potential support for renewable energy policies, which might be seen as a distraction from the core responsibilities of the state. High unemployment rates work in the same manner: voters reward policies they can directly connect to lower unemployment rates more than those they associate with environmental protection – or potentially even perceive as donor-driven.

Furthermore, the need for higher social spending due to unemployment lowers the scope of action in other policy fields. As electricity supply in South Africa can hardly keep up with demand, policy-makers tend to focus on bulk electricity generation rather than on decentralised, small-scale projects. However, most renewable energy projects are among the latter. The focus on centralised solutions implies specific technological pathways that may have contributed to the country being locked into emissions-intensive development.

The economics of renewable energy technologies (RETs)

If RETs were price-competitive or even cheaper than fossil fuel-based technologies, they would be much easier to advocate in the face of the challenges noted above. However, in most cases they are not. As environmental costs are usually not reflected in the price of coal-based electricity, this form of energy is still comparatively cheap. Most RETs, in contrast, are still rather costly. Support schemes have to be financed either through higher taxes or higher consumer prices for electricity. The effects depend on the level of support, but also on the success of the scheme in promoting investment in RETs. The higher the amount of 'green' electricity supported, the stronger the impact on taxes or electricity prices. The German renewable energy law is estimated to have caused a price increase of about 12 per cent between 2002 and 2006 (BMU, 2007, 13). This moderate increase may be due to the already comparatively high price of electricity in Germany. However, the situation may differ in South Africa, where electricity prices are low. In general, energy prices tend to be a very political issue in developing countries. Governments fear and can actually face social unrest when consumer prices increase rapidly. This was shown by widespread protests in Indonesia in 2008, caused by a steep rise in oil prices (Reuters 2008). While the steeply rising electricity prices in South Africa have not led to social unrest, they do attract public opposition, being perceived as a threat to the aims of economic growth and poverty reduction. The political success of South Africa's ruling party, the African National Congress (ANC), is closely linked to and dependent on progress in reaching these aims (Pegels 2010).

The lack of state capacity and power dynamics

In addition to the complexity of effective renewable energy support, many South African government departments lack implementing capacity and experience and struggle to recruit and retain qualified personnel.[3] The effect of Broad Based Black Economic Empowerment (BBBEE) rules on the performance of government departments is still unclear. While these rules certainly have merit in restoring equality after the apartheid period, they also divert staff selection towards criteria other than expertise. This potentially has negative effects on overall performance, especially if employees are enticed by the private sector as soon as they have acquired relevant working experience.

Furthermore, power dynamics seem to have played an important role in the conversion from REFIT to REBID. In general, policy-makers are embedded in a dense network of social ties that structure their interactions, with social and business actors but also in-between government bodies (Foresti et al. 2011). Some of those actors are more influential than others: as long as Eskom's predominance in the South African electricity sector remains untouched, independent power producers (IPPs) will find it challenging to enter the market and supply significant amounts of clean energy. While attempts by the Department of Energy to liberalise the energy market in support of IPPs are underway, there is still no level playing field. At present, IPPs can sell their electricity only to the state-owned electricity supplier Eskom, who then distributes it to consumers. Being a competitor of IPPs and the single buyer of their electricity at the same time, Eskom clearly faces a conflict of interest. In his State of the Nation Address in early 2010, South African President Jacob Zuma therefore announced that an independent contractor would be established separately from Eskom. One year later, the Department of Energy published a draft bill for the establishment of an Independent Systems and Market Operator (ISMO), along with a request for comments. The passing of this bill may be an important step in limiting Eskom's market power and creating an enabling environment for renewable energy power-producers. The ISMO would be responsible for planning generation capacity, entering into power purchase agreements with generators, dispatching the power generated and coordinating the wholesale market for the generation of electricity.

However, the process of transition from the current centralised system to a new and independent agency is not yet clear. Eskom favours an incremental process with various stages of independence, beginning with an entity ring-fenced within Eskom itself. Renewable energy project-developers, in contrast, see Eskom's role as single buyer of renewable electricity as a major impediment to IPP activity and would prefer a fully independent entity to be established sooner rather than later (Creamer 2011b).

However, power struggles not only occur between the renewable and fossil-fuel industries, but also between government entities themselves. The fractured responsibilities in South African energy policy make the different actors prone to turf wars (Fakir 2011). Conflicts of competence seem to involve the Department of Energy, other government departments and the energy regulator NERSA. In expert interviews conducted by the author in May 2011, several interviewees stated that NERSA may have stretched – if not overstretched – its mandate in determining the REFIT tariffs. This view was confirmed by the National Treasury (Creamer 2011a). Naturally, NERSA disagreed and even secured a confirmatory legal opinion on the matter. This did not, however, prevent the government from abandoning the REFIT scheme preferred by NERSA. Although drafted and introduced by NERSA, REFIT was altered and eventually abolished by the Department of Energy and, most notably, the National Treasury. The conflicting positions clearly indicate a lack of coordination among the departments and government entities involved (SAIIA 2008; Fakir 2011).

What can be learned?

South Africa is well endowed with renewable energy resources, especially solar energy. Tapping into this resource would help meet both the emissions and the energy supply challenge. In addition, the deployment of renewable energy can lead to considerable job creation – even if South Africa will most likely not be able to repeat the first-mover countries' growth in 'green' jobs.

While rising electricity prices will improve the competitive position of RETs in the future, these technologies will still need support if they are to be deployed on a commercial, large-scale basis. This support is needed as soon as possible, since investment cycles are comparatively long in the energy sector. Investments in fossil fuel-powered stations undertaken today lock these technologies in for decades to come. The South African government has acknowledged this and consequently taken measures to support private investment in renewable energy and other clean technologies.

However, in spite of a high resource potential, there has so far been little progress in the deployment of renewables. As a main barrier, this paper identifies the instability of the required political support. Insecurity about the level of tariffs, delays in the issuing of power purchase agreements, conflicting messages from different government entities and the eventual reorganisation of the entire scheme resulted in a loss of investment security.

Rebuilding this security through stable policies will not be easy, as the underlying challenges are structural. First, the public pressure on South African policy-makers to safeguard issues other than the decarbonisation of the economy is high: electrification, unemployment and public infrastructure take priority. Secondly, RETs are not yet economically competitive with conventional energy technologies. This complicates their advocacy in the light of the social priorities mentioned above. Thirdly, while some South African policy-makers can show outstanding qualifications and performance, the technical capacity of many to manage the extremely complex energy transition efficiently is low. This lack of expertise is often compensated for by advice from energy experts based in fossil fuel companies. Their main interest is, of course, not in RETs. Power struggles and a lack of coordination between the political proponents of RETs further exacerbate the situation.

However, the recent decision for a competitive bidding process may mark the beginning of a more stable system of support for RETs. The National Treasury, one of the most powerful and capable South African government departments, is backing the scheme. Even though competitive bidding does not have as positive an international track record as feed-in tariffs, it may provide a starting point. South African policy-makers may address the above-mentioned structural challenges and strengthen the impact of the newly established process by

- informing the public about climate change and the need for a low-carbon energy transition, thereby building public support. In parallel, they may stress the positive side effects of RETs, such as reduced air pollution, rural electrification and job creation.
- making use of international mechanisms to build political momentum, such as those established under bi- and multilateral development cooperation or the United Nations Framework Convention on Climate Change. Many of the barriers to renewable energy deployment, such as the additional financial burden on consumers caused by feed-in tariffs, high investment costs for grid extensions, the need for additional education and research, and risk cover for early-stage technologies, can be overcome with external funding and technological assistance. The upcoming climate-change negotiations in Durban may provide an excellent opportunity to advance respective support mechanisms on a multilateral level. Additional opportunities exist on bilateral levels.
- forming clean energy coalitions with powerful groups in the society. In South Africa, energy-intensive firms may not support RETs for environmental reasons alone, but they may be willing to pay price premiums for quickly installable electricity generation to secure supply. Compared to fossil fuel-based bulk generation, decentralised and small renewable energy solutions have a competitive advantage in this area.
- communicating support rules as early and as clearly as possible. Any later adjustments to the rules must be predictable if investment certainty is to be maintained. This also means that rules have to be negotiated and coordinated internally (i.e., within and between government bodies) before they are communicated to the outside world, thereby avoiding conflicting messages. Coordination can be enhanced by the establishment of inter-ministerial groups with oversight authority, such as the South African Inter-Ministerial Committee on Energy. These groups, however, require the necessary training to build up the expertise needed for effective oversight.
- supporting established energy suppliers, such as Sasol and Eskom, in their discovery of RETs as a new business field. As Eskom's single shareholder, the government should exert its influence towards the use of cleaner and non-finite sources of energy. The capacity and expertise in RETs built up in these companies can be drawn upon when policy advice is needed. This may help to balance the current bias towards fossil fuels.
- strengthening the position and capacity of independent power producers (IPPs). As long as Eskom's predominance in the electricity sector remains untouched, IPPs will find it challenging to enter the market and supply significant amounts of clean energy. The planned outsourcing of the Single Buyer's Office from Eskom to an independent entity is an important step, and the implementation strategy should be clarified as soon as possible.

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Endnotes

1. The international dollar is a hypothetical unit of currency that has the same purchasing power as the US dollar at a given point in time. The benchmark year used by the World Resources Institute (2010) is 2005.
2. Personal interview with a South African wind-energy project-developer, May 2011.
3. Personal interviews with a South African policy think-tank, an NGO and a representative of academia, May 2011.

Biogas from household biodigesters is not only used for cooking, but also for lamps in Cambodia
Photo: Jasmine Hyman

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Promotion of renewable energy in Latin America: Policy and lessons

Abstract

While historical contributions to greenhouse gas emissions (GHG) from Latin America have been minor in comparison with those of other areas around the globe, all the major countries have introduced or revised existing laws, regulations and incentives in order to contribute to international mitigation efforts. In particular, governments in Latin America have promoted legal frameworks, market incentives and other options to increase the rates of renewable energy penetration in the national energy mix through price or demand certainty. By comparison with fossil fuels, a singular benefit of renewable energy is that it can reduce GHG emissions to zero during the generation phase. Against the backdrop of international investment in the region, the article analyses the main renewable energy policies of Latin American countries, indicates the extent to which different policies have been introduced and where, seeks to draw some lessons from their experience and notes the nevertheless limited expansion of renewable energy in the region. Together with national targets for future share of energy from renewable sources, price and quantity-driven regulatory frameworks have focussed primarily on feed-in tariffs, quotas and competitive bidding, instruments analysed in this article. The article also stresses that, while emissions reductions are an important objective of the promotion of renewables in Latin America, developing positive market conditions for independent energy producers, addressing the regional shortfall in energy supply and tackling the problem of poor rural populations without energy all determine the character of renewable energy policy in Latin America. The cases of Argentina, Brazil and Peru are discussed in particular.

Introduction

Since the 1990s, many developing countries have deregulated electricity markets and embraced privatisation. In this context, governments also sanctioned policies to reduce GHG emissions in their own energy systems. All the major South American and Caribbean countries (collectively referred to here as Latin America) have introduced or revised existing laws, regulations and incentives to stimulate the use of alternative sources of energy and attract investment to enhance the penetration rates of renewable energy technology and increase the energy efficiency of their domestic energy mix. Market and other stimuli have been devised to increase price or demand certainty through instruments such as renewable quotas, feed-in tariff schemes, tendering, fiscal incentives and dedicated auctions. While this article explains crucial liberalisation policies and investment trends for the region, it focuses on national energy policies, regulation and economic and fiscal incentives in Latin America (LA) that promote the uptake of renewable energy technologies – small hydro, wind, solar, biomass waste and biogas.

By promoting renewable energy, LA governments have demonstrated considerable enthusiasm for joining international efforts to tackle climate change in the light of the forecast rise in both regional energy demand and GHG emissions. It is predicted that by 2030 lower-income non-OECD countries will be showing the strongest per annum increases in electricity demand, almost four times greater than that of the OECD countries, as they expand their power grids to support economic growth (EIA, 2008; World Bank, 2009). According to these predictions, energy demand in developing countries will double over the next two to three decades, primarily due to economic activity, electricity generation, intensification of land use and motorisation. Energy-related global GHG emissions, mainly from fossil fuel combustion, are projected to rise by over 50 percent by 2030 (IPCC SRES, 2000). However, historically, the contributions to GHG emissions from LA have been minor in comparison with those of other regions. For example, in Argentina and Peru, a large proportion of electricity generation comes from hydro and natural gas, so that their baseline emissions factor is relatively low.

Yet, increasing access to energy is crucial for economic growth in order to reduce poverty, promote specialisation and labour productivity, and build infrastructure in the LA region. To the extent that fossil fuel continues to be the main energy source, this would add significant GHG to the atmosphere. In order to mitigate emissions, the IPCC stresses the urgency of developing targeted economic and regulatory initiatives and appropriate energy technology (IPCC, 2007).

Arguably, the most important benefit of renewable energy is that, by comparison with fossil fuels, it dramatically reduces GHG to zero during the generation phase (IPCC, 2007, p. 13). However, the purpose of introducing renewable energy regulation in LA has also been to develop market conditions for independent energy producers, as well as to address other energy-related problems of the region, especially shortages of energy supply, the fact that 26% of the rural population are without access to energy (WEO, 2002, 2010). In fact, renewable energy can make a notable contribution not only to emissions reductions, but also to ensuring energy independence and security and promoting rural electrification (REN21, 2011; Cherni, 2008; Ghosh et al., 2002; Anderson et al., 1999; Karekezi and Ranja, 1997). Recognition of such attributes has shifted renewable energy from the fringe to the mainstream of not only sustainable development technologies in both the developed and developing worlds (Martinot et al., 2002), but also of energy policy in LA.

Discussion of policies for the promotion of renewable energy in connection with climate change mitigation in LA must therefore refer to the pervasive impact of market reforms on the strategy for the energy sector, regional energy security, and equitable and affordable energy access. In this analytical context, and making reference to figures that point to the still minor deployment of renewable energy in the region, this article analyses the legal and regulatory frameworks that have been designed by governments in LA to promote the adoption of renewable energy technology and asks how they relate to the above issues. The experiences of three countries in particular are analysed, namely Argentina, Brazil and Peru.

Reform policies and investment trends in renewable energy in LA

The electricity market has been at the centre of many energy reform programmes (MacKerron, 2000), including those undertaken in Latin America. Indeed, in a few countries in LA privatisation was expected to provide the resources for the replacement of a decaying state infrastructure and to increase access to energy. Yet, the contribution of wind, small hydro, geo-thermal and solar technologies remains marginal, and electricity generation from renewable sources is highly uneven across sub-regions.

