A WORLD BANK STUDY

Unleashing the Potential of Renewable Energy in India

Gevorg Sargsyan, Mikul Bhatia,
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Acronyms and Abbreviations

CERC	Central Electricity Regulatory Commission
FIT	Feed-in tariffs
GBI	Generation-based incentive
GIS	Geographic Information System
HT	High-tension
IEA	International Energy Agency
IEGC	Indian Electricity Grid Code
IEP	Integrated Energy Policy
IREDA	India Renewable Energy Development Agency
JNNSM	Jawaharlal Nehru National Solar Mission
MNRE	Ministry of New and Renewable Energy
NAPCC	National Action Plan on Climate Change
OECD	Organization for Economic Co-operation and Development
PPA	Power purchase agreement
R&D	Research and development
RE	Renewable energy
REC	Renewable energy certificate
RGGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana
RPO	Renewable purchase obligation
SERC	State electricity regulatory commission
UI	Unscheduled interchange
UNFCCC	United Nations Framework Convention on Climate Change

Executive Summary

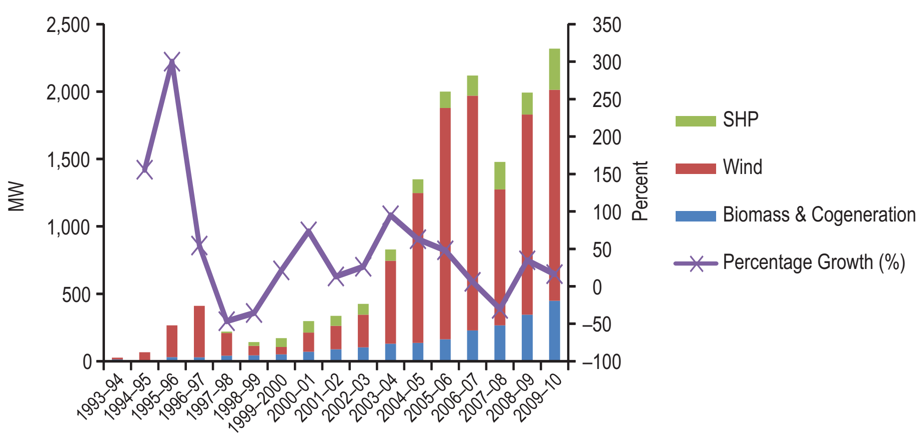
India has 150 GW of renewable energy potential, about half in the form of small hydropower, biomass, and wind and half in solar, cogeneration, and waste-to-energy. Developing renewable energy can help India increase its energy security, reduce the adverse impacts on the local environment, lower its carbon intensity, contribute to more balanced regional development, and realize its aspirations for leadership in high-technology industries.

Since 2005 the energy and climate change agenda has taken center stage in the domestic and international policy arena. India is well placed to build on this momentum. It has tripled its renewable energy generation capacity in the past five years (figure 1), now ranking fifth in the world in total installed renewable energy capacity, and it has established a legal and regulatory framework for sector oversight.

The government has set ambitious targets. It aims to increase the capacity to generate renewable energy by 40 GW to 55 GW by the end of the 13th Five-Year Plan (2022). The National Action Plan on Climate Change (NAPCC) has set an even more ambitious goal of a 1 percent annual increase in renewable energy generation which stands at about 3.5 percent in 2008. Meeting this goal may require 40–80 GW of additional capacity in renewable energy capacity by 2017, depending on India's demand for power and plant capacity factor. The Jawaharlal Nehru National Solar Mission (JNNSM) has set its own ambitious target of adding 1 GW of capacity between 2010 and 2013. It seeks to increase combined solar capacity from 9 MW in 2010 to 20 GW by 2022.

To achieve these goals, India needs an order-of-magnitude increase in renewable energy growth in the next decade. To add 40 GW by 2022, India will have to meet the ambitious target of the JNNSM, double its wind capacity, quadruple its small hydropower

Figure 1. Additions to renewable energy capacity, 1993/94–2009/10



Source: MNRE 2009.

power capacity, fully realize co-generation capacity, and increase biomass realization by a factor of five to six. These ambitious targets have made creation of an enabling environment for renewable energy development particularly urgent and topical.

This diagnostic note draws on a detailed analysis conducted by a PricewaterhouseCoopers India consulting team in 2008–09 for the World Bank. The data are based on information on about 180 wind, biomass, and small hydropower projects in 20 states, as well as information from and norms of the Ministry of New and Renewable Energy (MNRE) and the Central Electricity Regulatory Commission (CERC).

The study is intended to provoke discussions of the feasibility of renewable energy development in India. Why is renewable energy development relevant? How much development is economically feasible? What needs to be done to realize the potential? Each of these topics is addressed in a separate chapter, all of which suggest a few implementable measures that India can consider to tap its economically feasible unharnessed potential.

Why: Role of Renewable Energy in India

India has a severe electricity shortage. It needs massive additions in capacity to meet the demand of its rapidly growing economy. The country's overall power deficit—11 percent in 2009—has risen steadily, from 8.4 percent in 2006. About 100,000 villages (17 percent) remain unelectrified, and almost 400 million Indians are without electricity coverage. India's per capita consumption (639 kWh) is one of the lowest in the world.

The Integrated Energy Policy Report, 2006, estimates that India will need to increase primary energy supply by three to four times and electricity generation by five to six times to meet the lifeline per capita consumption needs of its citizens and to sustain a 8 percent growth rate. The government plans to provide universal access and to increase per capita consumption to 1,000 kWh by 2012. This translates into a required generation capacity of 800 GW compared to 160 GW today. The need to bring on new generation capacity—and to improve operational efficiency in transmission and distribution—is clear.

Renewable energy can be an important part of India's plan not only to add new capacity but also to increase energy security, address environmental concerns, and lead the massive market for renewable energy. More than three-fourths of India's electricity production depends on coal and natural gas. At current usage levels, India's coal reserves are projected to run out in 45 years. India already imports 10 percent of its coal for electricity generation, and the figure is projected to increase to 16 percent by 2011.

Like coal, gas and oil have witnessed considerable price volatility in recent years. Development of renewable energy sources, which are indigenous and distributed and have low marginal costs of generation, can increase energy security by diversifying supply, reducing import dependence, and mitigating fuel price volatility.

Accelerating the use of renewable energy is also indispensable if India is to meet its commitments to reduce its carbon intensity. The power sector contributes nearly half of the country's carbon emissions. On average, every 1 GW of additional renewable energy capacity reduces CO_2 emissions by 3.3 million tons a year. Local ancillary benefits in terms of reduced mortality and morbidity from lower particulate concentrations are estimated at 334 lives saved/million tons of carbon abated.

Renewable energy development can also be an important tool for spurring regional economic development, particularly for many underdeveloped states, which have the greatest potential for developing such resources. It can provide secure electricity supply to foster domestic industrial development, attract new investments, and hence serve as an important employment growth engine, generating additional income.

Renewable energy is seen as the next big technology industry, with the potential to transform the trillion dollar energy industry across the world. China seized this initiative to become a world leader in manufacturing renewable energy equipment. India's early and aggressive incentives for the wind sector have led to the development of world-class players. Investing in renewable energy would enable India to develop globally competitive industries and technologies that can provide new opportunities for growth and leadership by corporate India.

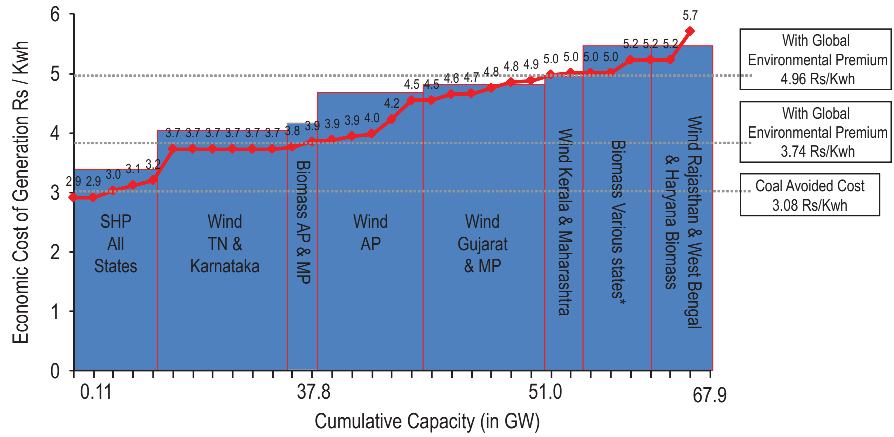
How Much: Economic and Financial Potential of Renewable Energy

India could produce about 62 GW—90 percent of technically available renewable capacity in wind, biomass, and small hydropower—in an economically feasible manner, if the local and global environmental premiums of coal-based generation are brought into consideration. About 3 GW of renewable energy is economically feasible at the avoided cost of coal-based generation of Rs 3.08/kWh, all of it from small hydropower. About 59 GW of renewable energy in wind, biomass, and small hydropower is available at an avoided cost of less than Rs 5/kWh. The full capacity of 68 GW in these three technologies can be harnessed at a price of less than Rs 6/kWh.

Although the global pricing of carbon is still variable, the economic value of local environmental and health impacts is more clearly understood. In the absence of a global agreement on climate change mitigation efforts, the global economic benefits cannot be internalized. The estimate presented in this report provides a lower bound of benefits, as it compares renewable energy against the opportunity cost. Internalization of other externalities, such as the impact on economic development and energy security, will only increase the economic potential.

Small hydropower is the most economically viable form of renewable technology, with an average economic cost of Rs 3.56/kWh. This resource is the most attractive in Andhra Pradesh, Haryana, Himachal Pradesh, Punjab, and Uttaranchal. In all of these states, the cost of producing energy through small hydropower technology is less than the average economic cost of small hydropwer (SHP). The average economic costs are Rs 4.6/kWh for biomass-based generation and Rs 4.9/kWh for wind-based generation. However, biomass fuel availability and price fluctuation under a regulated market pose a significant risk to scaling-up biomass-based generation. The economic cost of biomass-generated power ranges between Rs 3.9 and Rs 5.7/kWh. The generation cost of wind projects is highly sensitive to the capacity utilization factor, which is quite low at about 23 percent. The economic cost of wind power ranges between Rs 3.8 and Rs 5.2/kWh. A substantial proportion of wind capacity (about 37 GW) is available in the four states of Andhra Pradesh, Gujarat, Karnataka, and Tamil Nadu. Solar is the most expensive renewable resource, with estimated unit costs of Rs 12/kWh for solar thermal and Rs 17/kWh for solar photovoltaic (figure 2).

Figure 2. Economic competitiveness of wind, biomass, and small hydropower



Source: Authors
Note: The economic costs of generation include all capital, operational, and financial expenses and exclude all taxes and subsidies.

The financial incentives for state utilities to buy renewable power are substantial only when compared with short-term power procurement cost. The feed-in tariffs for wind, small hydropower, and biomass are typically lower than the short-term power purchase charges, such as trading and unscheduled interchange (UI). Reallocating the money that would have been spent buying short-term power to investment in renewable energy can yield significant savings. However, the core of electricity procurement by utilities still rests with power purchase agreements (PPAs) with coal- or gas-fired plants. At the financial cost of coal-based generation, renewable capacity is not financially viable. About 5 GW of capacity is viable at the cost of gas-based generation; the entire capacity of wind, biomass, and small hydropower is viable at the cost of diesel-based generation. Solar energy is not financially viable at any of these opportunity costs and will require subsidies in the short to medium term particularly if renewable purchase obligations are enhanced rapidly in line with the targets of the NAPCC.

There is almost zero escalation in the variable cost of generation from renewable sources; in contrast, the variable cost of fossil-fuel based power generation is expected to increase. Most utility expansion models are unable to account for the hedging value of renewables against the price volatility of fossil fuel-based generation. Renewables are the only free hedging mechanism against the price volatility of fossil fuels. Experts have concluded that the risk-adjusted cost of generation portfolio that includes renewable energy is lower than that of a fossil fuels only portfolio. Moreover, renewable energy increases the price certainty of the entire portfolio and enhances energy security. (In the United States, for example, every MWh of non-gas generation saves consumers $7.50–$20.00/MWh) Utilities therefore need to be incentivized to diversify the energy mix.

Achieving the government's goal for the next decade will require an annual subsidy of $ 1 billion–$ 6 billion, depending on choices made. This may change as the renewable energy certificate trading mechanism evolves. There is still significant scope for improving the bankability of renewable energy to attract developers to invest in renewable energy. To reach the goal of installing 40 GW of additional capacity of renewables in the next 10 years, the government could provide subsidies to achieve parity between the cost of renewable energy and coal-based generation A back-of-the-envelope estimation is made by identifying the size of subsidy required to bring levelized cost of renewable energy to avoided cost (at a coal-based generation price of Rs 3.08/kWh). The amount is equal to the up-front capital subsidy or net present value of generation-based incentives. The estimated resource requirement ranges from Rs 450 billion (about $10 billion) for low-cost renewable energy but low diversity of renewable energy sources to Rs 2.9 trillion (about $64 billion) for high-cost renewable energy with significant diversity of renewable energy sources. Provision of low-cost renewable energy is not prohibitively expensive when spread over 10 years, with an annual bill of about $1 billion.

What: Establishment of an Enabling Environment for Renewable Energy Development

Significant barriers to renewable energy development remain in India. Given the high upfront capital costs of renewable energy technologies, financial barriers are substantial. But nonfinancial barriers are equally important in limiting the growth of renewable energy.

Barriers can be grouped into three categories: financial viability, support infrastructure, and regulatory approval (table 1):

- The cost plus approach to tariff setting—along with the technology-specific focus—has led to incentives that hinder the economic development of India's renewable energy resources. India currently offers a wide variety of incentives, including feed-in tariffs; generation-based incentives; renewable *purchase obligations* **(**RPOs); central, state, and regional capital subsidies; accelerated deprecia-

Table 1. Renewable energy barriers and suggested solutions

Type of barrier	Remaining issues	Suggested solutions
Financial Viability	• Skewed financial incentives for facilitating investments in renewable energy • Too many incentive programs • Failure to adequately address utilities' long-term financial concerns • Failure to develop least-cost resources first • Inadequate long-term funding sources	• Provide streamlined, market-based government interventions • Create national renewable energy fund to mitigate impact on utilities • Enable direct purchase and distributed generation of renewable energy • Facilitate financing of renewable energy
Support Infrastructure	• Inadequate evacuation and access infrastructure • Lack of good-quality data • Underdeveloped industry value chain	• Make renewable energy evacuation a high-transmission priority • Introduce and enforce "take or pay" for renewable energy generation • Invest in high-quality, integrated resource monitoring systems • Catalyze research and development (R&D) and supply chain innovations and investments
Regulatory Approvals	• Delays in clearances and approvals and long development cycle • Land and resource acquisition issues	• Move to unified, light-touch regulation for renewable energy. • Strengthen state nodal agencies and state regulators

Source: Authors.

tion; and tax incentives. The lack of coordination between incentives and state programs makes it difficult to adopt an economics-based least-cost development approach to tapping the country's renewable energy potential.