The structural reforms implemented in most LA countries have created a new environment for public policies, with remarkable effects on energy policy and the choice of instruments for promoting renewable energy (Bouille, 2010). Although this article does not aim to analyse the impact of economic restructuring on the expansion of renewable energy in the region, it should be noted that liberalisation policies have been widespread and significant for the region. In fact, of all developing regions that had implemented energy market reforms by the late 1990s, privatisation of power distribution assets was greatest in LA (44%), regions where corporate restructuring was also significantly more advanced (72%) (Bacon, 1999). Under the neo-liberal reforms of the 1990s, where possible management and investment were provided by the private sector, with the state confining itself to the regulation of the market.

For national governments and rural populations in particular, a considerable hope had been that electricity market reform would also finance and deliver the extension of transmission and distribution networks to provide greater access to electricity (Cherni and Preston, 2007). However, uncertainties and fears emerged concerning the likelihood of renewable energy technologies expanding – many of which could be used precisely to increase both access to electricity and power supply in LA – under the new schemes which reduced R&D expenditures and tax credits (Rickerson and Grace, 2007, in Mendonça, 2010). As a response to the introduction of electricity restructuring, and since renewable energy sources were not competitive within a market that did not include the full social and environmental costs of fossil electricity, in the mid-1990s the US and EU agreed that additional policies were required to promote their positive benefits. The Renewable Portfolio Standards (RPS; also called, e.g., Renewables Obligations, Renewable Purchase Obligations or RPO, and Mandatory Renewable Energy Targets) were then developed to set quotas to force suppliers to utilise renewable energy resources. RPS has been implemented in at least 49 countries worldwide, including Chile and Uruguay in LA.

As a result of reforms, the development and deployment of renewable energy are expected to be largely financed by the private sector (Wagner, 2010; Stern, 2007). Off-grid electrification comprised almost 10 percent of the total assistance to electrification provided by the World Bank in 2003-2005, a proportion that is expected to grow along with progress to universal access, as remaining populations will be harder to connect using conventional grid extension arrangements (ESMAP, 2007). However, the considerable investment in renewable energy in LA in the mid-2000s was sporadically interrupted: while global financial investment in renewable energy was higher than ever during 2008-9, most of Latin America (and a large part of Africa) attracted little investment during that period (UNEP, 2010; DB, 2009). In 2010, regional investment trends again favoured LA, an indication of some encouraging government regulatory frameworks, as well as an acknowledgement of the availability of appropriate natural resources for generating energy. In 2010 alone, LA, excluding Brazil, saw the biggest absolute increase in renewable energy investment in the developing world (Africa achieved the largest percentage increase, after China, India and Brazil; investment increased significantly in Argentina, Mexico and Chile; for details of investment growth, see REN21, 2011). After China, Brazil has led the renewable energy market in developing countries (Science Daily, 2009).

Notwithstanding the increase in regional investment in LA, the contribution of renewable energy to total energy generation stands at less than 20% (IEA, 2008): 19.1% mainly from sugarcane waste and biomass geothermal energy, and 0.5% from small hydro, solar and wind. While the contribution of large hydro plants to electricity generation in the region is relatively large at 10.6%, LA's primary energy supply relies heavily on fossil fuels (40.7% oil, and 20% gas; ibid., 2008). Therefore, in the context of liberalisation, the government still has the crucial role of providing a stable framework of incentives and establishing policies that stimulate changes in energy provision (IPCC, 2011; Stern, 2007 p 409). Although there is no one-size-fits-all policy, the existence of an enabling policy environment could facilitate the deployment of renewable energy and the evolution to low-cost applications (IPCC, 2011). Policy frameworks that are transparent and sustained in order to reduce risks and that enable attractive returns over a relevant investment facilitate the deployment of technology. In LA, the promotion of renewable energy technologies has been undertaken centrally by governments, with the tendency being towards regulation, although countries' experiences differ markedly.

By 2010, renewable energy support policies continued to be a driving force behind the increasing shares of renewable energy globally, despite setbacks due to the lack of long-term policy certainty (REN21, 2011). In LA, policies to promote renewable energy have mostly mirrored practices elsewhere, with a considerable number of governments having endorsed a wide range of regulatory instruments.

Policy and regulatory instruments to promote renewable energy

Most of the countries producing the largest amounts of renewable energy have pursued proactive policies to promote renewable energy technologies (REN21, 2011). For both emissions-mitigation and energy-security reasons, many industrialised and developing countries have introduced and increased subsidy schemes for the production of electricity, heat and transport fuels based on renewable energy sources (IPCC, 2007). Many countries, including in LA, have also set up regulations, quantitative targets, and various important energy schemes. Regulatory measures are particularly important because in almost every Latin American country with low rural electrification rates there is a large potential for renewable energy.

Although the main motivation for investing in renewable energy is its contribution to both sustainable development and climate change mitigation, these technologies still do not tend to provide the most economically viable option for electricity generation, despite their desirable non-market benefits (see, e.g., Valverde et al., 2010; Karekezi and Kithyoma, 2003; Martinot et al., 2002). Since they are particularly capital-intensive, financial issues can be a huge barrier to renewable energy development. Moreover, in general electricity liberalisation policies have done little to emphasise the potential strategic contribution of renewable technologies. Therefore, national policies in LA have been crucial in promoting a more substantial deployment of renewable energy in the region. For example, the regulation of feed-in tariff schemes in particular has been designed to reduce the above difficulties. Policy targets for various penetration levels of renewable energy as part of future energy supplies continue to proliferate. Targets to increase the share of renewable sources in the energy mix now exist in at least 98 countries, more than half of which are developing countries (REN21, 2011). To foster and facilitate the use of renewables in LA, the majority of countries have deployed some form of legal framework, adopted quantitative targets, or introduced regulatory instruments and a variety of supporting schemes. The stage of development of renewable energy policy frameworks varies considerably among countries in LA, though, in addition to Argentina, Brazil and Peru, most other Latin American countries have implemented some sort of legal initiative (see Annex I in Bouille, 2009).

Four main types of regulatory generation-based policies have been used in LA to increase the share of renewable energy in the electricity grid: i) feed-in tariffs; ii) quotas; iii) competitive bidding; and iv) green energy tradable certificates. This article looks specifically at how feed-in tariffs, quotas and competitive bidding have developed in the region.

Feed-in tariff (i) and quotas (ii) are price-driven regulatory instruments which, instead of establishing a target, offer financial assistance per unit of electricity or capacity for the generation of renewable energy. The schemes accompanying these instruments either pay a predetermined price per unit of production (feed-in tariffs) and do not depend on the cost of production, or else they pay as quota, in which case the market price of electricity increases by the premium set.

Competitive bidding (iii) and green energy tradable certificates (iv) are regulatory instruments whereby the relevant authority specifies the amount of renewable energy to be generated from particular renewable energy technologies by a determined date. Quantitative regulation ensures market share through government-mandated targets or quotas. Following calls for tenders and a selection process, designated bidders sign contracts with the government for a set period and have a guaranteed tariff. Green tradable certificates (iv) are a scheme to complement tenders that require renewable energy in their mix, allowing the parties (generators, utilities retailers and renewable energy producers) to trade at market prices and exchange certificates in order to comply with the contracts (IEA, 2010c; Bouille, 2009).

At least eight countries in Latin America have introduced feed-in tariffs (Argentina, Brazil, Chile, Ecuador, Honduras, Nicaragua, Peru and Panama), two employ quotas (Chile, Uruguay), and one (Brazil) employs a tradable green certificates system. To achieve their quota targets (see below), Argentina and Brazil use a combination of feed-in tariffs with long-term (15 or 20 years) tendering systems, complemented by price-driven instruments such as tax relief and investment incentives. Finally, Colombia, Guatemala, El Salvador, Mexico and the Dominican Republic have introduced legislation to provide fiscal and economic incentives to increase the deployment of renewable energy in their national energy mix (Bouille, 2009).

Of all the policies employed by governments globally to promote renewable energy, feed-in tariffs (also called premium payments, advanced renewable tariffs and minimum price standards) remain the most common (REN21, 2011). Advocates of feed-in tariffs argue that, while most other support mechanisms for renewable energy require very high levels of regulation and steps towards the liberalisation of energy markets, feed-in tariffs can play an important role, as they are simple in design and easily adaptable to all sorts of energy market frameworks (e.g., Mendonça et al., 2010). Also, the IPCC (2007) emphasises that incentives to support 'green power' by rewarding performance, such as feed-in tariffs, are preferable to a capital investment grant because they encourage market deployment while simultaneously promoting increases in production. The price-driven feed-in tariff scheme has been implemented in more than 57 countries, 26 of which are developing (Global Feed-In Tariffs, 2010). Tariffs are normally calculated to offer a 5-8 percent return on initial investment, which, with adjustments for inflation, could rise to 7-10 percent. At the household level, the incentive also states that any income derived from residential renewable electricity will not be taxable (for a detailed explanation of feed-in tariffs, see the article by J. Haselip in this collection).

In contrast to the vast literature and avid debate on the European and US experience with regulatory instruments to promote renewable energy uptake to increase the latter's share in the energy mix (particularly with feed-in tariffs), the LA experience with the same type of policies has received less scrutiny. Lessons from policy frameworks that promote renewable energy have only recently started to emerge, and therefore an examination of the experiences of certain countries is useful in order to learn more about their procedures, difficulties and achievements.

Promotion of renewable energy in Argentina, Brazil and Peru

This section analyses the introduction of specific policy instruments, particularly, but not only, feed-in tariffs, in three LA countries, namely Argentina, Brazil and Peru. Argentina and Brazil have set the same, relatively high mandatory quota share of 8% by 2010 and 10% by 2029 of total electricity generated from renewable sources; the target in Peru is lower, at 5% by 2014. The design and effectiveness may vary widely among these countries, as does the stage of implementation (in many countries there have been implementation difficulties, such as lack of finance, grid infrastructure and/or regulatory framework for full policy implementation), but significant similarities also exist.

Argentina

One factor that has impacted on the structure of the renewable energy sector in Argentina is the tendency of the privatised energy companies to operate within the urban and industrial sectors while ignoring the rural areas, particularly where electricity access was significantly deficient, which in 1994 prompted the Argentine government to introduce PAEPRA (Programme for the Provision of Electricity for the Rural Population of Argentina), a fee-for-service plan to supply the rural population of the country with electricity (Dubash, 2002). In 1999, the Argentine government and the World Bank launched the competitive bidding and concession project PERMER (Renewable Energy Project for Rural Electricity Markets) with the objective of reinvigorating the original PAEPRA.

A further element that has had an effect on the furthering of renewable energy in Argentina has been the increasing role of natural gas. The 1991 privatisation policy adopted in the electricity sector provided for the current energy generation mix to be determined by liberalised market competition (Haselip and Potter, 2010). Since Argentina has the third largest reserves of natural gas in Latin America, as the cheapest option for electricity production, 46 percent of total power produced in 2003 came from natural gas (EIA, 2006). Renewable technologies, on the other hand, make up a very small part of national electricity generation in the country. Therefore, the availability of substantial amounts of natural gas and hydropower in Argentina makes other grid-connected sources uncompetitive.

In line with its comprehensive energy market reforms, Argentina has taken a lead in making strong statements about tackling climate change. It was one of the first developing countries to ratify the Kyoto Protocol and, in 1999, was the first to establish a voluntary target under the UNFCCC. The aim was to reduce GHG emissions to between 2% and 10% below the projected baseline emissions for 2012 (Bouille et al., 2000). While there has been little monitoring of whether the country is on course to reach its target and no road map showing how this is to be achieved (ibid.), progress has been made, at least in producing relevant policies. The Argentine government introduced two main regulatory instruments to promote renewable energy: competitive bidding, and feed-in tariff schemes.

Competitive bidding and concessions quota. The increase in rural electrification using renewable technology and simple off-grid systems was part of the PERMER initiative (Kaufman, 2000). The first phase of PERMER took place between 1994 and 2005 but was extended to 2008; in 2009 it was further prolonged into Phase 2 until 2011. PERMER aimed at the promotion of private investment and concessions together with government subsidies that would cover most of the initial costs. The innovation in the Argentine model of competitive bidding relates to the award of concessions to independent power producers that require the lowest subsidy to electrify regions; successful firms are also expected to provide electricity services through renewable technology to rural areas. The quantity or quota of renewable energy supply is stipulated in the bid (e.g., number of solar panels installed in households schools and public service buildings). The PERMER was financed by a World Bank loan, a donation from GEF, the Argentine Electricity Development Fund, the Concessionaires and customers themselves (World Bank, 1999). In other words, by absorbing major costs in the initial stages, PERMER paid subsidies for the installation of PV as an incentive for users and tendered for private investment. To qualify for these loans and grants from the international banks, however, the bottom line package of policies designed by the Washington Consensus had to be implemented by the hosting authority. Provincial electricity sectors must therefore comply with a certain level of deregulation and privatisation as a precondition for participating in PERMER. The customer tariff is set by the provincial government every two years and, with the return on investment for concessionaires anticipated at 14%, this is what makes investment relatively attractive (Alazraki and Haselip, 2007).

Feed-in Tariff scheme. Argentina now has in place a system that facilitates the uptake of renewable energy into the national grid (Procopper, 2010). In Argentina, feed-in tariffs for supporting the generation of renewable energy, particularly electricity from wind and solar resources, started with Law No. 25.019 of 1998 (IEA, 2010a). Where the electricity generated through these renewable sources was sold to the Argentine national grid or used for public services, the law pledged, for the first time, to pay a premium to independent power producers on top of the market price at the time of sale. This amounted to EUR 0.23/kWh for wind energy and was secured for fifteen years. The same law also provided tax incentives in the form of delayed remittances of value-added tax for fifteen years (Davies, 2006).

However, Law 25.019 was too narrow, first because it applied only to wind and solar energy, and other renewable technologies did not qualify for any of the benefits. Secondly, it was introduced in 1998 at a time when the Argentine currency stood at around three times its current value: since the 2002 Argentina currency devaluation, the value of the subsidy has been considerably reduced (IEA, 2010b). As a result, the 1998 national law no longer offered sufficient incentives and was accordingly superseded by Law 26.190, Promotion of Renewable Sources of Energy for Electricity Production, passed on 6 December 2006. The new Law includes financial incentives in terms of deferred tax payments and defines feed-in tariff premiums, but for a larger range of renewable technologies and with an entitlement period of fifteen years. The updated tariff for energy from photovoltaic systems is EUR 0.22/kWh and EUR 0.37/kWh if electricity is generated through wind technology. For all other sources with a generating capacity of up to 30 MW (i.e., geothermal, tidal, biomass, biogas and small-scale hydropower), the feed-in-tariff paid by the Argentine government is EUR 0.37/kWh (EIA, 2010b). Feed-in tariffs in Argentina are paid in local currency rather than in US dollars or EUR (as is paid in Ecuador, Nicaragua and Honduras and in other developing countries, e.g., Tanzania and Thailand) (DB, 2010).