- The limited availability of evacuation infrastructure and grid interconnections is one of the biggest obstacles to harnessing renewable energy potential. Much economically attractive wind and small hydropower potential remains untapped because of lack of adequate grid evacuation capacity and approach roads. The lack of good-quality data on renewable resources also remains a problem, despite heavy investment by the MNRE in collecting data on renewable energy. The lack of support infrastructure in the form of a strong indigenous supply chain remains a major barrier.
- Existing mechanisms—including single-window clearances, facilitation by state nodal agencies, and simplified regulation for smaller renewable energy projects—have proved to be of limited effectiveness. In some cases multiple bottlenecks have been replaced by single, larger, and more powerful roadblocks, and significant delays remain the norm. In addition, speculative blocking of land has become common, leading to unsustainable price increases.

To reduce financial barriers, policy makers need to consider ways to bridge the higher costs that ensure least economic cost development of India's plentiful renewable resources. There is a need to simplify the numerous and overlapping financial incentives into a cogent set of synchronized policies established on a sound economic and market foundation. Policies could be based on short- and long-term national targets and broken down into state-level RPOs that are mandatory and enforced. Technology-specific incentives could be supported by earmarked funding and increasingly allocated on a competitive basis.

India needs to make renewable energy evacuation a high transmission priority—as high a priority as village electrification. This is especially true for large-scale renewable energy plants. Dedicated funding should be allocated as part of existing programs, such as the government's rural electrification initiative - Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), or new green funds.

Steps also need to be taken to address nonfinancial barriers that increase the cost of doing business. Like information technology and telecommunications, clean technology and renewable energy have enormous growth potential and can transform the trillion dollar energy markets across the world. To realize this potential, India needs to streamline bureaucratic processes for clearances and approvals through the use of light-touch regulation. State nodal agencies, which are supposed to play a leading role in guiding renewable energy projects through the regulatory maze, need to be strengthened. A comprehensive capacity-building program on emerging regulatory, legal, and financing issues to facilitate grid-connected renewable energy should be structured.

The way forward is complicated, but it provides India with the opportunity to dramatically increase the security of its energy future. Based on stakeholder discussions, three key messages emerge:

- Recognizing and managing risks is crucial. Any discussions of radical new approaches to achieve an order-of-magnitude change in renewable energy should first recognize the existing risks. Key risks that have to be managed include untimely access to evacuation networks and equipment, difficulties in the acquisition of land, lack of access to reliable resource estimates, and delays in payment because of the weak financial state of the utilities and the weak institutional capacity of renewable energy developmental institutions, especially at the state level. Concerns from key stakeholders should be listened to and addressed to head off resistance to project implementation, which rendered previous reform attempts ineffective. Implementation will have to be gradual in scale and sequencing and tolerant of the chance of failure.

- Early adoption of "quick wins" can build momentum for high-effort, high-impact structural reforms. Some solutions take time to design and implement and may require significant resources. Achieving and demonstrating some quick results helps gain political support for longer-term solutions. Policy initiatives such as enforcement of state-level RPOs could provide an immediate boost to the sector. Initiatives that increase financial sector capability and awareness, strengthen state nodal agencies, and invest in high-quality resource information systems can also be implemented relatively quickly.
- Perhaps the best way to create substantive change is to implement comprehensive pilot models in a few states. One potential quick win that could have a strong impact would be the creation of renewable energy parks, which can serve as integrated implementation platforms for testing and refining solutions. Such parks could be created as joint national and state initiatives in pilot states. The central government could commit substantive financial and administrative resources to attract states rich in renewable energy resources, which could be selected based on their demonstrated commitment to such a program, including co-financing and capacity to implement. Renewable energy parks can be attractive to both small and large players. They can provide ready-to-bid project pipelines; prefeasibility studies, including resource assessment data; access to land; transmission infrastructure; and preferential open access policies. They can be used to create simplified light-touch regulations, including accelerated environmental and social clearances and package clearances. The India Renewable Energy Development Agency (IREDA) could pilot new risk guarantee and financing schemes. State and central funds could catalyze R&D and supply chain innovations in renewable energy parks. Initially, the parks would require specific kick-off grants or subsidies from the MNRE and other agencies. These subsidies could be recovered from developers as projects reach critical mass. If proven successful, solutions tested in the parks could be replicated across India.

CHAPTER 1

Why: Role of Renewable Energy in India

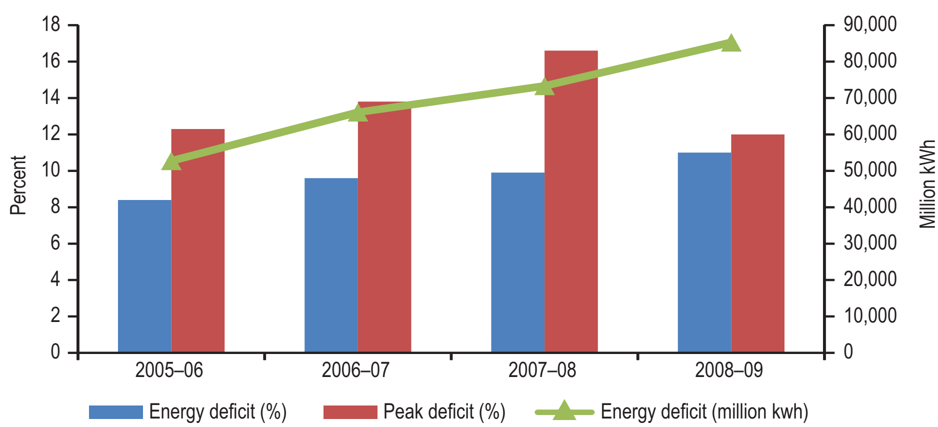
This chapter explores the rationale for developing renewable energy in India.[1] It presents a snapshot of the current status of renewable energy development and summarizes key issues in each of the major industry segments. It also examines crucial gaps in the renewable energy market, describes the goals set out by various government programs, and estimates the resources and effort required to meet these goals.

India's significant untapped renewable energy resources can be an important contributor to alleviating power shortages. They can also increase energy security, contribute to regional development, enhance access in remote (rural) areas, diversify fuel sources, and provide local and global environmental benefits. Recognizing these benefits, India's policy makers have given much attention to renewable energy, setting ambitious goals for the sector. Meeting these goals will require significant capital investments and concerted action to solve the many issues faced by the different renewable energy sectors.

Contribution to India's Energy Future

Persistent electricity shortages have been identified as a key bottleneck for sustaining India's growth rate (figure 1.1). India's per capita consumption (of just 639 kWh) is one of the lowest in the world.[2] According to the Ministry of Power, out of the total 593,732

Figure 1.1. Annual average and peak power deficits, 2005/06–2008/09



Source: Ministry of Power Website (CEA Report).

villages in the country as per the 2001 census, 496,365 have been electrified as of Dec 31, 2009. In 2009–10 the national power shortage averaged 10.1 percent.[3] Access to grid power remains low, with an electrification rate of just 55 percent, leaving almost 412 million people without electricity coverage.[4] About 42 percent of rural households in India use kerosene-based lighting, paying 20–30 times more than they would for electricity-based lighting.[5] Supply is not sufficient even in urban areas, where about 6 percent of households use kerosene for lighting.