Finally, the Argentine government launched the GENREN Programme (Generación por Energías Renovables), another initiative to promote public-private investment in renewable energy. The state electricity company ENARSA (Argentine Energy, PLC, of the National Secretary of Energy) launched GENREN in 2009 in order to tackle the shortfall in energy supply, deal with organic waste (e.g., bagasse in the provinces of Tucumán and sawdust in Corrientes), reduce GHG emissions and increase electricity access to rural areas (Río Negro, 2009). The initiative attracted unexpected interest from national and international investors, and before the end of 2009 more than half of the projects (49 in total) had been sold (Renou, 2009). It is predicted that, due to the low generation power of each individual project, the GENEREN scheme will have an impact on both remote rural populations and people with low-energy demand.

Brazil

Brazil has adopted a quota system, feed-in tariffs, guaranteed sale and state financing. However, progress in incorporating renewable forms of energy into the national grid has been slower than planned, and their relative contribution to the energy mix is still low (Bouille, 2009).

Brazil is among the biggest producers of electricity from renewable sources in the developing world. In 2009, it was the second largest producer of hydro-electricity, including large hydro plants, after China (ObservEr, 2010), and in 2003 it accounted for 31% of the total generated by developing countries (IEA, 2003). Early in the 1990s, the national Electric Energy Regulating Authority (ANEEL) introduced policies to stimulate renewable sources, including allowing free access to the grid, reducing bureaucracy and extending benefits previously available only for power generation from conventional fuels. For example, Law 9648/98 extended the existing subsidies for diesel generation in isolated communities in the north of Brazil to renewable technologies (Goldemberg et al, 2005). In 1994, Brazil promoted off-grid electrification of villages through the Program for Energy Development in State and Municipalities (PRODEEM). In November 2003, the government launched the federal Luz para todos (Light for Everyone) programme aimed at providing electricity generated from renewable sources.

The programme for Alternative Electric Generation Sources (PROINFA) was initiated in 2002 and established a target of 10% of power to be produced from wind, small-scale hydro and biomass within twenty years. PROINFA also sets prices for purchasing electricity generated using different sources of renewable energy (Goldemberg et al., 2005). PROINFA is funded by end-users through an increase in energy bills (exemptions exist for low-income households). Through competitive bidding, the national electricity firm Electrobras enters into twenty-year contracts with renewable energy generators, sets prices for purchasing electricity generated using different sources of renewable energy (ibid.) and buys, in local currency, energy from the green energy producers at pre-set preferential prices (feed-in tariff premiums), which are adjusted according to a market index. Electrobras guarantees a minimum income, and the Brazilian National Development Bank enables financing of up to 80% of capital for eligible projects (Boiulle, 2009).

Peru

Like Argentina, the availability of cheaper natural gas in Peru has inevitably interfered with a more significant increase in renewable energy technologies in the country. Peru has the sixth largest natural gas reserves in the region, most of which are located in the Camisea area in the Amazon. While nowhere near the level of some of the region's energy powerhouses, Peru's natural gas has nonetheless been a spur to its economy (Spencer, 2009, 2010). Apart from renewable energy legislation, the Peruvian government has introduced comprehensive feed-in tariffs.

The Peruvian government has promoted renewable energy through a quota system, feed-in tariffs and preferential premiums. The Rural Electrification Law (REL) of 2002 was intended to provide energy solutions to rural and remote areas and recognised the need to access alternative sources of electricity in order to reach isolated locations (MEM, 2002). That renewable energy could play an increasing role in the future of the Peruvian electricity market was then little more than an aspiration; no specific commitment or plan had been formulated in 2002 (Cherni and Preston, 2007).

The REL reflected the government's decision to address some of the market failures ingrained in Peru's electricity reforms, such as the large percentage of unmet energy demand of the rural population and the environmental consequences of increasing GHG emissions (Olivas, 2010). However, the failure of the REL to deliver significant improvements in rural access to electricity has created a pressing need to implement alternative ways of supplying electricity (ibid.). The 2008 Renewable Energy Investment Promotion Law (REIPL, Decree No. 1.002) envisages that 5 percent of national electric energy demand will be met by non-conventional renewable energy sources under 20 MW, such as wind, solar, geothermal and small hydro plants, between 2008-2013, totalling approximately 250 MW of installed capacity (68 percent of Peru's current energy mix comes from oil and gas).

Between August 2009 and February 2010, under the 2008 REIPL law, the Peruvian government's Energy and Mining Regulator (OSINERGMIN) held its first auction for licences to build 200 MW of energy generation through solar, wind and biomass provision, and a further 300 MW for mini-hydro to supply the national grid (UKTI, 2010; Olivas, 2010). The licence lasts for twenty years, and construction by the winning independent power producers is now underway. Total expected investment is around US$ 1 billion for the construction of three wind, four solar, two biomass and seventeen micro-hydro plants in the country's interior (Portillo, 2010). By 2012, it is expected that the 26 energy projects will be operational and generate 411.7 MW (UKTI, 2010). Under the 2008 REIPL, the Regulator is legally committed to hold a round of auctions for 500 MW of renewable energy generation every two years.

In addition, the government paid feed-in tariffs to auction winners. In the first auction the payments were US$ 0.087/kWh for wind energy, US$ 0.0225/kWh for solar technology, US$ 0.0635/kWh for energy generated through biomass and US$ 0.06/kWh for hydroelectricity (Global Feed-in Tariffs, 2010) (NB: prices were significantly lower than the tariffs paid in Argentina). The first auction was considered a great success by investors in particular, given the certainty that the regulation provides for future cash flows for any given project. However, while the quota for generating energy from water and wind sources was achieved, the auction did not attracted bidders for solar or biomass sources. Therefore, the objective of the second round of auctions was to construct 8 MW of solar and 419 MW of biomass generation capacity, but due to the low tariffs set by OSINERGMIN, only three companies were awarded licenses. Due to the extremely low prices set by OSINERGMIN, the second auction was unsuccessful, with only three companies being awarded licences (two mini-hydro plants and a biomass project; UKTI, 2010).

A further development in relation to feed-in tariffs in Peru is the introduction of additional concessions in order to encourage investment for the further generation of electricity from renewable energy. The Peruvian government has not only guaranteed it will purchase from power plants using renewable energy, it has also set premiums on top of electricity tariffs to guarantee at least 12% profit to renewable energy producers (Boiulle, 2009).

The LA experience of policies to promote renewable energy: Reflections and lessons

LA countries have introduced both price- and quantity-driven regulations, including feed-in tariffs, quotas and competitive bidding. Governments have designed some unique combinations of competitive bidding, provided concessions and set premiums to increase the deployment of renewable energy in rural areas. The social component of part of the renewable energy policy in LA has also been notable. So far, the lessons to be drawn from LA are mixed, with some pointing to disappointments and difficulties, while others show some degree of success.

In LA, governments had two main reasons to launch feed-in tariffs, quotas and competitive bidding price- and quantity-driven regulations, i.e., to expand the use of renewable energy technology in their countries, and to engage the private sector by offering a range of state subsidies, such as facilities, exemptions and premiums, to invest in renewable energy generation. Interestingly, some of the motivations that Latin American countries have shown in promoting renewable energy have been absent from similar policies in developed countries.

Developed economies have introduced renewable energy policies in order to help achieve legally binding targets for reducing CO_2 emissions (e.g., in Europe, the UK has a 15 percent target to generate total energy from renewable sources by 2020, and Germany has the more aggressive goal of 30 percent). Developing countries, on the other hand, have not only introduced or outdone previous legislation to promote renewable energy in order to to contribute to global GHG reductions and appeal to the private market. Renewable energy promotion policy has also been aimed to tackle the predicament over rural energy access, i.e., populations that remained cut off from the main national electricity distribution grid, were very poor and had low and irregular electricity demand. Whereas electrification levels in LA are among the highest in the developing world (93%), electrification in rural areas remains significantly lower. Competitive bidding and concessions for implementing renewable energy policy have been aimed partly at tackling the fact that electricity liberalisation policies favoured improving services to the urban market (which has a 98.8% electrification connection rate) and overlooked rural areas (with 74% connection levels) (data from WEO, 2010). Indeed, the PERMER in Argentina was the first rural electrification concession project world-wide. It was first implemented in the northern province of Jujuy, but has since expanded to remote rural areas in other provinces. By 1999, it had successfully supplied 556 rural households and 43 schools with single PV SHS of different sizes (no data are yet available for the second phase). In total, PERMER has enabled electricity access to more than 10,000 households and 1,800 rural schools and other public buildings. The programme aims to reach a further 18,000 homes (Best, 2011).

The engagement of the private sector, combined with public subsidies and regulated tariffs, was apparently more successful than the Peruvian approach at overcoming the lack of funds by the Argentine government to provide off-grid services to the rural poor. A key problem with such an approach, however, is attracting a sufficient number of bidders to make the process competitive. In addition, there have been sufficient institutional and capacity barriers, particularly in provincial governments, to delay progress due to resource and staff capacity restraints, regulatory weaknesses and insufficient political interest among rural populations (Best, 2011, p. 12).

Moreover, under PERMER, the cost to users of the connection and tariff has been subsidised to the tune of about 90% through subsidies paid to the concession-holding energy company by the Government of Argentina. The payable 10% represents an onerous amount and, due to the market reform nature of the PERMER, the planned reduction of subsidies over time will likely be shouldered by the group of users in Argentina, rather than energy producers, for whom the return has been enshrined in law. Checchi et al. (2009) have documented the increasing popular discontent with market reform policies in LA. Should this discontent continue and escalate, it could put in jeopardy a backbone of the current policy to promote renewable energy, i.e., the return incentive expected from investment.

The PERMER represents a rigid renewable-energy delivery model that placed excessive expectations on the private sector and induced deregulation policies in the provinces, causing barriers to PERMER's implementation in some provinces which had not privatised electricity services. In fact, the main reason for the Argentine government choosing the PERMER private concession approach 'appears to be that it was consistent with the reform process under way and with the broader ideological drive for private sector-led approaches, promoted by the Menem government and by institutions like the World Bank' (Best, 2011, p. 19).

Brazil PROINFA apparently encountered a number of problems in implementing renewable energy incentive policies. For example, it was initially difficult to comply with the requirement that 60% of total manufacturing investment be undertaken nationally: the price paid for feed-in tariff biomass was considered too low due to its opportunity cost, and state caps needed to be introduced to prevent excessive regional concentration of renewable energy contracts (Bouille 2009).

A few general lessons also emerge from the experience of introducing legal frameworks and regulatory instruments to promote renewable energy in LA in general, and in Argentina, Brazil and Peru in particular.

It is apparent that feed-in tariffs have tended to be more successful than other schemes for renewable energy markets and local industrial development. This is because feed-in tariff schemes are flexible and can be adjusted following technological changes and market trends, transaction costs are lower than for other schemes, and funding is accessible due to the 15-20 years of guaranteed prices. These factors significantly reduce green energy producers' uncertainties while allowing for competition among small and medium producers (Mendonca et al., 2010; Bouille, 2009). The flexibility of price-driven feed-in tariff schemes has increased confidence among green energy producers and enabled small and medium producers to compete on equal terms. However, the level of the premium is a key factor, as it should guarantee both the development of renewable energy in a country and avoid market distortions, as may happen if tariffs remain unmodified and the prices paid are unnecessarily high.

A key lesson of the Argentine experience, and of the LA region generally, is that it is impossible to overlook the remarkable availability of natural gas, which has a dominant place in the current energy mix and market (e.g., Peru has aimed to become a large exporter of liquid nitrogen gas; OAS, 2007). Furthermore, Argentina's reliance on large hydroelectricity plants cannot but inhibit prospects for the introduction of small-scale renewable energy technologies.

The introduction of renewable energy policies in LA has been a response to several objectives: first, to create national renewable energy markets and reduce CO_2 emissions; secondly, to enhance energy access in rural areas and in zones off the national grid; thirdly, to increase energy efficiency and security of supply through diversification of a country's energy mix; and, finally, to reduce oil bills, contribute to sustainable development and open up new markets for innovative energy technologies (OAS and ESG, 2007). While these are compelling reasons for LA governments to increase the share of renewables in their national energy mix – and there is indeed significant natural resource potential in LA – the spread of energy generation from renewable technologies remains woefully small. Whereas renewable sources supply about 30% of total electricity generated in LA, large hydroelectric power is the main renewable energy source. By contrast, only about 1.4% of total of energy in LA is generated from solar, wind, micro-hydro and biomass waste (Tradingeconomics, 2009).

Advancing renewable energy policy in LA

Since the early 1990s, the governments of Argentina, Brazil and Peru have initiated numerous policies, attracted private capital and provided public funds to drive the deployment of renewable technology. The introduction of feed-in tariff regulation in a few LA countries, including connection to the grid, electricity purchases and preferential premiums, has provided the legal requirement for independent power producers to access the renewable energy market. A few of the legislative bodies in countries such as Argentina and Peru have gone quite a long way and are as comprehensive in their approach as are European countries – at least on paper. It is likely that to consolidate existing renewable energy policies further, regulators will need to consider whether the adoption of renewable purchase obligations by the large electricity providers would make a definite impact. Deployment of renewable energy in LA countries might be boosted if some form of mandate, such as the Renewable Purchase Obligations used in Europe and the US, were enforced in more LA countries (as noted above, only Chile and Uruguay have RPOs).

Critically, as an additional tool to promote the use of renewable energy technology, Latin American governments could create (where lacking), implement and monitor supportive institutional economic and policy frameworks similar to those found in Denmark and Germany. Specifically, it is recommended that feed-in tariffs become part of larger policy frameworks to develop renewable energy technology in general to mitigate GHG emissions, as well as to ensure regional sustainable development. More comprehensive and inclusive policy objectives could pave the way to funding for national feed-in tariff schemes under national and international emission trading schemes.

From a market perspective, tariffs need to be high enough to cover costs and encourage the development of particular technologies. Not least they must be guaranteed for a long enough period to assure investors of a sufficient rate of return. The appropriateness of pricing laws is also determined by factors such as charges for access to the electric grid, limits set on qualifying capacity, and the ease of permit acquisition and siting, influenced by the existence and specific requirements of national and regional standards (UN, ECLAC and GTZ, 2004, p. 125). However, three other elements may be crucial. First, regulatory instruments must guarantee that the offer is sufficiently attractive and carries hardly any commercial risk. Secondly, policy will be more attractive to both private and international aid organisations if renewable energy schemes incorporate aspects, such as social equity components, that do not necessarily respond to liberalisation market ideology and are designed also to tackle regional energy problems, and if policy structures are relatively stable and reliable. Thirdly, it is recommended that the costs of feeding renewable energy into the grid, or of supplying energy services to unconnected areas, be passed on to consumers via a system benefit charge or paid for by a carbon tax (e.g., Girardet and Mondonca, 2009; OESD, 2007). Clarity regarding the costs to end-users is of paramount importance, particularly for rural populations.

Conclusion

This article has analysed the policy frameworks that Latin American governments have designed in order to promote renewable energy. The region has large untapped renewable energy potential, which, even if only partially developed, could have a positive impact on the continent's energy security, significantly improve universal access to electricity and definitely contribute to global GHG mitigation. This study has shown that there is relatively rich experience in designing policy frameworks for promoting renewable energy in LA, with some frameworks being highly advanced, such as the combination of competitive bidding with concessions in Argentina, feed-in tariffs, and guaranteed purchase and top premiums in Peru.

The general impact that national liberalisation policies have had on the structure of energy policy and on renewable energy in particular has been notable. The exclusion of energy service for rural areas has been a main feature of market reforms in the region. Undoubtedly international investment in renewable energy has been growing in the region (but nowhere sufficiently to increase the actual share of renewables in the energy mix), and competitive bidding instruments have incorporated rural energy through renewable sources. However, it is likely that further governmental support will be required to boost deployment among the most needy populations and to ensure that the costs that subsidies may not cover do not fall on the end consumer.

It is likely, therefore, that not only climate change mitigation, but also regional energy security, economic development and rural electrification will constitute key policy-drivers for renewable energy and energy efficiency development in the region. The low penetration of renewable generation technologies relative to the region's resource potential provides an opportunity to develop new renewable energy projects for which both price and quantitative policy initiatives could offer a low risk and attractive framework. Excluding conventional hydro, the LA region has a relatively insignificant share of alternative sources of energy generation, despite having abundant natural resources. But these natural sources (e.g., solar radiation, wind and agricultural waste) remain mostly untapped due to the costs of exploration, reliance on and availability of fossil fuels, and policy barriers. Technological improvements, combined with regulatory incentives such as adequate feed-in tariffs and incentives, could generally increase the acceptance and deployment of alternative energy technologies in Latin America.

The existence of numerous legal frameworks, comprehensive policies and some elegant instruments, some of which have been put into operation but still face numerous difficulties, points to the relatively advanced stage of renewable energy policy in many Latin American countries. Yet, the implementation of these considerable bodies of policy seems to be lagging behind when specific and relevant indicators are considered. The records for actual installations and the amount of power generated by alternative sources have been somewhat disappointing. It is likely, now that more information has been gathered and some lessons drawn from the LA experience with the promotion of renewable energy that greater attention will need to be paid to policy implementation.

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Biofuel (ethanol) production from sugarcane harvest
Photo: UNEP internal archive

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Bioenergy in India: Barriers and policy options

Abstract

India offers a conducive environment for accelerating the use and internalisation of bioenergy technologies (BETs). Nearly 25% of its primary energy comes from biomass resources, and close to 70% of rural population depend on biomass to meet their daily energy needs. India has over two decades of experience in demonstrating bioenergy packages. The Ministry of New and Renewable Energy (MNRE) recognises this potential. MNRE, state governments, and central and state regulatory commissions have developed a number of policy instruments (tariff support) and financial incentives (capital subsidy, interest subsidy etc.) to support bioenergy development. Despite this, empirical evidence shows that the rate of spread of BETs is rather low because of institutional, technical, informational, market and financial barriers.

This study analyses the barriers and proposes recommendations to overcome them. If carefully constructed, these policy instruments will not only demonstrate the effectiveness of BETs in a developing country such as India but will also help the government meet its renewable energy targets. This is particularly important bearing in mind that India is likely to be at the centre of discussions in the next round of global negotiations in South Africa (December 2011).

Introduction

Energy is the primary driver of the world's economies. Increasing populations and expectations of improved standards of living are accelerating the demand for energy. Theorists have acknowledged the positive or direct relationship between economic growth and greenhouse gas (GHG) emissions. One of the key variables affecting this positive relationship is increased energy demand as a result of economic well-being. India is one of the fastest growing countries in the world, with a GDP growth exceeding 8% consistently for the last two years, and this trend is expected to continue. India's energy demand is expected to be more than three to four times its current level in another 25 years (Planning Commission, 2005).

Present primary energy use in India is dominated by fossil fuels: 40% of primary energy supply and 59% of power generation come from coal (IEA, 2007). The rising energy demand in India is expected to lead to a further increase in the use of fossil fuels. This will not only lead to growing GHG emissions and increased environmental problems, but will also to vast social problems such as inequalities between rural and urban populations, health-related disorders, and other community-level issues.

Whilst looking to reduce fossil fuel use, India faces a tough task in meeting its energy needs, especially rural energy needs. The rural population of India, which constitutes close to 70% of the population, consumes less than 40% of the total energy supply and one-third of the total power generated. Furthermore, though 74% of Indian villages were electrified as of March 2005, only 54.9% of households had access to electricity, compared to 92% of urban households. Close to 45% of rural households still depend on kerosene for lighting and about 75% still depend on fuel wood (in traditional stoves) for cooking (Census of India 2001; NSSO, 2007).

India has large potential for the adoption of renewable energy, a potential that goes beyond addressing environmental concerns. Overall, the underlying principle is to gain from the current worldwide interest in renewable energy for three reasons:

1. To meet the growing demand for energy within the country, especially in rural areas
2. To reduce GHG emissions and help contribute to climate change mitigation
3. To capitalise on the expanding market for renewable energy and secure an early market advantage

India, together with other developing countries, has for the first time given indications that it is reducing GHG emissions, as is evident in the Cancun Climate Agreement of 2010. Although the emissions cuts are not currently legally binding, policy-makers have made it clear that reliance on traditional sources of energy will no longer suffice as a policy option.

The market for renewable energy systems in rural and urban markets in India is set to grow exponentially. Of these, bioenergy is especially prominent. 90% of rural energy needs and 40% of urban energy needs are met by biomass (TERI, 2010). Despite this, bioenergy does not figure in most energy studies and is classified as 'non-commercial' energy. Bioenergy data are considered as 'inadequate and not up-to-date', since it is not transacted on the market (FAO, 2010). While India has progressed well in initiating renewable energy programmes in general, increasing renewable energy (electricity) share from 2% (1628 MW) in 2002 to 11% (18,155 MW) in 2010, bioenergy programmes have not been on par with traditional sources of energy and at their full potential (MNRE, 2010).

The article highlights the evolution of bioenergy from an institutional and policy standpoint, underlines progress and achievements, identifies barriers and proposes recommendations for their removal. Although the article focuses on India, it is hoped that its recommendations are relevant to other developing countries looking to further their bioenergy technology (BET) agendas.

Bioenergy technologies

Bioenergy consists of organic matter derived from trees, plants, crops or from human, animal, municipal and industrial wastes (Meshram and Mohan, 2007).

Table 1. Key Bioenergy Technologies

	Bioenergy Technologies	Features	Benefits
For Power	**Biomass Gasification**	• Biomass converted to combustible gas for use in internal combustion engines for mechanical or electrical applications • Capacities in the range of 10 kg/h to about 500 kg/h • Possible to meet rural electricity needs and feed into grid • Requires sustainable supply of biomass	• Small-scale gasifiers (of 20–500 kW) have the potential to meet all the rural electricity needs and leave a surplus to feed into the national grid. • Diesel savings of up to 80% possible in dual fuel systems and 100% diesel savings possible in 100% producer gas • Rural employment generation • Degraded land reclamation • Fossil-fuel substitution • Carbon sequestration due to forestry in degraded lands
For Power	**Biomass Combustion**	• Biomass is burnt in a boiler to generate steam which is used to generate power • Possible to meet rural electricity needs and feed into grid • Requires sustainable supply of biomass	• Degraded land reclamation • Fossil-fuel substitution • Carbon sequestration due to forestry in degraded lands • Relatively more economical • Employment generation
For cooking	**Biogas**	• Ideal fuel for cooking • Simple and indigenous technology • High first cost but economical • Large experience of dissemination	• Forest plantation and tree conservation • Reduced indoor air pollution • Large improvements in quality of life • High forest carbon sink conservation potential due to fuel wood savings
For cooking	**Efficient cook stoves**	• Fuelled by small pieces of wood or special pellets made from dried and compressed agricultural waste • Emit less smoke and give more energy than dried wood or cow-dung cakes • Can reduce wood consumption by 50% or more	• Low cost of device Forest plantation and village tree conservation • Large improvements in quality of life, especially women • Moderate forest carbon sink conservation potential
For transport	**Bio-fuels**	• Extracting oil from non-edible seeds in plants like Jatropha curcas, Neem, Mahua and other wild plants; to be mixed with diesel/petrol • Technology not fully evolved in India • Land and water constraint	• Self-reliance • Transport fuel demands can be met • Fossil fuel substitution and therefore GHG mitigation

Source: CGPL, 2010; Pathak, et al., 2009; Ravindranath et al., 2000; Ravindranath et al., 2010

Table 1 presents the features and benefits of key BETs in meeting power, cooking and transport energy requirements.

Biofuels are fairly new to the market, and there are no available examples of projects implemented or lessons learnt. Improved cooking stoves have been in use since the late 1980s and deserve a separate discussion.

Bioenergy in India

Policy and institutional evolution of BETs

Renewable energy promotion in India, including bioenergy, was stepped up in response to the oil crisis of the 1970s. The Fuel Policy Committee (FPC) (1974) and the Working Group on Energy Policy (1979) (WGEP) were set up in response to this focus to understand the energy situation in light of developments both nationally and internationally. The two committees were tasked with developing a solid plan and recommendations for appropriate policy measures for available energy resources and non-conventional energy resources for the ensuing five to fifteen years. Despite the emphasis the two committees placed on the need for a new energy plan, no formal institutional mechanism was established immediately.

Institutional mechanisms were first set up in the early 1980s. A Commission for Additional Sources of Energy (CASE) was created in 1981 in the Department of Science and Technology. This was converted into a separate department, the Department of Non-Conventional Energy Sources (DNES), in 1982. In 1983, the Advisory Board on Energy (ABE) was instituted. ABE proposed and provided for the Nodal Energy Conservation Organization (NECO), whose observations and recommendations were binding on all central and state government agencies, as well as on the prescribed authorities (Dey, 2007). NECO was soon replaced by the Energy Management Centre (EMC) in 1989.

Bioenergy policies during this period (1980s) focused on technologies (Shukla, 1997):

- Improving efficiency of traditional biomass use (e.g., improved cooking stove programme)
- Improving the supply of biomass (e.g., social forestry, wasteland development)
- Improving the quality of biomass use through technologies (e.g., biogas, improved cooking stoves)
- Introducing biomass-based technologies (wood gasifiers for irrigation, biomass electricity generation) to deliver services provided by conventional energy sources
- Establishing institutional support for programme formulation and implementation.

Shukla (2000) further indicated that the BETs that had been implemented lacked institutional mechanisms to support their continued operation and maintenance, and accelerate replications. Economic and financial support was mainly a matter of capital subsidies. Various evaluations showed a large number of installed devices did not function for a variety of reasons. Strategies to promote devices were oriented by assigning targets to state government agencies for the implementation of programmes and lacked a market-oriented approach.

Following liberalisation in 1992, some changes were made to strategies to accelerate bioenergy to address some of the gaps identified above. To expand further the scope of the activities to promote RE in India, government upgraded DNES to a fully fledged ministry, the Ministry of Non-Conventional Energy Sources (MNES), in 1992. MNES thus came into existence with the responsibility for supporting research and development, and the promotion and coordination of renewable energy sources, including bioenergy (MNRE, 2010). MNES was later renamed the Ministry of New and Renewable Energy (MNRE) in 2006. The Ministry has regional offices, three specialised research institutions and a non-banking financial company, the Indian Renewable Energy Development Agency (IREDA), under its administrative control to promote its policy and programme initiatives.

The Energy Conservation Bill was passed by the Indian Parliament in September 2001. The Act provides for a legal framework, institutional arrangements and a regulatory mechanism at the central and state levels to promote an energy efficiency drive in the country. The Bureau of Energy Efficiency (BEE) was created to implement the provisions of the Act, which was critical in laying the foundations for future energy policy formulation.

The eleventh five-year plan (2007-2012) highlighted the severe shortages of energy, the dominance of coal and the need to expand resources through exploration, energy efficiency, renewables, and research and development (Planning Commission, 2007).

Further to this, the most recent policy initiative to be developed is the National Action Plan on Climate Change, launched in June 2008. This is partially in response to global concerns to address climate change. Though India does not have any binding emissions targets, the initiative is aimed at showcasing national responsibility. Eight national missions comprise the main response to addressing climate change, covering Solar Energy, Enhanced Energy Efficiency, Sustainable Habitat, Water, Sustaining the Himalayan Eco-system, Green India, Sustainable Agriculture and Strategic Knowledge for Climate Change. The National Mission on Enhanced Energy Efficiency estimates that these initiatives will yield 10,000 MW of savings by 2012 and result in business of approximately USD 16 billion. The National Mission for a 'Green India' aims to achieve afforestation of 6 million hectares of degraded forest lands and to expand forest cover from 23% to 33% of India's territory by 2022. (MNREa, 2010). However, there is no emphasis on harnessing and nurturing biomass resources and biomass technologies.

BET programmes and implementation strategies

Biomass power

MNRE and several other agencies have therefore realised the potential and role of bioenergy in the Indian context. Over the last decade, biomass power has become an industry attracting an annual investment of over USD 130 million (INR 600 crore), generating about 5000 million units of electricity and yearly employment of more than 10 million man-days in rural areas (MNREb 2010).