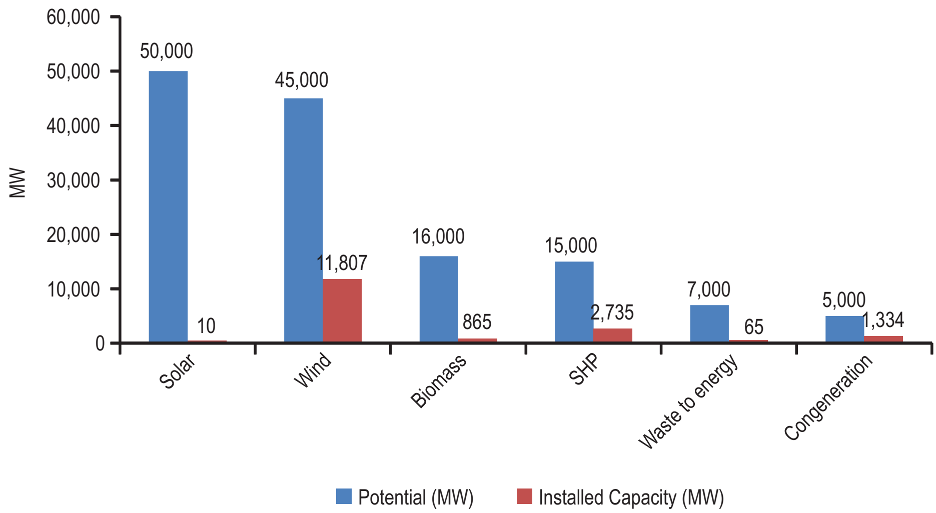
The economic and opportunity costs of these shortages are very high. Substantial segments of Indian business and some household customers use expensive diesel generators to cope with grid shortages. About 60 percent of Indian firms rely on captive or back-up generation (compared with just 21 percent in China). Grid-connected captive generation capacity is estimated to be about 20 GW and growing at 30–40 percent a year.[6]

In the next 25 years, India's electricity demand is expected to grow at an average annual rate of 7.4 percent. Generation capacity will have to increase fivefold to keep pace with demand growth. India needs massive additions in generation capacity to meet the demands of its fast-growing economy. In 2008 India had 148 GW of generation capacity, with annual electricity generation of about 724 Billion kWh.[7] The Integrated Energy Policy (IEP) Report, 2006,[8] estimates that India will need to increase primary energy supply by three to four times and electricity generation by five to six times to meet the lifeline per capita consumption needs of its citizens and to sustain an eight percent growth rate. The government plans to provide universal access and to increase per capita consumption to 1,000 kWh by 2012. This translates to an installed generation capacity requirement of approximately 800 GW in 2031–32 compared to the installed capacity of 160 GW in 2010 (at 8 percent GDP growth rate).[9] The IEP report projects that nearly three-fourths of the installed capacity will be thermal-based (coal and gas). The gap between supply and demand is likely to increase unless adequate measures are taken to bring on new generation capacity and improve operational efficiency in the distribution and management of power utilities.

With about 150 GW of known resource potential—of which only about 10 percent has been developed—renewable energy should be an important part of the solution to India's energy shortage (figure 1.2). The country's huge energy potential is likely to be even greater than 150 GW, as resources from sources with significant generation capacity (such as energy plantation of wastelands and offshore wind farms) have not yet been mapped. In sectors such as wind and small hydropower, application of the latest developments in engineering design and equipment technology are also likely to increase potential, as are the discovery of new small hydropower sites and the development of the irrigation network. The potential for solar power will likely increase significantly as technology improves.

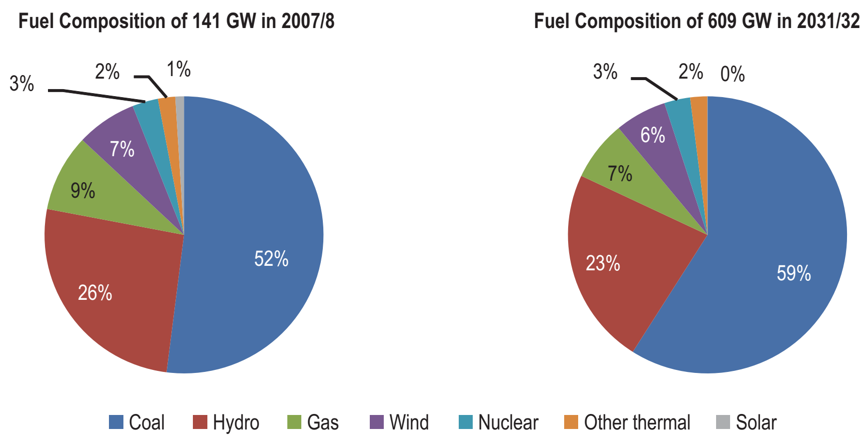
Development of renewable energy sources, which are indigenous and distributed and have low marginal costs of generation, can increase energy security by diversifying supply, reducing import dependence, and mitigating fuel price volatility. India produces three-fourths of its electricity from coal and natural gas (figure 1.3). At current usage, its coal reserves are projected to be depleted in 45 years.[10] India already imports 10 percent of its coal for electricity generation; it is projected to import 16 percent by 2011. With the increase in demand for coal in Asia, global coal prices are projected to rise, exerting greater pressure on India's power sector.

Figure 1.2. Potential and installed renewable energy capacity, by type



Source: MNRE Website (as of December 31, 2009).

Figure 1.3. Actual (2007–08) and projected (2031–32) installed grid capacity, by type of energy



Source: World Bank 2010.
Note: Solar power accounts for a negligible share of capacity in both years.

Natural gas also constitutes about 9 percent of India's current fuel mix and it is expected to go up to 20 percent in 2025, according to India's Hydrocarbon Vision, 2025. The International Energy Agency (IEA) estimates that nominal prices of coal will likely triple during the next two decades. Coal, gas, and oil prices have seen considerable volatility in recent years, and the trend will likely continue. At the same time, the cost of renewable energy is expected to fall significantly. Under the business-as-usual scenario of supply, energy diversification is expected to worsen because of the increasing share of coal generation.[11] The energy diversification index—measured as the sum of the squares of generation mix resources—is expected to decline by 20 percent between 2009 and 2032, from 0.42 to 0.35.[12]

Accelerating the use of renewable energy is also indispensable for improving air quality and the local environment and for meeting India's commitments to reducing its carbon intensity. The power sector contributes nearly half of India's carbon emissions. On average, every 1 GW of additional renewable energy capacity reduces 3.3 million tons of CO_2 a year. Reducing particulate concentrations is also estimated to save 334 lives for every million tons of carbon abated.[13]

Renewable energy has the potential to transform energy markets across the world. Globally, the clean technology industry is considered the next big high-tech industry (similar to the information technology and telecommunications sectors). Recognizing the sector's potential, China has made a strategic decision to lead the world in manufacturing solar, wind, and hydro equipment. As of 2008, it was the world's top producer of small hydropower equipment, solar water heaters, and solar photovoltaic panels, surpassing Japan. It has achieved a high level of domestic sourcing for most components for wind turbines and is expected to become the number one manufacturer in 2010.

India's early and aggressive incentives for the wind sector have led to the development of world-class players in the sector. The government's JNNSM has the potential to develop both domestic research and development (R&D) and manufacturing capability in the sector. Investing in renewable energy would facilitate the creation of globally competitive industries in wind, solar, and other technologies that can provide new opportunities for growth and leadership for corporate India.

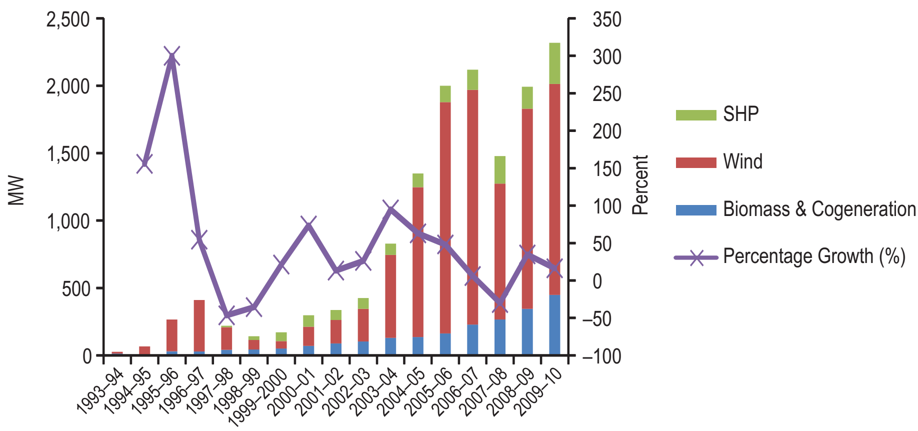
Renewable energy development can also be an important tool for regional economic development within India. Many of the states endowed with rich renewable energy potential (Arunachal Pradesh, Himachal Pradesh, Orissa, Uttarakhand) lag in economic development. Developing renewable energy in these states can provide secure electricity supply to foster domestic industrial development, attract new investments, create employment, and generate additional state income by allowing the states to sell renewable energy trading certificates to other states. Investments to develop the attractive renewable energy potential of these states would thus give a huge boost to their economies.

There are thus many good reasons for placing high priority on renewable energy development. Renewable energy should be developed, however, only if the economic benefits outweigh the costs. The economic rationale behind accelerating renewable energy growth must be made on a unified, nationwide, least-cost basis.

Strong Momentum behind Development of Renewable Energy

India ranks fifth in the world in terms of installed renewable energy potential, with more than 5 percent of the world's capacity in 2008.[14] Starting with the 10th plan period (1997–2001), India accelerated the pace of renewable energy development (figure 1.4). Renewable energy capacity increased by 6.7 GW—more than twice the target of about 3 GW—in 2002–07, according to MNRE. India's renewable energy installed capacity has grown at an annual rate of 31 percent, rising from about 2.5 GW in 2003 to about 15 GW in December 2009.

Figure 1.4. Additions to renewable energy capacity, 1993/94–2009/10



Source: MNRE 2009.

Wind

Wind energy dominates India's renewable energy industry, accounting for 70 percent of installed potential. The sector has received more support than any other renewable energy sector to date. Wind continues to be the biggest renewable energy sector in India, in terms of both current installed capacity (11 GW) and total known potential (45 GW).[15] Significant tax incentives—offering 100 percent (and later 80 percent) accelerated depreciation in the first year—have induced substantial investments by corporations and high net worth individuals in wind energy projects. State-level actions, such as preferential tariffs and special directives for wind, have also accelerated the development of the industry. Investments by the MNRE in the Wind Resource Assessment Program and establishment of the Centre for Wind Energy Technology, which serves as a focal point for the MNRE's research and development work in the wind energy sector, have also helped develop new wind projects. As a result, many strong private integrated technology and project development firms have emerged in the sector.

Although more than 99 percent of all investments in wind energy have come from the private sector, strong competition is lacking, and technology improvements and economies of scale have not reduced costs in the industry. On the contrary, the average capital costs increased from Rs 4/MW to Rs 6/MW between 2003 and 2008.[16] The increase can be at least partially attributed to continued use of accelerated depreciation, which has attracted investors who buy completed turnkey projects from equipment vendors and take profits from the accelerated depreciation and feed-in tariff.[17] Under the turnkey model, wind equipment manufacturers act as project developers; they do not face competition (as players in solar, small hydropower, and biomass do) in the supply of equipment. Although this model has enabled rapid growth of the sector and creation of strong domestic champions, it has discouraged a competitive equipment and technology selection. There are few established global technology leaders in the Indian market. As a result, the performance of commissioned projects has suffered and the cost of equipment soared. More important, there is no competition for the allotment of sites with good wind resources; investors who acquire the land control the resource, effectively blocking any competition. Wind energy installations in many other countries are provided a fixed feed-in tariff, which provides predictability but does not necessarily encourage competition with other power producers. Promoting competition might be an appropriate option for a sector that has reached maturity.

Small hydropower

Small hydropower—one of the least expensive and most attractive forms of renewable energy—lies largely untapped. It is a very attractive renewable energy source because it uses mature and largely indigenous technology and its maximum power production is in the summer, which coincides with peak seasonal demand in India. India has an estimated small hydropower potential of about 15 GW, of which about 2.5 GW has been developed. The pace of small hydropower development, which increased significantly during the 11th Plan period (2008–2012), has now stabilized. Development has been relatively slow because of long delays in getting clearances and acquiring access to evacuation infrastructure, lack of clear policy for private sector participation in some states, and issues associated with land acquisition. Small hydropower–rich north and northeastern states have lagged in tapping this resource. With their perennial Himalayan rivers, Himachal Pradesh, Jammu and Kashmir, and Uttarakhand have 65 percent of India's small hydropower resource and among the lowest generation costs. Despite these advantages, resource utilization is only in the low to mid teens.[18] Raising the utilization rate requires immediate attention.

Biomass

Biomass has huge potential in an agrarian economy like India. Generation costs for biomass are similar to those of wind.

Like small hydropower, biomass remains largely underdeveloped. According to the MNRE, India has nearly 700 million tons a year of biomass agri-residues, of which about a fifth can be used for electricity generation. (The rest goes to alternative usages, including household and small business heating, animal fodder, and packaging.) This biomass could produce about 17 GW of power.[19] The MNRE estimates that another 34 GW of power could be produced from wood and energy plantations on wasteland.[20] In addition, India has 61 GW of additional capacity of bioenergy, which includes agri-residues and biomass, from plantations.[21] Despite these resources, the sector is the least developed in India, with only about 0.8 GW (less than 5 percent) of potential realized to date.

Biomass has two unique characteristics. First, biomass plants require large quantities of fuel input for operations (biomass feedstock), which requires a well-developed supply chain. This disadvantage is also a strength, because biomass is the only renewable energy technology that can serve as a reliable alternative to diesel. However, the presence of multiple middlemen, difficulties in administering and enforcing agricultural contracts, and the development of wastelands have led to underdeveloped fuel supply chains.

Second, the sector suffers from lack of reliable resource assessment. The development of the biomass industry has been limited to only a few states, such as Andhra Pradesh and Tamil Nadu. Significant potential exists in economically underdeveloped states like Uttar Pradesh for developing biomass. Developing biomass in such states is a win-win strategy, as it can both reduce the electricity shortage and provide farmers with reliable additional sources of income.

Co-generation

Co-generation is a highly cost-effective and industrially attractive generation source that is gaining industry attention. With the ready availability of low-cost and abundant fuel supply, the levelized costs are lower than those of even small hydropower.[22] The potential to reach higher efficiencies in heat recovery and usage also make it an attractive energy source. India has about 5 GW of estimated co-generation potential from sugarcane, paper making, and other agriprocessing industries, of which only about 0.2 GW had been realized as of December 2009.[23] Interest in this source has been growing.

Solar

Solar power represents a strategic long-term solution for India. An extensive program is planned as part of the JNNSM.

India has an estimated 50 MW/km^2 of potential solar power,[24] of which only about 9 MW had been developed as of December 2009, because generation costs are even higher than those for diesel. There is a huge potential for solar energy applications in grid-interactive solar power generation plants, solar thermal industrial applications, rural electrification, roof top–based applications and mobile towers in off-grid areas, and domestic water heating. As one of the eight missions under the National Action Plan on Climate Change (NAPCC), the JNNSM pursues ambitious goals on generation capacity additions from solar technology (solar thermal and solar photovoltaic) in terms of both grid-connected and off-grid applications. Implementation will take place in three phases—Phase I (2009–13), Phase II (2013–17), and Phase III (2017–22)—to achieve the target of deploying 20 GW of solar power by 2022. Milestones to reach this target include ramping up the current capacity of grid-connected solar power generation to 1 GW by the end of Phase I and adding 3 GW of capacity through mandatory renewable purchase obligations (RPOs) by utilities coupled with preferential tariffs by 2017.