A key programme of the MNRE is the Biomass Power/ Cogeneration Programme under which a number of financial and fiscal incentives for the manufacture and installation of gasifier systems have been provided. Another important programme is the biomass gasifier programme, which promotes demonstrations that can be taken up by village-level organisations such as village panchayats (the Indian government has decentralised several functions to the panchayats, which consist of respected village locals forming a committee to address local problems). The gasifier programme is being implemented through state nodal agencies with the involvement of energy service companies (ESCOs), co-operatives, panchayats, NGOs, and manufacturers or entrepreneurs (TERI, 2010).

The central government has also introduced support schemes such as the National Biomass Resource Assessment Programme (NBRAP), aimed at developing biomass assessments. The Indian Renewable Energy Development Agency (IREDA) provides loans for setting up biomass power and bagasse cogeneration projects. State-level actions also support the central initiatives. These include:

- Buyback/Wheeling/Banking of generated electricity by the State Electricity Boards. State-specific incentives in the form of preferential tariffs have been introduced for the purchase of biomass power. For example, in Andhra Pradesh, an incentive has been introduced equivalent to Rs 2.63 per unit at 1% escalation for five years. In Haryana, a much higher incentive of Rs 4.00 per unit at 2% escalation every year is provided.
- State Electricity Regulatory Commissions have been guided to provide Renewable Portfolio Standards (RPS). RPS places an obligation on energy supply companies to produce a specified fraction of their electricity from renewable energy sources. Specified RPSs include 10%

in Tamil Nadu, 7-10% in Karnataka, 3-6% in Maharashtra and 5% in Andhra Pradesh, among others.

- Funding opportunities including grants and contracts, loans, equity investments, and direct incentive payments for bioenergy projects for pre-development activities, the installation of small and large systems, and business development and equity.
- Sales tax exemptions, in certain states from a purchase of biomass gasifiers.
- Accelerated depreciation, i.e., 80% depreciation in the first year, can be claimed for gasifier equipment such as pressure boilers and vapour absorption refrigeration systems.
- Concessional import duty, excise duty, tax holiday for ten years. The benefits of concessional custom duty and excise duty exemption are available on equipment required for the initial setting up of biomass projects based on certification by MNRE.

The key achievements of the programmes and incentives provided thus far have been (MNRE, 2010):

- Deployment: a total of 259 biomass power and cogeneration projects aggregating to 2312MW capacity have been installed for feeding power to the grid. In addition, 135 biomass power and cogeneration projects aggregating to 1700 MW of electricity are under implementation.
- Manufacturing capability: a majority of the infrastructure and equipment required for setting up biomass projects can be procured from indigenous sources. For instance, biomass gasifiers in the capacity range of 5 kW to 1 MW equivalent electric capacity have been developed indigenously and are being manufactured by around 15 MNRE-approved manufacturers in the country.
- Supply chain development: a number of multinational companies are currently involved in the supply chain of biomass power plants in India.

Biogas

The Central Sector Scheme on National Biogas Programme, which mainly caters to setting up family-type biogas plants, has been under implementation since 1981-82. The scheme, which is still functional today and is managed by MNRE, is called the National Biogas and Manure Management Programme (NBMMP). Its objectives are as follows (MNREc, 2010):

- To provide fuel for cooking purposes and organic manure to rural households through family-type biogas plants;
- To reduce the drudgery of rural women, reduce pressure on forests and increase the social benefits;
- To improve sanitation in villages by linking sanitary toilets with biogas plants.

The programme is being implemented by State Nodal Departments and Agencies and the Khadi and Village Industries Commission (KVIC), Mumbai. The NBMMP provides for:

- Central subsidy in fixed amounts
- Turn-key job fee linked with three years' free maintenance warranty
- Financial support for repair of old-non functional plants
- Training of users, masons, entrepreneurs etc.
- Publicity and extension
- Service charges or staff support
- State-level Biogas Development and Training Centres (BDTC)
- Financial support for institutions for cattle dung-based power generation plants etc.

The key achievements of the programme have been highlighted by MNRE. The estimated potential of biogas plants in India is 12,339,300 units. As of December 2009, the cumulative achievement has been 4,185,442 units. Thus, the programme has been a moderate success only, implementing approximately 34% of the estimated potential as indicated by MNRE (2010). The latest figures for 2009-2010 suggest a similar success rate, with 34% of family-type biogas plants being implemented.

Summary of success of programmes

Table 2 indicates that, despite the enormous potential for BETs to tap into in a country such as India, and taking into consideration the renewable energy policies and programmes set out by the government, actual on-field implementation of BET's is falling short. Overall, the policies and programmes instituted have led to only sporadic success. Looking at the overall picture is disappointing since the policies and programmes put forward by the Government have not succeeded in achieving their optimum technical potential. This has been highlighted on many occasions in the literature (Ghosh S., et al., 2004; Pathak et al., 2009; Ravindranath et al., 2004; Ravindranath et al., 2010; Ravindranath and Balachandra, 2009; Singh and Gu, 2010).

Barriers and lessons learnt

The slow rate of spread of BETs such as biomass power and biogas, despite a seemingly strong policy framework, leads to questions concerning the potential barriers to BET dissemination in India. Several studies have identified the existence of a number of barriers, as well as the inadequacy of policies and measures to address them (TERI, 2010; Ghosh, D et al, 2005; Ravindranath and Hall. 1995). These barriers need to be explored in more detail, so that policies and programmes targeting BETs in the future will have a more bespoke role to play in closing the gap between existing and potential capacity.

The existing barriers are divided into technology-specific barriers and generic barriers.

Technology-specific barriers

BETs are multi-faceted and differ in many ways, for instance, input resources needed (i.e., woody biomass, rice husk, cow dung etc.), length of life cycle (short, medium, long-term), types of usage (cooking, thermal etc), and maintenance required (daily, weekly, monthly). Inconsistencies in the nature of bioenergy technologies and uncertainties in technological performance are a key concern for policy-makers (Ghosh, D. et al., 2002). Policies and programmes initiated by the MNRE have made an attempt to address the distinct features of these BETs (Rao and Ravindranath, 2002). The technology-specific barriers are highlighted in Table 2.

Generic barriers

Generic barriers are barriers that affect all BETs. They include institutional, informational, financial, policy-related, and overall market barriers.

Institutional barriers

Initially, in promoting BETs the government followed a technology-push approach. This approach focuses on introducing new innovative technologies through research and development, regardless of demand. BETs in their nascent stages were offered as possible improvements on existing rural energy sources. The abundance of biomass was initially the push needed to promote BETs. There was therefore little or no interaction with rural communities in formulating the technologies. This approach almost entirely led to the isolation of a multitude of actors, who potentially could become crucial players in the adoption and use of BETs (Shukla, 2000). In traditional innovation theory, the technology-push approach can be differentiated from the demand-pull approach. A demand-pull approach refers to innovation driven by changes in demand through competitive market structures (Scherer, 1982). Stakeholders' demand for and understanding of the economic benefits of the technology are critical to this approach.

The shift in the government's focus to a demand-pull, essentially market-centric approach promised greater inclusion through a more consolidated institutional framework incorporating the whole gamut of potential stakeholders. Participation by the local community,

Table 2. Technology-specific barriers

Bioenergy Technologies	Technology-specific Barriers
Biomass Gasification	**Gasifier-engine and distribution related** • Dual fuel systems do not seem economically feasible, and hence the focus is on producer gas. But 100% producer gas engines still are not very common, not readily available at all capacities • Gas cleaning systems are still not robust and hence high in terms of maintenance • Variations in power delivered depend on quality of biomass – ensuring either quality of biomass or governing the power delivered is still not robust • Tar generated during gasification is still not under control – they vary/increase with time elapsed • Very few systems have gone through life-cycle operations, so there are significant deficiencies in terms of designing operation and maintenance protocols • The complications are much higher with lower kilowatt scale capacities • To evacuate power, an active grid is a necessity. But in rural set-up this is not well established, and dedicated 11 kV lines are essential. • Evacuating small power in the existing grid is still not favoured by utilities (who consider up to 500 kW small). Synchronising quality of power produced by the gasifier power plant and the grid is still not well established. **Biomass-related** • Absence of package of practices and quality seed material or clones for high yields for energy plantations • Sizing techniques (choppers, cutters) used have low processing capacity and are not very safe • Poor understanding of managing moisture content • Biomass drying techniques are not well established
Biomass combustion	• Do not have supply of systems in capacities less than 2 MW • The present biomass combustion system is not very flexible, with varying fuel quality and quantity • Negative impact on flue gas cleaning • Operational risks of boilers **Energy plantations:** • Absence of package of practices and quality seed material or clones for high yields for energy plantations • Techniques for bailing and sizing of biomass are yet to established (choppers, cutters) • Poor understanding of drying and managing moisture content
Biogas units	• Biogas units are less successful in the interiors of villages, due to difficulties in arranging for land and water required for the plant • Biogas plants are successful in homes situated on village outskirts or in fields.

Source: Akshay Urjha, 2010; Ravindranath et al., 2000 grassroots organisations, including NGOs, and local government agencies, among others, was a cornerstone of the new shift in policy (Sudha, et al., 2003). While a more inclusive institutional structure is good strategically, in practice in a country as vast and esoteric as India, it leads to problems in implementation if it is not managed and monitored effectively.

As indicated above, all BET programmes, the Biomass Power/Cogeneration programme, National Biogas and Manure Management Programme (NBMMP) are all budgeted and planned at the national level. A critical problem has been overcoming issues arising out of bureaucracy. In the case of BETs, this includes dealing with cumbersome paperwork, delays in issuing planning permission and other contractual details. Many developers have mentioned the significant periods of delay in obtaining technical approvals.

Additionally the programmes are driven largely by targets. For instance, the NBMMP sets annual targets for the number of biogas units to be installed (Kumar and Mohan, 2005). While a target-driven approach is important to ensure institutions function in an accountable fashion, the targets are not regularly monitored and are mostly based on antecedents. Thus institutions often end up chasing targets that are extraneous and unachievable, instead of developing innovative approaches to sustainable dissemination at the local level.

Further, the institutional framework in India currently lacks a viable strategy to empower local communities. Community organisations and institutions are rarely involved in the planning, implementation and management of, say, the rural electrification programme through biomass gasifiers. The failure of a large number of small village systems, such as biogas plants, and stand-alone gasifiers is to a large extent related to the fact that there is no coordinated local, institutional and government support (Kaundinya et al., 2009).

Informational barriers

Information asymmetries are present on various levels and between various players, institutions, rural communities, consumers, financing institutions, entrepreneurs, and all other stakeholders in the supply chain. The information barrier is central to any debate on climate change. The Stern Review identifies raising awareness as one of the three elements of the coordinated policy package that is needed to tackle climate change, alongside carbon pricing and innovation support (Stern, 2007). Traditionally, the rural community responds to more conventional fossil fuel-based energy as a 'rich man's fuel' and therefore expectedly believes this to be the most reliable and efficient. Intermediate stakeholders such as NGOs, industry groups and micro-finance institutions that often play a key role in delivering products and services, as well as policy-makers, are also unaware of the benefits of bioenergy, which often results in a greater push for other renewable energy technologies, such as wind and solar (Ghosh, D. et al., 2006).

This represents a critical barrier for the development of BET in India. Such uncertainties for BETs in rural areas could be a result of:

- Lack of knowledge
- Uncertainty and distrust in the source of information
- Climate change is not being seen an immediate threat or priority for rural communities
- Social behaviour and expectations
- Absence of an enabling environment, i.e., government, local organisations, village panchayat
- Inadequate training, capacity-building and user-education programmes.

Information and knowledge dissemination, in the right form and using appropriate tools, is not currently available to the larger public using BETs. There is also no monitoring of the translation of theory into practice. Pathak et al. (2009) observed a number of installed biogas units become immediately inoperative under the NBMMP. Agencies are not technically upgraded for periodic collection monitoring on the usage and mitigation potential of biogas plants. A sampling plan can be developed for some representative biogas plants in different districts for regular monitoring of biogas use.

The information dissemination policies of the MNRE are very generic in nature. They seldom provide information on the failure or poor performance of bioenergy systems and the reasons for them. This lack of information and awareness regarding the correct methods of operation and maintenance, as in the case of both biomass gasifiers and biogas plants, acts as a barrier to the long-term acceptance of such systems.

Financial barriers

The high initial costs of BETs are perceived by many as a key barrier to the penetration of BETs vis-à-vis conventional technologies (Bhattachrya and Cropper, 2010; Nouni et al., 2007) The principal capital cost of biomass power projects includes the costs of the gasifier, the engine generator, civil construction, biomass preparation unit, electricity distribution network and electrical and piping connections to the site of gasifier installation and need subsidisation (Buragohain et al., 2010).

While subsidies have been introduced as an incentive to induce early adoption, implementation has not been well thought out. In some cases, subsidies are set too low to overcome the burgeoning gap between the cost of generation and the level of financial assistance provided by the government. In other cases, subsidies which should ideally be phased out in line with cost reductions have continued for more than two decades, thus becoming defunct as an incentive to improve performance. Additional fiscal policies such as depreciation benefits given to biomass power projects by MNRE have had a very marginal impact on BETs.

Mainstream financial institutions have been reluctant to take risks in lending due to a long history of poor recovery of loans in rural areas (Rao and Ravindranath, 2002). Even though IREDA's financial intermediary scheme provides incentives such as interest subsidy and covers the transaction costs, existing financial institutions participating in these schemes have not shown a sustained interest due to falling returns, high technological risks, and the high costs of servicing these dispersed and low-volume markets (Planning Commission, 2006).

Policy barriers

A fundamental barrier to the diffusion of BETs is government policies. A key government policy that fails the renewable energy sector in general is the distortion of energy prices. Energy pricing policies in India tend to favour fossil fuel-based energy sources (electricity, kerosene, LPG, petrol, diesel). Since the conventional technologies are also supported by subsidies, there is no level playing field for the new technologies that compete with them (UN, 2004).

One example of policy-induced energy inefficiency relates to the low agricultural tariffs (subsidies are as high as 80%– 90% in most states) that have resulted in gross overuse of both electricity and groundwater. For domestic and agricultural suppliers, electricity pricing is kept below the cost of supply with additional subsidies. The energy efficiency of agricultural pump sets in India is extremely low, which coincides with policies that heavily subsidise electricity use for farmers. Replacing most pump sets would be fully cost-effective if electricity were priced at marginal cost; however, the subsidies to electricity have prevented their replacement (Phadke, 2006).

A National Electricity Plan and National Tariff Policy were drafted as part of the Electricity Act in 2003. The National Tariff policy states that the tariffs for all new generation and transmission projects are to be decided on the basis of competitive bidding after a period of five years or when the regulatory commission feels the market is suitable for bidding. Since then, the Central Electricity Regulatory Commission (CERC) has designed a cost-plus approach to determining the tariff levels for renewable energy technologies. In estimating, it sets varying parameters for the individual technologies. For instance, biomass projects based on Rankine Cycle technology (i.e., biomass power plants relying on combustion to generate power) are given their own set of assessment parameters. Individual states can use CERC guidelines and determine variable tariff levels. This system, while an improvement from the previous system, is still riddled with loopholes. Developers complain that tariffs in certain states such as Karnataka (Rs. 2.85/kWh) are significantly lower than the tariffs in Haryana (Rs 5.52/kWh) and Punjab (Rs. 5.49/kWh) (KERC, 2005; CERC, 2010). A key concern is that that there are no agreed centralised or state-level parameters to fix tariffs for biomass gasification projects. CERC indicates that the tariff designed for combustion will also hold true for gasification. However, these are not adaptable in their entirety to biomass gasification projects, and duplicating the assumptions is fallacious.

Ravindranath and Rao (2002) stated that the land-tenure policy acts as a barrier for farmers and communities entering into any long-term contract to supply wood-fuel to the bioenergy utility.

Overall market barriers

The BET market is not an easy market for new entrants. For instance, there are only approximately twelve MNRE-approved manufacturers and suppliers of biomass gasifiers in the country. The initial investment required for such technology is huge. Government policies on licensing requirements, limits on access to raw materials, pollution standards and product testing regulations further make it difficult for new competitors to enter the market.

Recommendations

India has one of the most progressive set of renewable energy policies in the world. BETs consist of a number of technologies with diverse applications from cooking to power generation and assisting the poor. Thus the transfer or diffusion of some BETs pose many challenges. First, BETs are still in an evolving phase, which makes it difficult to decide what exactly should be diffused in terms of knowledge, techniques and hardware. Secondly, it requires a series of difficult technological choices concerning biomass sources, production, transportation, conversion and end-use. Finally, a multitude of actors are involved at the various stages, including the poorest. In the above context, appropriate policies, institutions and financing play a catalytic role in technology transfer and the diffusion of BETs (Ravindranath and Balachandra, 2009). The existence of barriers prevents the large-scale dissemination and deployment of BETs. Recommendations and policy options to overcome the barriers need to be assessed. The categories of interventions required include technical, institutional, educational, awareness and regulatory interventions.

Increased assistance to R&D

Rigorous R&D aimed at promoting innovation in BETs, for cost reduction, improved reliability and efficiency is important for the large-scale spread of BETs in India. Investments in R&D on renewables, particularly BETs, has declined (Balachandra et al., 2010). MNRE needs to foster a conducive environment for R&D in India through:

- Increased budget allocation for all R&D activities spawning BETs, including biogas, ICs, biomass power and biofuels. The 11th five-year plan mentions increased R&D to ensure an improvement in the yield of jatropha and other oilseeds for biodiesel. This needs to be further expanded to include other BETs in the new plan.
- Provision of grants and funds for R&D, which would lead to greater interest among the premier research institutions to explore BET and translate R&D leads into scalable technologies.
- Promoting collaboration between industry and academia, for field demonstrations, and promoting feedback and communication between developers and implementers.

Training and skills development

There is need for a large number of entrepreneurs and skilled personnel for building biogas plants and maintaining small-scale biomass power systems. Both current and future suppliers of BETs need to be equipped with the necessary skills to integrate the novel technologies into their functioning. With BETs, it has been observed that, even when the technology is ready and has been demonstrated, a skills shortage has been a hindrance to successful implementation. The development of training schemes could provide a route to alleviating this skill shortage. It is important to ensure that all staff involved in training and development have been adequately trained themselves. Use of R&D institutions in training could be beneficial (see BERI case study, Section 6).

Large-scale demonstrations

Demonstration projects are critical to overcoming technical barriers and creating confidence in the users. They showcase the technologies to prospective developers and investors. Demonstrations are likely to be more successful when they are conducted on a larger scale. The lessons leant must be transferred and publicised by MNRE. Successful pilot schemes must be followed up to ensure implementation. Demonstrations must also incorporate aspects that allow for community participation.

Need for quality control

BETs, especially small-scale systems, are often manufactured by the unorganised sector. Unlike solar photovoltaic or wind turbines, biogas, and even biomass gasifiers, are manufactured in small-scale industries and even in rural areas. Biogas plants are built in situ by local skilled persons so quality control is very necessary for high performance. The issuing of performance and product guarantees needs to be addressed (see BERI case study).

Technology transfer

Technology transfer for BETs poses a challenge due to the small and decentralised scale of operations and the presence of a large number of entrepreneurs. Transferring any new biogas design to thousands of entrepreneurs is a challenge. India may not require import of BETs since most of BETs are designed by Indian institutions.

Revise tariff structures

Feed-in-tariffs (FITs) have been a successful tool in the promotion of renewable energy-based power systems. There is an abundance of literature highlighting the positive relationship between tariffs and accelerating investment in renewable energy (Bilharz 2006), which can provide long-term financial stability for the renewable energy markets. However, if they are not properly designed, FITs can be economically inefficient. Thus tariffs must be designed with care, keeping in mind the individual characteristics of different BETs. Bespoke tariff models must be developed through interactions with the local, rural population, as was the case in Hosahalli in Karnataka (Ravindranath, et al. 2004) and the Sundarbans in West Bengal (Mukhopadhyay 2004).

Performance based subsidies

Since subsidies do not guarantee improved performance or cost reductions, subsidies as a policy instrument must be time-bound with a sunset clause and must be justified on the basis that they are definitely promoting technological advances and organisational learning. Importantly, subsidies should not be based on capital costs but should be linked to performance or output. The costs of the commercial scaling-up of biomass production, processing, transportation, market development etc., are yet to be established (see Bahalupani case study, section 6).

Awareness and training programmes

Awareness needs to be created in rural areas of the requirement to shift to efficient energy systems. Women will have to be trained in using the new cooking designs. Biogas plant and biomass gasifier operators need to be trained (see Alwar case study, section 6).

Technology-specific programmes

In addition to all-encompassing recommendations and options, each technology is unique and requires prescriptions in line with its idiosyncrasies. Key recommendations are highlighted in Table 3.

Case studies

Case studies are critical in highlighting the barriers and providing recommendations. They show that converging with the application of new technologies

Table 3. Recommendations for BETs

	Technology options	Financial options	Policy and institutional options
Biomass gasification	• Facilitating design change with greater operational effectiveness • Supporting pilot/demonstration projects • Developing information packages on technology to be distributed to all stakeholders	• Innovative loan schemes to reduce costs • Well-designed tariff plans that take into consideration high initial costs of setting up power generation systems • Incentives for enhanced private-sector participation	• Encouraging skilled personnel and entrepreneurship development programs • Effective monitoring and evaluation systems • Increased support for R&D in projects highlighting performance enhancement under practical/field conditions
Biogas units	• Exploring new designs for using organic household wastes and leaf biomass in biogas plants • Supporting pilot/demonstration projects for new designs	• Placing fees on manure treatment in biogas plants. Fees should be paid by farmers in case no organic waste is available. • Facilitating design change and innovative loan schemes to reduce costs	• Increasing public awareness • Increasing funding for R&D • Monitoring use of biogas plants

were activities focused on the provision of operational experience, mobilising local community, extensive R&D and firming up institutional arrangements, through the intervention of implementing partners. It should be reiterated that the following examples are studies of projects involving extensive personal field-level expertise of the authors.

Biomass Energy for Rural India (BERI), Tumkur, Karnataka (UNDP, 2010)

Initiated in 2001 by UNDP and the Government of Karnataka, the project aimed at biomass gasifiers to provide electricity to the 24 project villages and community biogas systems for the provision of clean energy.

The project's progress on the overall objectives has been tardy. A host of barriers had to be overcome to get the project to its current stage, including a shortage of biomass feedstock, the availability of land for biomass production, the non-availability of readily available, off-the-shelf gasifier systems, community-level problems in uptake, and the higher cost of biomass power compared to the tariff and subsidised centralised power.

The Indian Institute of Science (IISc), a premier R&D institution, was engaged to supervise, advise and train locals on the gasifier plant operation. Extensive community mobilisation was actuated through the creation of no less than 26 Village Bio-energy Management Committees (VBEMC), 26 Village Forest Committees (VFC) and 72 Self Help Groups (SHGs) led by women, and the strengthening of 68 old SHGs, 31 Water User Associations and 33 Biogas User Groups. The development of biomass was activated through 'energy' plantations. About 2015 ha of common land was taken under forestation. A nursery with nearly two million seedlings was set up, alongside tree-based farming over 900 hectares of land. To address the immediate need for a cleaner cooking fuel, community biogas plants were built. Irrigation problems were reduced through drip irrigation.

On the technical front, the poor performance of the turnkey contractors led to alternative steps being taken to complete performance guarantee tests and warranty runs. Furthermore, the evacuation of electricity produced from gasifiers required the grid to be active. This required dedicated 11 kV lines, which were not present at the gasifier sites and therefore had to be constructed as a priority. All the gasifiers are now connected to evacuate electricity to the grid. A total of 1,050 kW is the cumulative installed capacity through the 11 gasifiers, of which 900 kW is from 100 per cent producer gas.

Operation and maintenance charges are not recovered from users since power is sold to the grid, against which electricity is supplied to the users at subsidised tariffs. The present tariff ranges between Rs.2.85 per kW to Rs.4 per kW. The actual cost of generation ranges from Rs. 7 to Rs. 15 per kW, depending on the plant load factor.

As of July 2010, a total 383 MWh of green energy had been generated, leading to reductions of 11,880 tonnes of CO_2 after taking into account carbon sequestration.

Alwar, Rajasthan

The key to the success of this project was the multi-layered strategy to strengthen the institution of rural women and improve their sources of livelihood, conserve bio-diversity and promote biogas as means of energy, establish mechanisms for better cattle health care and productivity, and enhance incomes from animal and land resources.

To ensure effective implementation and monitoring of the above objectives, institutional links with the government were a pre-requisite. Two federations of self-help groups (SHGs) were set up, all activities being implemented through them subsequently. Women were trained as community leaders, being educated and trained on the biogas project, its objectives, activity implementation and outcomes in relation to livelihoods and bio-diversity conservation. A total of 2500 women emerged as trainees, of whom 45 became the leaders of institutions. Three local masons were also trained and employed to construct and repair the plants.

The successful installation of biogas plants depended on an efficient supply of animal waste. For this, the health of the existing livestock became quintessential to the running of the project, as was the need to purchase more cattle. Women were to be trained as animal health workers or Pashu Sakhis (para-vets), and government resources were mobilised to provide better credit facilities to promote purchases of cattle. To augment the income from land resources, a subsidiary initiative promoting horticulture and organic farming was introduced alongside; however, it did not have much success owing to land constraints.

Today, forty biogas plants are up and running in as many households spread across fifteen villages. Clear evidence of the success of the project lies in the ever-increasing demand for more plants from the villages falling within the project region.

Bahalupani, Orissa

The project's vision was to build a self-reliant, energy-efficient community in a remote biosphere reserve consisting of tribal villages not connected to the grid. A Village Energy Committee (VEC), comprising the villagers themselves, was constituted to spearhead the initiative. To obtain technical expertise and mobilise local resources, links were established with the Light a Billion Lives (LaBL) Campaign supported by TERI (Solar light campaign), the Forest Department and the District Rural Development Authority (DRDA). The project received funding from the Orissa Renewable Energy Development Agency (OREDA). The implementing agencies were quick to identify the pressing need in the village, which was to serve as the first entry point for renewable energy in the tribal realm, thus easing the strain in cooking. Energy-efficient stoves were introduced to gain the confidence of the villagers. Henceforth, it was easier to integrate biomass gasification into the energy mandate.

To feed the Biomass gasification unit, the VEC ensured that fuel wood was planted. The VEC now collects 1.5 kg of biomass daily from each family and Rs. 1.50 as consumer fees. The energy production is 10 kW per day, of which 6 kW is directed towards household consumption and remainder used for commercial purposes as and when required. A block level federation pays Rs. 5 per hour for a commercial honey-processing unit. The biomass power unit is now the mainstay of the energy sphere of the village.

Conclusions

India has an aggressive renewable energy programme. It has increased its share of renewable energy (electricity) from 2% (1628 MW) in 2002 to 11% (18,155 MW) in 2010. Though the government has put forward policy instruments to encourage BETs, the strengthening of policy instruments is critical if the full estimated potential is to be realised, especially for the BETs, as they have the potential to energise rural areas, plough back money into rural markets and the rural economy and create employment. Tariff structures for biomass power have been developed; subsidies for improved cooking stoves and biogas units have been introduced, and are continually being fine-tuned.

BETs consist of a complex mix of technologies that face different types of barriers, requiring different policies for large-scale dissemination. This study has provided a high-level analysis of the opportunities and challenges presented by BETs in India. The barriers identified in the report need to be discussed further with various stakeholders to rank and prioritise the barriers so that targeted policies can be developed. The case studies further highlight the fact that targeted policies can be successful if designed with care. If targeted policies are evolved, these will not only demonstrate the effectiveness of BETs in a large developing country such as India, but will also help the government meet its renewable energy targets.

The key policy options to overcoming barriers and for the promotion of BETs include R&D for cost reduction and reliable performance, large-scale demonstrations, capital cost subsidies and other performance-based financial incentives, competitive tariffs for biomass power, performance guarantees, the creation of a large network of entrepreneurs and skilled persons for the construction, operation and maintenance of bioenergy systems, and education and awareness regarding BETs.

About the authors

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Family with solar cooker Ningxia, China
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Role of open innovation models and IPR in technology transfer in the context of climate change mitigation

Abstract

Although the importance of Technology Transfer (TT) in Climate Change Mitigation is well accepted, the role of IPR (Intellectual Property Rights) in facilitating TT is a controversial issue. While there are extreme views on whether or not IPR presents a major barrier to technology transfer, the mainstream debate has moved beyond such polarised positions. Scholars have advanced nuanced positions, supported by empirical research. These include the use of alternative models like Open Innovation that go beyond traditional approaches on innovation and IPR, in order to facilitate TT, which is the focus of this article. The article discusses Open Innovation and Open Source Models, and various options like patent pools, and clearinghouses. The scope and limitations of these models, and the options in facilitating TT are discussed. The topic is assessed by way of a hypothetical example regarding the application of an Open Innovation Model to develop and transfer a technology relevant to climate change mitigation, i.e., development of rice varieties with enhanced nitrogen use efficiency. The article concludes that Open Innovation Models can play an important role in facilitating TT in the context of climate change mitigation.