Meeting the targets set by the JNNSM will be a challenge. Solar plants have high capital costs because of expensive input material and the high cost of components. Adequate solar radiation levels for large-scale solar generation also require the availability of transmission infrastructure to evacuate power from the project location; large stretches of flat land, particularly for parabolic trough systems; and continual water supply to generate steam and cool turbines, in the case of solar thermal plants. Solar technology also requires high precision–engineered components, such as parabolic mirrors and receiver tubes, which are not available locally. Because of limited field experience and data, process standardization and quality benchmarks are not uniform across projects under preparation, with each manufacturer imposing its own standard. The level of customization means that equipment has to be commissioned on a project-by-project basis, preventing manufacturers from enjoying economies of larger scale production. The problem is accentuated by the lack of a learning curve and data gained from ground-level experience for simulating capital and operating costs for potential projects.

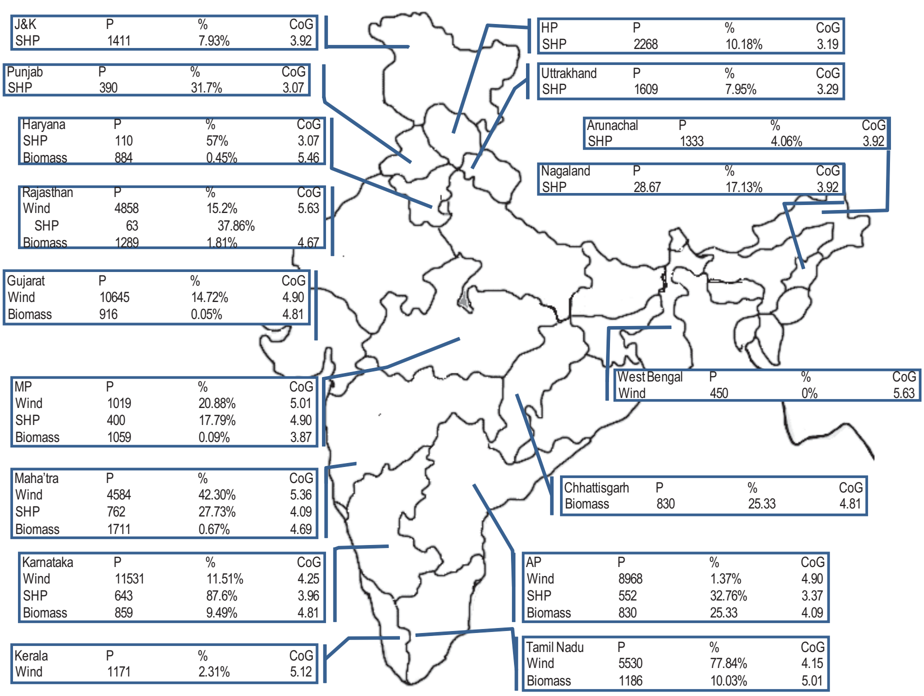
India's Ambitious Targets for Renewable Energy Development

India needs to step up the development of its renewable energy–rich but underdeveloped states. Although national policies enable renewable energy, the pace of development depends largely on each state's policy and regulatory support. State-level renewable energy policies, specific feed-in tariff and RPO programs from state energy regulatory commissions (SERCs), utility evacuation programs, clearance mechanisms, open access policies, and capacity of state nodal agencies all have significant influence on the pace of renewable energy development.

Renewable energy development has lacked an integrated national economic perspective and has been largely driven by uncoordinated state policies. Many states with the richest renewable energy resources lag farthest in development. Himachal Pradesh, Jammu and Kashmir, and Uttarakhand have 65 percent of India's small hydropower resources, thanks to the rich natural resources of the perennial Himalayan rivers in the northeast states. Despite these resources, their combined installed capacity is less than the combined capacity of Andhra Pradesh and Karnataka (figure 1.5). Much of the economically attractive wind potential in Orissa or the biomass potential in Madhya Pradesh also lies largely undeveloped. With credit trading mechanisms in place and key barriers removed, renewable energy could be a source of both substantial investment and income generation for these states.

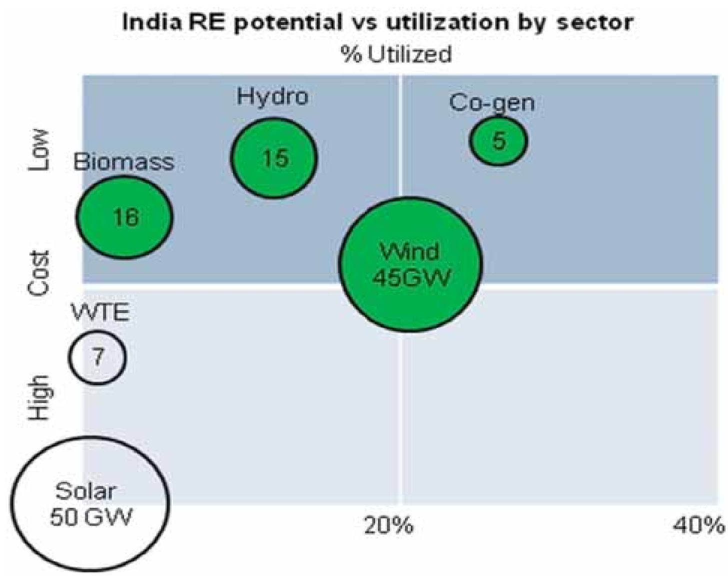
India needs to address uneven development across renewable energy sectors. Although all renewable energy technologies have been underused, small hydropower and biomass sectors need special attention (figure 1.6). Both sectors have attractive economics. In fact, the generation costs of small hydropower are comparable to those of thermal generation sources, and the generation costs of biomass are comparable to those of wind.

Figure 1.5. Potential capacity, installed capacity, and cost of generation of renewable energy sources, by state as of fiscal year 2009–2010



Source: MNRE, authors.
Note: P: potential; I: installed capacity; CoG: economic cost of generation.

Figure 1.6. Cost and use of renewable energy potential



Source: Authors' calculations.

Small hydropower development is held back by the large number of clearances required during the development cycle; the biomass sector is paralyzed by spiraling fuel costs. Although these sectors may not have the private sector clout of wind or the technology appeal of solar, they need at least as much policy attention as those sectors to overcome these barriers.

Realizing the need to bridge this gap, the government has set ambitious targets for renewable energy development. It aims to increase installed capacity to 55 GW by the end of the 13th Five-Year Plan.[25] The NAPCC has set a goal of increasing annual renewable energy generation by 1 percent a year,[26] which may require 40–80 GW of additional capacity of renewable energy capacity by 2017, depending on the plan capacity factor.[27] The JNNSM has set an ambitious target of adding 20 GW of solar capacity by 2022, up from current installed capacity of 9 MW. It also seeks to amend the 2006 national tariff policy to mandate that the SERCs fix an RPO percentage for the purchase of solar power, which could start at 0.25 percent in Phase I and go up to 3.0 percent by 2022.

Accelerated growth in renewable energy is possible, however daunting it may seem, as the experience of other countries and some states in India reveals. China increased its installed wind capacity by a factor of 21 between 2004 and 2009, from 1.2 GW to more than 25 GW. Even within India, several positive experiences indicate that a high level of renewable energy potential realization is indeed possible. For instance, faced with the right financial incentives, Tamil Nadu has developed more than 70 percent of its rich wind potential. If states such as Andhra Pradesh and Karnataka, which have similar costs for wind, would do the same, they would create 12 GW of additional wind capacity. High realization has been achieved in other sectors as well. For example, 85 percent of the known small hydropower potential in Karnataka and the biomass potential in Andhra Pradesh and Chhattisgarh has been tapped.