Introduction

The need for Technology Transfer (TT) in climate change mitigation is well recognised. The IPCC (Intergovernmental Panel on Climate Change) defines technology transfer (TT) as 'a broad set of processes covering the flows of know-how, experience, and equipment for mitigating and adapting to climate change.' (IPCC, 2000; 3). Thus TT is much more than the transfer and installation of equipment, involving transfers of know-how and experience, including information about processes. TT enables the recipient to use the technology transferred, understand it and absorb it.

Innovators invest money and other resources in inventions of new products and processes, which results in innovation. Innovators need protection from others free-riding on their innovation. Intellectual Property Rights (IPR) constitutes a legally sanctioned mechanism to challenge such free-riding and to ensure that innovators' interests are protected. IPR is an incentive for innovation as the innovator receives specific rights in exchange for the disclosure of knowledge through patents etc. The rights available under IPR are subject to limitations as specified in the laws.

The role of IPR in TT, particularly in climate change, is contested. It has proved controversial in the UNFCCC (United Nations Framework Convention on Climate Change) negotiations, and developing nations and developed nations had disagreed about it (Gerstetter et al., 2010). In the final text of the Cancun Agreements there was no reference to IPR. Whether the proposed Technology Mechanism will handle IPR issues is not currently certain. In the debate over the role of IPR, many alternative models, which go beyond the traditional approaches to invention and transfers of technology, have been suggested (Reichman et al., 2008). This article examines the scope and limitations of some of the alternative models in relation to IPR/TT issues in respect of climate change mitigation.

The article is structured into six sections. The second section reviews the literature and conclusions drawn in it. The third section discusses the regulation of IPR, asking whether it facilitates or hinders TT, as well as the relevance of the TRIPS (Trade Related Intellectual Property Rights) Agreement for TT. The fourth section deals with open innovation models, the case for patent pools, commons and clearing houses and their scope, and the limitations in TT. The fifth section provides a hypothetical example of the application of open innovation for TT in climate change mitigation. The last section provides the conclusion.

Empirical evidence for IPR and climate-change related technology transfer

A survey of the literature shows that there are divergent views on whether IPR hinder or promote TT in climate change. According to Maskus (2010; 136), 'how IPR and ITT (i.e., International Technology Transfer) interact in these areas are highly context specific and broad claims are not particularly helpful. Secondly, economists have barely begun the task of analysing the task of linkages between public-goods externalities and ITT'. Finally, as noted above, it is possible that transparent and enforced IPR could reduce the cost of TT.

The various positions expressed in the literature can be broadly classified as follows:

1) IPR is not a barrier to TT; in fact IPR is a necessary incentive for innovation. Although many factors affect TT, IPR is not the factor that hinders it (Brandi et al., 2010; Copenhagen Economics and IPR Co., 2009).
2) Those who argue that IPR is a barrier point out the North-South gap in terms of ownership of technology and royalty and licensing income. They cite previous experiences to argue that the North has been reluctant to transfer technology to the South. The roots of this position can be traced to the North-South divide on TT issues (Kariawasam, 2007, Ockwell et al., 2010). It is contended that the global legal regime has not been effective in achieving technology transfers to poor nations and that the market factors that determine the trade in technology are increasing the technological gaps between nations (Krishnachar, 2006). This view is similar

to those expressed by the G77 (Group of 77) and NGOs like TWN (Third World Network) (TWN, 2008).

3) It has been argued that in climate change TT, IPR is not a barrier, as most of the old technologies are in the public domain and developing nations' innovative capacity has increased (Barton, 2007).

4) Even if IPR seems to be a barrier, it is not an insurmountable one and should not become part of the UNFCCC negotiations. Many solutions are available for governments to intervene and facilitate TT. Proponents of this view (Lane, 2011; Ueono, 2009) point out that private-sector firms have successfully transferred climate change-related technology to developing countries without IPR becoming a barrier. Options are available under TRIPS, and caution is needed in taking steps that may undermine the role of IPR as an incentive for innovation (Maskus, 2010). Another view is that it is better to deal with the specific issues and to keep the IPR issue out of the UNFCCC negotiations (Drahos, 2009).

5) A group of scholars associated with the University of Sussex, UK, have concluded that a better approach to addressing this issue is to consider TT and IPR on a case-by-case basis rather than assume at the outset that IPR is or is not a barrier (Mallett et al., 2009; Ockwell et al., 2007; Watson et al., 2011). These authors have made their conclusions following extensive case studies on TT in climate change technologies to China and India and point out that factors like the capacity to absorb technology affect TT and vary from sector to sector. Hence generalisations are not helpful in formulating policies for TT. They have also come up with suggestions for addressing this complex issue.

6) Some studies examine TT and climate change with reference to TRIPS (e.g., Hutchison, 2006) and analyze how TRIPS can hinder or promote TT. I discuss this in the third section.

Although Mallett et al., (2009), Ockwell et al., (2007) and Watson et al., (2011), and, Lane (2011) and Ueono (2009) argue on the basis of case studies, their conclusions are not identical: while the former group situate their findings within a broader context of innovation policies, IPR and other factors like technology absorption and the market for technology, the latter two take into account only those studies where TT by private firms has been successful and argue on that basis.

Similarly Barton (2007) takes the position that most of the relevant technologies are in the public domain or are old. Since developing countries have become innovative, he argues, access and TT will not be hindered by IPR. However, the TWN bases its arguments on the historical experience and the North-South gap in technology ownership. Some studies (Maskus 2010; Maskus and Okediji 2010) take a nuanced position in making suggestions, while Brown (2010) calls for a holistic perspective on climate change-related TT.

The World Bank (2010) states that, '[t] here is no evidence that overly restrictive IPRs have been a big barrier to transferring renewable energy production capacity to middle-income countries. […] In low-income countries, weak IPRs do not appear to be a barrier to deploying sophisticated climate-smart technologies' (p. 310). This resonates with the view that IPR protection is not the most important or deciding factor in TT and that its role in influencing TT can vary from technology to technology.

In recent years there has been much empirical research on patenting trends, patents in selected technologies and the ownership and transfer of technology in climate change mitigation (e.g., Dechezleprêtre et al., 2010; Lee et al., 2009; UNEP-EPO-ICTSD, 2010). These studies indicate that, while a handful of countries own a significant percentage of patents, some developing countries are also catching up. These studies point out that the top three or four countries have a significant share in all the relevant technologies. Thus, the debate has moved beyond these polarised views, and many new ideas, like using open innovation models, have been put forward for facilitating TT. I discuss some of them in Sections 4, 5 and 6.

It is necessary to understand the gaps in the literature, some of which are listed below.

1. These empirical findings are limited to certain technologies. There are not many case studies on IPR issues in TT in the context of climate change (both in adaptation and mitigation).
2. Many studies give more information on patenting and the ownership of patents and less about commercialisation or patterns in licensing and their impact on TT, particularly TT to developing countries.
3. Most of the studies on developing nations are limited to just a few countries. There is not much in the literature on TT to LDCs (Least Developed Countries) or to other developing countries.

Thus today, despite the above gaps, the literature has provided a nuanced and balanced idea of the role of IPR in TT in climate change mitigation and has also suggested new ideas and solutions.

The role of IPR in technology transfer and relevance of TRIPS

The Expert Group on Technology Transfer (EGTT) of UNFCCC has identified Enabling Environments (EE) as one of the five themes in the framework to promote, facilitate and finance TT to non-Annex II Parties, particularly developing countries. Enabling Environments have been 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'(FCCC/CP/2001/13/Add.1). IPR regulation is part of the enabling environment as it provides an incentive for innovation and transfer of technology. It is a part of the regulatory and trade policies of any nation. An IPR regime can thus hinder or promote TT.

Prima facie it may appear that the stronger the level of IPR protection the greater will be the tendency to transfer technology, as IPR are protected and respected. If so, how the state should regulate IPR protection and whether it should opt for stronger IPR protection as a strategy to encourage flows of technology through TT are the main questions.

A survey of the literature shows that there are no easy answers to such questions, and cautions against over-generalisation have been made by academics (see UNIDO, 2006; Hall and Helmers, 2010; Maskus, 2010; WIPO 2011 for surveys of the literature, while Johnson and Lybecker, 2009 can be consulted for an extensive survey of literature on TT). In the case of Foreign Direct Investment (FDI) and TT, in general the literature points to a positive correlation between IPR enforcement and TT via FDI, while other factors like country risk, investment policies, market size and the availability of low-cost skilled labour also influence TT through FDI. In other words, IPR enforcement may be necessary as an attractive factor, but it may not always be sufficient for TT through FDI. For example, despite the weak IPR protection, China could attract FDI and TT on account of other factors. In cases of TT through licensing, while the strength of the IPR protection does influence flows of TT, other factors like absorptive capacity are important for a country to benefit from the TT. Thus, while IPR protection does encourage TT, other factors too are important, and firms consider other factors as well, instead of deciding on the basis of IPR protection only. In other words, the specificities should be taken into account in understanding the flow of TT and a country's ability to benefit from it.

The historical evidence cautions us against taking a view that all countries should opt for stronger IPR protection as a strategy to attract TT and promote innovation. Kumar (2003) and Kim (2002) also arrive at the same conclusion and point out that Korea, Japan and Taiwan actually benefited from a weaker IPR protection regime in the early phases as this enabled substantial technological learning. On the other hand, the Commission on IPR and Development has drawn attention to the question of access to technology through TT and its implications for development of the host country (CIPR, 2002). WIPO (2011) points out 'that there is no one single intellectual property law and policy that maximises the transfer of technology in any given country' and underscores the differences in the dynamics of TT and its relationship with IPR regimes across countries (p. 18). Hence it is reasonable to argue that a strong IPR regime is desirable as a factor to attract TT, though it has to be balanced with the need to absorb technology and develop the capacity to innovate through learning-by-doing.

However, countries do not have an infinite number of choices in IPR law and policy, as most countries have become Members of WTO (World Trade Organization) and hence are bound to implement the TRIPS Agreement. The TRIPS Agreement is the outcome of protracted negotiations in the Uruguay Round and lays down the ground rules for IP protection. Being part of WTO Agreements, it has a strong linkage with WTO's Dispute Settlement Mechanism (see Maskus and Reichman (eds.), 2005 for articles on TRIPS and TT). TRIPS has provisions that emphasise the development dimension of IP rights and the role of TT in enabling countries to establish a sound technological base. Articles 7, 8 and 66.2 underscore this, while the latter also states: 'Developed country Members shall provide incentives to enterprises and institutions in their territories for the purpose of promoting and encouraging technology transfer to least-developed country Members in order to enable them to create a sound and viable technological base'. However, as the TT through Article 66.2 has not met the expectations of LDCs, suggestions have been made to establish mechanisms and provide incentives to facilitate TT by using Article 66.2 (Moon, 2011).

Some authors are skeptical about the positive role of TRIPS in facilitating TT (e.g., Correa, 2005). Referring to TT, climate change and TRIPS, Adams (2009) argues that TRIPS may impede the transfer of environmentally sound technologies (ESTS) to developing countries, while Hutchinson (2006) points out that countries can take advantage of the flexibilities of TRIPS. He is less sanguine about the positive contributions of TRIPS to TT. On the other hand, O'Regan (2009) takes the view that, while IPR is a hurdle in TT to developing countries, it can be overcome by various means.

Open innovation and similar mechanisms to facilitate technology transfer

The discussion in the previous section indicates that, while the role of IPR in facilitating TT is controversial, the TRIPS Agreement can either facilitate or hinder TT. Instead of thinking solely in terms of limitations and barriers in TT on account of IPR, innovative solutions that combine the flexibility within the IPR regime and novel paradigms in owning and sharing knowledge and technology can be explored as potential solutions to facilitate TT. This section discusses two such novel paradigms, Open Innovation and Open Source, and illustrates their relevance and limitations in facilitating TT.

Open innovation models

Open Innovation refers to a model of innovation in which firms seek ideas from a variety of sources, including users, universities, experts, etc. The core idea of Open Innovation is that firms can and should leverage ideas that are beyond the firm's boundaries and develop strategies to use them by making the innovation process more open, and that this can be done proactively. According to Chesbrough (2006), who pioneered the idea of Open Innovation, 'At its root, Open Innovation assumes that useful knowledge is widely distributed, and that even the most capable R&D organisations must identify, connect to, and leverage external knowledge sources as a core process in innovation' (p. 2). Herzog (2011) points out that the shift from 'closed' innovation to 'open' innovation needs to be accompanied by a change in the culture of innovation (p. 228).

Open Innovation is facilitated by advances in the distribution of knowledge and collaborative possibilities that are made available by information and communication technologies. Open Innovation networks can be organised for a specific purpose, while firms embrace Open Innovation as a philosophy and practice for pragmatic reasons. For example, companies are creating value by licensing intellectual property, establishing joint R&D ventures, or making other arrangements to benefit from technology outside the boundaries of the firm (Chesbrough, 2003, 2007).

The rationale for firms opting for Open Innovation stems from a pragmatic view that there are occasions in which cooperation in production and sharing can benefit all participants more than each participant trying to secure monopoly rights through patents and enforcing them. A study of 39 open-source initiatives in biopharmaceutical innovation highlighted the different ways in which companies are willing to share, excluding others outside the consortium but allowing access to members and opting for the joint management of knowledge assets so that all members can benefit and take advantage of knowledge and technology outside the firm (Allarakhia et al., 2010). Reichman (2003) and Foray (2004) point out that it makes sense to undertake cooperative knowledge production and open knowledge dissemination, as they provide joint benefits in circumstances when upstream discovery research cannot result in commercial products and when the costs of upstream competition are high.

Open source models

The Open Source model is a collaborative mode of production, testing and distribution in which voluntary labour is a key component and the IPR is handled by using licenses, either GPL (General Public License) or a license derived from it. The contributor to an Open Source project cannot use Open Source licensing to acquire monopoly rights or to block others from using the contribution made to the project. Lakhani and von Hippel (2003) have identified the three incentives that induce a firm to participate in Open Source projects.

Open Source models are currently being applied and tested in diverse fields like drugs development, biotechnology (Srinivas, 2010; Hope, 2008) and product development in some industries (Balka, 2011; Jasski, 2007). There is a growing interest in applying Open Innovation and Open Source models in the context of climate change. For example, the Clean Energy Group has come out with a comprehensive report on the relevance of 'open and distributed' innovation for climate change (Morey et al., 2011; see also Rattray, 2009 for a discussion of the relevance of Open Source approaches).