Notes

1. This review examines the renewable energy sector only from an electricity generation point of view. The many applications for leveraging renewable energy resources in areas such as decentralized household lighting, commercial cooking, residential heating and hot water, industrial heating, and power generation and transportation through the use of biofuel generation are not covered.
2. World Bank (World Development Indicators, 2010).
3. Ministry of Power, June 2009 http://powermin.nic.in/JSP_SERVLETS/internal.jsp.
4. World Energy Outlook 2007.
5. National Sample Survey Organization, Ministry of Statistics and Program Implementation 2007.
6. Central Electricity Authority 2009.
7. Central Electricity Authority, April 2009.
8. http://planningcommission.nic.in/reports/genrep/rep_intengy.pdf.
9. Integrated Energy Policy, Planning Commission, 2006, p. 20.
10. Planning Commission, India 2006.
11. World Bank, 2010. "Energy intensive sectors of the Indian economy: Path to low carbon development." South Asia Sustainable Development. See discussion in chapter 2.
12. The Herfindahl index, a measure widely used to describe the concentration of firms in an industry, is used here to quantify the diversity of the generation mix.
13. Bussolo, Maurizio, and D. O'Connor, 2001. *Clearing the Air in India: The Economics of Climate Policy*.
14. REN21 (2009) Renewables Global Status Report: 2009 Update, REN21 Secretariat, Paris, www.ren21.net/pdf/RE_GSR_2009_update.pdf, p. 11.
15. MNRE figures of estimated renewable energy potential, achievement as of December 31, 2009.
16. The estimation of capital cost in this study is based on a review of wind tariff orders by SERCs and review of about 50 wind-based power projects in India (UNFCC).
17. The increase in global demand between 2004 and 2008 could have also contributed to price increases.
18. PwC.
19. As per MNRE estimates of renewable energy potential as of December 31, 2009.
20. Biomass Atlas prepared by MNRE and Indian Institute of Science 2000.
21. Biomass Atlas prepared by MNRE and Indian Institute of Science 2000.
22. Levelized costs are the present value of the total cost of building and operating a generating plant over its economic life, converted into equal annual payments and allocated as per unit electricity generation costs.
23. As per MNRE estimates of renewable energy potential as of December 31, 2009.
24. As per MNRE estimates of renewable energy potential as of December 31, 2009.
25. Report of the Working Group on New and Renewable Energy for the 11th Five Year Plan (2007–12), Government of India, Ministry of New and Renewable Energy, December 2006, p. 56.
26. National Action Plan on Climate Change, Government of India, Prime Minister's Council on Climate Change, p. 43.
27. The 40 GW figure assumes a 40 percent plant capacity factor. The average plant capacity factor in India is about 20 percent. If the efficiency of plants of generation is not improved, the additional capacity requirement will be as much as 80 GW.

CHAPTER 2

How Much: Economic and Financial Potential of Renewable Energy

This chapter compares the economics of renewable energy and conventional generation and develops a national profile of economically viable renewable energy supply using a project database created for this study (box 2.1). It evaluates the potential and financially viability of renewable energy under current conditions from both the utility and developer point of view. It also estimates the volume of generation that is economically feasible and presents an indicative renewable energy supply curve in order to identify priority areas for development. The analysis presents a lower bound of benefits. The focus is on understanding the availability of renewable energy capacity compared with its opportunity cost of generation.

The analysis suggests that about 3 GW of renewable energy is economically feasible at the avoided cost of coal-based generation of Rs 3.08/kWh, all of it from small hydropower. About 59 GW of renewable energy in wind, biomass, and small hydropower is available at less than Rs 5/kWh. The entire cumulative capacity of 68 GW in these three

Box 2.1. Creating a renewable energy project database

The dataset used for this analysis includes capacity and cost information for renewable energy generation in 20 Indian states. The cumulative capacity of the states in the dataset is 68 GW, including 13 GW in installed capacity and 55 GW in unharnessed potential. A sample size of 180 projects covers the major renewable energy technologies (wind, small hydropower, and biomass).

Data were collected for key parameters, such as total capital cost, capacity, year of commissioning, and capacity utilization factor. For biomass projects, data on fuel cost, type of fuel, and gross calorific value were also collected. Secondary sources, primarily project design documents and monitoring reports on renewable energy projects in India and data from the United Nations Framework Convention on Climate Change (UNFCCC) website, were also used. Data for 136 renewable energy projects (wind, biomass, and small hydropower) were taken from the UNFCCC website. For small hydropower projects, data on 44 projects was taken from the World Bank project India Renewable Energy Development Agency (IREDA)–II. This information was supplemented by stakeholder consultations and recent norms established by the Central Electricity Regulatory Commission (CERC) on the technological and financial attributes of renewables. The CERC norms are indicative and have not yet been adopted by all states.

Source: Authors.

technologies can be harnessed at less than Rs 6/kWh. About 62 GW—90 percent of cumulative renewable capacity in wind, biomass, and small hydropower—is economically feasible when the environmental premiums on coal are brought into consideration.

The financial incentives for state utilities to buy renewable power are substantial only when compared with short-term power procurement. The feed-in tariffs for wind, small hydropower, and biomass are typically lower than short-term power purchase cost such as trading and unscheduled interchange (UI) charges. The savings from investing in renewable energy rather than purchasing short-term power can be significant. Utilities therefore need to be incentivized to develop their ability to diversify the energy mix. Full implementation of RPOs and renewable energy certificate (REC) mechanisms would help address this concern. The core of the electricity supply procurement in utilities still lie with power purchase agreements (PPAs) with coal- or gas-fired plants. At the opportunity cost of coal-based generation, renewable capacity is not financially available. About 5 GW of capacity is available at the cost of gas-based generation, and the entire capacity of wind, biomass, and small hydropower is viable at diesel-based generation cost. Solar power is not financially viable at any of the opportunity costs without subsidies or preferential tariffs.

Economic Viability of Renewable Energy Generation

India's renewable energy potential is both large and varied. The estimated technically feasible potential of renewable energy is estimated to be 150 GW, of which about 76 GW is in the relatively active wind, small hydropower, and biomass sectors. However, the high up-front cost of renewable energy generation compared with conventional energy sources has often posed a barrier to their development. A more economically competitive picture emerges when an environmental premium is imposed on the cost of conventional sources.

The trends in international fuel and equipment markets are likely to favor renewable energy technologies. Among the technologies considered here, fuel expenses form a substantial part of total cost only for biomass. The largest cost component is the high up-front capital costs of equipment. Fuel costs constitute the largest proportion of total economic costs for thermal generation, which is therefore exposed to future input inflation. Given the structural changes in global oil markets in the past decade and the accelerating global demand and shrinking supply of known fuel sources, fuel costs are projected to increase consistently in the coming decades. According to the International Energy Agency, demand for fossil fuels in the base reference scenario is expected to increase by 77 percent by 2030. In volume terms coal is expected to have the largest increase: its share in primary energy demand will rise from 27 percent to 29 percent between 2007 and 2030. The average real price of coal is projected to rise from $65/ton in 2009 to $100/ton by 2020 and $110/ton by 2030. Oil is expected to follow a similar trend, with the average price projected to rise from $65/barrel to $100/barrel by 2020 and $115/barrel by 2030 ($190/barrel in nominal terms).[1]

In contrast, the costs of capital equipment for renewable energy have been decreasing and are likely to continue to decline as technology advances. The levelized cost of onshore wind power is projected to fall to $5.3/kWh for high wind sites by 2015. Offshore wind costs are projected to fall about 20 percent by 2020 (in 2006 prices). The cost of solar photovoltaic systems is projected to fall from about $4/W in 2009/10 to $1.9–$2.2/W in

2020 and $1.07–$1.23/W in 2050. Electricity generation costs are projected to be in the range of $0.05–$0.07 kWh at sites with good irradiation. The U.S. Department of Energy has set the objective of making concentrated solar power competitive with carbon-constrained base-load power by 2020. Similarly, the JNNSM expects to bring the solar cost to parity with grid electricity.[2] These trends in the cost of conventional and renewable power are expected to make renewable energy sources more cost competitive than conventional sources. Fossil fuels are also exposed to frequent market shocks and high price volatility. Although domestic coal and gas prices are controlled by the government in India, a significant share of fuel supply is imported, which increases the risks associated with supply and price. For example, the average price of steam coal imported by OECD countries jumped from $74/ton in 2007 to $121/ton in early 2009; by mid-2009 it had dropped back to $90/ton.[3] Price volatility is one of the major market risks of fossil fuels. It can be mitigated by using financial instruments (hedging) or diversifying the portfolio with renewable energy. Hedging is not costless, however, and the risk is merely shifted, not eliminated. Moreover, hedging may not be beneficial for consumers, because it can reduce available generation when prices rise.