Open innovation and open source: Comparison and differentiation

Both models stress the need for collaboration and for tapping resources outside the boundary of the firm through collaborative processes and networks. This will facilitate flow of ideas and synergies in working and can result in solutions that a single firm or group alone would not have been able to develop. The major difference between them is that, while in Open Innovation efforts are usually made by the firm that is trying to innovate by reaching out to other firms or potential collaborators, in Open Source the problem or opportunity is the central point of focus that connects the people and organisations. In Open Innovation the firm is the centre of collaborative endeavor, while in Open Source the problem or opportunity is the connecting link, not any single firm.

The big difference between Open Source and Open Innovation in terms of handling IPR is that with Open Innovation products can be protected within a proprietary framework that respects the patent rights of the firms involved in Open Innovation, while the Open Source model relies on GPL or similar licenses to protect and enforce IPR. Thus, the major differences are in organizing for innovation and in handling IPR.

Licensing

Licensing is one method of deriving value from IP, and this can be exercised in many ways. For example, a firm can grant an exclusive license to a single party or can provide non-exclusive licenses to different parties on different terms. Licensing can serve both the purposes of benefiting from IP and controlling its use. Depending upon the considerations for licensing and the rights granted, there can be many different types of license, ranging from exclusive licensing to cross-licensing where parties grant licenses to each other. Licensing can thus be converted into a collaborative practice for mutual benefit.

In collaborative innovation, joint licensing may be desirable when there are different holders of IP rights (e.g., patents) and the technology covered by the patents is necessary for further innovation. Thus, to reduce transaction costs and to benefit from each others' technology, the patent-holders can opt for cross-licensing to each other and/or to third parties. Some of the mechanisms that facilitate such sharing and transfers of technology are discussed below.

Patent pools

The patent pool is a mechanism is which two or more patent-holders agree to share their IP with each other and/or with third parties through negotiated licenses, which might include cross-licensing. Patent pools can promote TT, facilitate innovation and promote diffusion. The Medicines Patent Pool (http://www.medicinespatentpool.org/) is a recent example enhancing access for medicines for HIV in developing countries through voluntary licensing. In the case of TT in the context of climate change mitigation, patent pools can be formed for different sectors and type of need. For example, the patent pool or patent pools can be formed where access to one technology or group of patents is needed for furthering TT. Thus, a patent pool on renewable energy technologies can combine many patents relevant for an application (e.g., increasing energy conversion efficiency) and license them to encourage TT. Patent-holders also acquire access to necessary technologies that are not owned by them but necessary to commercialise some applications. While patent pools are not panaceas, they have been tested in many contexts in some industries and hence can also be relevant for TT in climate change mitigation. For example, Iliev and Neuhoff (2009) have indicated circumstances under which patent pools will be useful in facilitating TT. An extensive review of patent pools and clearing-house mechanisms in different industries and contexts is available in van Overvalle (ed.) (2009). Patent pools can be classified under Open Innovation Models, as the objective is to combine the specific resources of all parties to form the pool and to license them on mutually agreed terms.

Patent commons

Under patent commons, patents are made available subject to certain rights and obligations. The commons is thus a collective resource which one can contribute to and draw from, subject to some rules. In 2005, a patent commons was created by Open Source Development Laboratories to enable the open source development community at large to make use of the resources from this Commons for open source development. While all users of this Commons may not be contributors to it, some are likely to be users as well as contributors.

The major difference between a pool and commons is that a pool is a mechanism to aggregate and license, while a commons is a mechanism to aggregate and to share for the purpose of further development and diffusion, subject to some conditions. Usually such commons make use of the General Public License (GPL) or any of the derivatives from GPL to enforce rights and produce certainty about obligations. Thus, resources in such commons are not for free riding because there is also an obligation.

In the context of climate change, the World Business Council for Sustainable Development based in Geneva launched Eco-Patent Commons in 2009. The objective of this is to enable the sharing of patents and to collaborate in furthering eco-innovation. As of now there are about a hundred patents available under this initiative. While for reasons of space I will not provide a detailed analysis of the pros and cons of this approach, such commons may facilitate TT (Boynton, 2011; Hall and Helmers, 2011; Lane, 2011).

A similar initiative drawing upon the principles of Creative Commons is the USA-based GreenXchange. Just as in Creative Commons, here too the holders of IPR, i.e., the patent-holders, permit some uses and give up some rights partially or fully subject to the licensing terms. For example, a patent-holder can permit the unrestricted use of some patents for product development and research by academic institutions, while insisting that any use by commercial firms will be restricted to licensing on commercial terms.

In Eco-Patent commons the patent-holders donate patents to the commons, while in GreenXchange they retain the patents but permit flexibility in using them and license them on specific terms. Both these approaches have their merits and demerits, but what is important is that they provide flexibility in making use of patents without denying IPR.

The Eco-Patent Commons is a typical example of an Open Source Model, as it enables the creation of Commons.

The GreenXChange cannot be considered an example of an Open Source Model or Open Innovation because it is based on the Creative Commons principle, which is derived from copyright. Licenses under Creative Commons grant some rights to users automatically, as indicated in that category of license. Such uses can be relevant for participants in Open Innovation or Open Source projects.

Alternative licensing mechanisms

Normally licenses are commercial contracts that allow little flexibility. But in the wake of the crisis in access to medicines, the need for flexible licensing mechanisms was felt. So some alternative licenses for the use of patents have been developed. The use of GPL and its derivatives in (open source) software has inspired the use of licenses modeled after GPL or its derivatives in other sectors. Thus, today there are many licenses that offer flexibility in use and facilitate transfers of technology, and most of the alternative licensing mechanisms encourage non-exclusive licensing. One license that can be used with modifications for TT in climate change is EAL (Equitable Access Licensing). Under EAL a university for fair royalty payment will grant a non-exclusive license to use patented technology for production and the sale of research tools in poor countries. The licensee agrees to grant back to the university any improvements it has made and cross-license any other rights owned by it. The idea here is that licensee will not use its rights to block the production. The university can offer the research tool on similar terms to other parties. The objective is to make this licensing applicable to low- and middle-income countries where access at affordable prices is a major issue. A neglected disease license permits the university to license the technology for research into neglected diseases and for commercialisation in poor or low-income countries (Hope 2009). This sort of mechanism would come under Open Source Models, as they are based on Open Source principles and make use of GPL or a license modeled on it.

Clearing houses

A clearing house is a mechanism for matching the users and providers of goods, services, information and technology (Zimmerman 2009). For example, technology exchange clearing houses offer information services and enable technology providers and seekers to find partners and conclude contracts. Eco-Patent Commons can be considered an open-access clearing house. There is scope for other types of clearing houses in TT in climate change mitigation. The clearing house mechanism under UNFCCC has been more a clearing house for information than for facilitating TT.

From the point of view of patent-holders, engaging in Open Innovation and/or choosing one of the above-mentioned options makes sense only if they are able to derive more advantage out of them when compared to normal licensing practices. For example, it is beneficial to join a patent pool and contribute to it if joining the pool can result in more revenue with lower transaction costs, and/or if it provides access to a technology that is available only to members. For the recipients of technology, accessing a patent pool is preferable to dealing with many patent-holders individually, as the transaction costs will be lower and access to a bundle of technologies is ensured. But if the recipient does not need all the technologies made available through a pool but only some of them, then dealing with patent-holders on a one-to-one basis may be less expensive. It is also likely that receivers of technology may prefer to opt for commercial licensing from a single firm if it provides all the technologies needed than access some from Commons/Patent Pool(s) and opt for commercial licensing for the rest, as the first option reduces legal uncertainties. In the case of licensing practices, while GPL and its derivatives have been used extensively in software contexts, their validity in non-software contexts is not clear, as there is not much case law on this. Some licenses like EAL that are being developed as a solution to a specific problem may not be relevant in other cases.

Using open source and open innovation for TT in climate change mitigation

In this section, an illustrative example is given of a hypothetical situation in which a climate mitigation technology is the object of an open innovation model. The climate mitigation technology being illustrated here is the development of rice varieties with enhanced nitrogen use efficiency and transfer of technology to breeders and research institutions. Stern (2006) points out that a significant proportion of the greenhouse gases (GHG) produced by agriculture are due to the application of nitrogen fertilizer alone, because a portion of the excess nitrogen not taken up by plants is released into the atmosphere as nitrous oxide, a potent greenhouse gas. Increase in nitrogen use efficiency by plants can result in lower applications of nitrogen fertilizer and thereby contribute substantially to mitigation of climate change.

This is a hypothetical example and not a case study or description of an ongoing project. The three important steps in organizing the development of rice varieties and TT are described below.

Step 1: Form a consortium of institutions working on this project and organise it on the basis of Open Innovation. The consortium should cover all activities, from the start to the development of varieties and their transfer through commercialisation by public or private sector. It should also address further research and development activities. Under this project, applying conventional breeding for the development of such varieties and of genetically modified rice with this trait will be undertaken, as both are needed.

Step 2: This has two components, as below

The consortium should identify the IPR issues involved in each stage, from development to transfer and diffusion. Normally, germplasm is available under Material Transfer Agreements (MTAs) and as such cannot be patented. The use of research tools and patented genes or gene fragments can become an issue. Thus the mapping of the technologies and tools needed, the issue of respective patents and an analysis of the patenting landscape are necessary. For example, while access to and use of germplam might not be an issue, the relevant processes and research tools might have been patented, as might the genes and gene fragments. The MTAs may have restrictive clauses on usage of the transferred material. Thus the consortium can identify the ways to overcome this by examining: 1) whether research exemptions are applicable, 2) what are the available alternatives, and 3) whether the resources available with the institutions in the consortium can be used to complement or replace the patented research tools, genes or gene fragments.

If IPR is a pressing issue in accessing them, the consortium can find out whether the patentee(s) is/are willing to license them using humanitarian licensing or licensing under EAL or similar licensing on a non-exclusive basis for use in developing countries or LDCs. Since this project envisages identification of the relevant gene from different crops and the development of genetically modified rice, access to the germplasm of crops like barley is important. The freedom to operate, i.e., whether the consortium is free to market the developed product or not, depends on access to and the right to use patented technologies, materials and processes. Therefore, an analysis of the issues in Freedom to Operate is essential.

The complexity in this can be illustrated by the fact that in the development of 'Golden Rice', transgenic rice enhanced with provitamin A, it has been estimated that 40 organisations hold 72 patents on the technology necessary to develop and disseminate this variety. A coordinated international programme resolved this issue by negotiating with the patent-holders by obtaining permissions and licenses (Dunwell, 2010).

In such efforts, organisations like the Public Intellectual Property Resource for Agriculture (PIPRA) or Biological Innovation for Open Society (BIOS) can help in mapping the IPR issues and identifying the options involved in using licenses and accessing alternative resources besides assisting in negotiations on IPR. Once this task has been completed, it is essential to ensure that all institutions have the same understanding of IPR issues and of access to, use of and sharing of resources covered by patents, MTAs and licenses.

2) The consortium should develop a coherent IPR policy for use within the consortium and in dealing with external agents. In this the consortium can make

use of GPL or its derivatives to share its IP assets. For sharing within the consortium, there can be a patent pool. Novel arrangements for sharing knowledge and accessing others' knowledge and technology can be established. The relevant examples of this are the SNP Consortium and the HapMap Project (NAP, 2010).

Step 3: Collaborative development of varieties and IPR issues

Once the varieties have been developed, it is necessary to seek IPR protection. Not all countries allow the patenting of plant varieties. Many developing countries provide Plant Breeders' Rights (PBR) as IPR for Plant Varieties, while in the USA both patent protection and PBR are available. Often the varieties developed are transferred to seed companies or breeding companies that sell seeds or incorporate the innovation in Open Pollinated Varieties (OPV) or hybrids. Therefore, it is essential that the appropriate mode of Intellectual Property is sought. IPR can be enforced and can be linked with TT to breeders and seed companies. Even also in other cases, obtaining IPR will help prevent misappropriation by others and help assert rights in cases of infringements.

In the above example, if the variety is a GMO, i.e., a genetically modified organism, then there are more issues to be addressed. Even if GM plants cannot be patented, the relevant processes, genes, gene fragments and research tools might be patentable. Hence, while PBR are applicable to plant varieties, IPR protection in terms of patents may be available for relevant processes, etc.

Here too, it is for the consortium to have a definitive IPR policy on patenting and enforcing IP rights. It is a good practice to introduce patent protection as a defensive mechanism. Patents can be used for sharing on a quid pro quo basis, as a defensive mechanism against misappropriation and in bargaining for access to other patented technologies. Moreover, a strong IP portfolio is valuable in terms of income from licenses and in assessing the value of innovations. The consortium should use IPR for the benefit of its members, as well as to facilitate TT.

Open innovation is applicable here in terms of organizing for innovation, developing a structure that engenders open innovation and handling IPR. In open innovation, the core principle is to link with knowledge resources within the organisations and external sources in such a way that knowledge resources are leveraged for a shared objective. Open Source is useful as an alternative mechanism for using IPR in such a way that sharing is encouraged, further development is permitted and access is permitted on some condition, instead of enforcing monopoly rights to prevent others from developing a resource further or to ensure that rent maximisation is made possible by exercising that right.

Thus, as described above, Open Innovation Models and Open Source Models can be used to develop technology and facilitate TT.

Conclusion

While there is a consensus on the need for TT in climate change mitigation, the role of IPR in facilitating TT is controversial. The debate has moved beyond polarised positions. This has also resulted in a search for alternative models and mechanisms to facilitate TT. The Open Innovation model as an alternative mechanism has much relevance to facilitate TT. Some mechanisms, like Patent Pools and Clearing Houses developed in other contexts, are being applied here, while new initiatives are being developed to build Commons. Although they are not a panacea, they can play an important role and can complement other approaches in facilitating TT.

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This edition of the *Technology Transfer Perspectives* Series focuses on how to create an 'enabling framework' for the diffusion of renewable energy technologies in developing countries, i.e., going beyond technology transfer to the scaling-up of investment. Through a number of case studies from around the world, this edition provides examples of policies for the diffusion of specific technologies such as solar, wind and biomass, as well as the establishment of broader frameworks targeting a portfolio of renewable technologies. As such, this issue provides examples of how to move from specific projects to effective frameworks for the market-based diffusion of technologies.

The nine articles in this issue provide a wealth of information targeted at consultants, stakeholders and policy-makers involved in the analysis and formulation of energy policy. The articles presented here highlight that, while policy measures need to be carefully designed and tailored to national circumstances, they first of all need to be simple, transparent, stable and predictable. Hence strong commitment by governments remains essential.

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