Renewable energy costs more than conventional energy on a stand-alone basis, but the picture changes when it is considered as part of the fossil fuel generating mix. Using portfolio analysis that adds in the fixed cost of renewable energy technologies to a fossil fuel–based portfolio reduces the overall risk and cost.[4] Renewables are the only free hedging mechanism against price volatility of fossil fuels. The risk-adjusted cost of renewable energy is lower than that of fossil fuel–based fuels, and their use enhances the price certainty of the portfolio and increases energy security. Every megawatt of nongas generation in the United States saves consumers $7.50–$20.00, and a 1 percent natural gas reduction results in long-term price reductions of 0.8–2.0 percent.[5] Fossil fuel volatility also hurts employment and GDP growth in oil-consuming and -producing nations. In the United States, for example, oil price volatility imposed $7 trillion in additional costs between 1970 and 2000.[6] In India spending on oil and gas imports is expected to increase from 4 percent of GDP in 2010 to 6.9 percent of GDP in 2020.

The availability of indefinite quantities of coal is also being challenged in India. Traditionally, it was believed that all proven reserves were extractable and that India had enough coal for 200 years. The Integrated Energy Policy (2006) suggests that if India continues to extract domestic coal at the rate of 5 percent a year, total extractable coal reserves will be exhausted within 45 years (box 2.2).[7]

Box 2.2. Coal and gas shortages in India

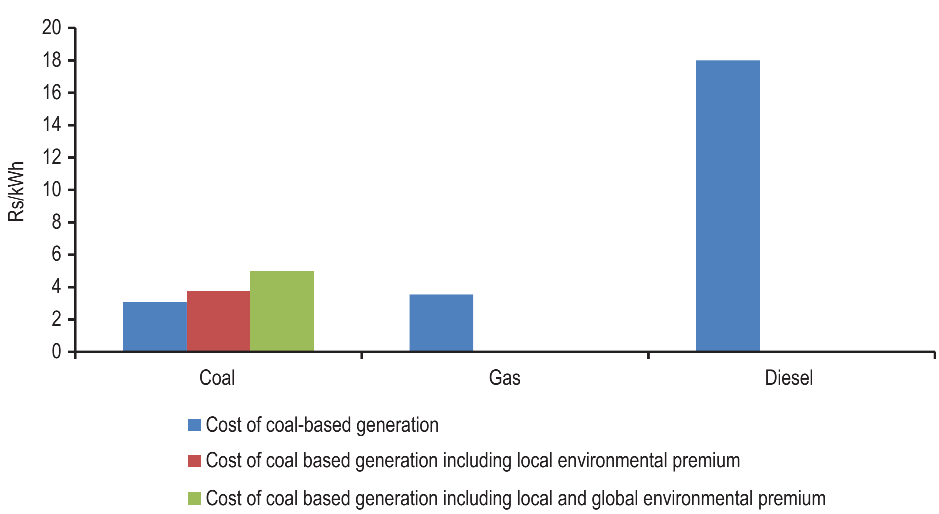
One of the major reasons for the shortfall in electricity supply in India over the past five years has been the shortage of coal and gas. In July 2005, 22 of 75 coal power stations (with a total capacity of 61,000 MW) faced severe coal shortages, even though all stations are required to maintain 15–30 days of coal stocks for emergencies. The NTPC Ltd., India's largest thermal power generator, ran short of gas to power its plants and had to resort to more expensive naphtha to operate some plants. In 2008, its 1,000 MW Simhadri project, in Andhra Pradesh, faced similar shortages of coal, with stocks falling to only 4 days against a norm of 25.*

Source: Authors.
* http://www.livemint.com/2008/08/2901.

The cost of coal-based generation can be considered the opportunity cost of building a renewable energy project. Given coal's predominance in India's electricity generation mix (it accounts for 53 percent of installed capacity), it is likely that a coal-powered power plant would be built instead of a renewable energy project. However, it is now recognized that coal is not the only fuel source that will meet India's energy needs. India is diversifying to other sources, not only for energy security, but also to facilitate growth on a low-carbon path. Therefore, the marginal plant could be gas based as well. If no alternative power plant is built, the avoided cost is the cost of diesel-based generators, for which households and businesses pay exorbitant amounts. The declared captive power capacity is estimated at 22 GW (17 percent of India's total installed generation capacity). The economic costs are estimated to be Rs 3.08/kWh for coal-based generation and Rs 3.5 kWh for gas-based generation (these costs are free of taxes and subsidies and assume that the fob (free on board) price of coal is $80/ton and the power plant is less than 680 kilometers from the port) (figure 2.1). Fuels, such as coal and gas include intrinsic subsidies and represent a lower bound, as the market price does not fully capture their scarcity value. The economic price of diesel at Rs 45/liters (as opposed to the regulated price of Rs 30/liters) results in a cost of diesel generation of Rs 18/kWh (box 2.3).

The global and local environmental premium associated with coal-based generation is estimated at Rs 1.88/kWh. The valuation of local air pollutants in India is very much dependent on how health and environmental benefits are measured. A major study by Bussolo and O'Connor (2001) uses a computable general equilibrium model to estimate the ancillary benefits of policies that reduce carbon emissions.[8] It models the links between emissions and concentrations of NOx, SO_2, and particulates at the regional level (the concentrations of major pollutants in major cities were modeled as a function of emissions in four regions of the country). The estimated ancillary benefits—defined in terms reduced mortality and morbidity caused by reduced particulate concentrations—

Figure 2.1. Avoided cost of coal-based generation



Source: Authors.

Box 2.3. Definition of economic cost and benefit

The economic cost of renewable power generation captures the total investment cost incurred by the economy to produce it. The levelized economic cost is discounted at a 10 percent rate, which is typically used for economic analysis. The economic cost is estimated net of taxes and subsidies imposed by the government.

The economic benefit of renewable energy is measured by opportunity or avoided cost. The cost of building the marginal coal power plant is considered the economic value of developing renewable energy. In addition to the base cost of building a coal-based power plant, there are associated local and global environmental effects because of the increase in carbon emissions at the global level and the contribution to local environmental damage. Reducing such damages through renewables raises the avoided cost of generation and represents the competitive advantage of renewable resources.

Assessing the competitiveness of renewable energy involves comparing the economic cost of coal-based generation with and without environmental premiums. The other avoided fuels considered are gas and diesel, which are used on a long-term basis to generate power.

The renewable energy supply curve shows the economically viable quantity of renewable energy that can be supplied at a given price. This curve intersects the avoided cost of coal generation at a specific point, identifying the economically optimal level of renewable energy supply. The supply curve is prepared by arranging the cost of generation for renewables for different states in ascending order and superimposing the cumulative capacity (installed capacity and unexploited potential) (figure 2.3).

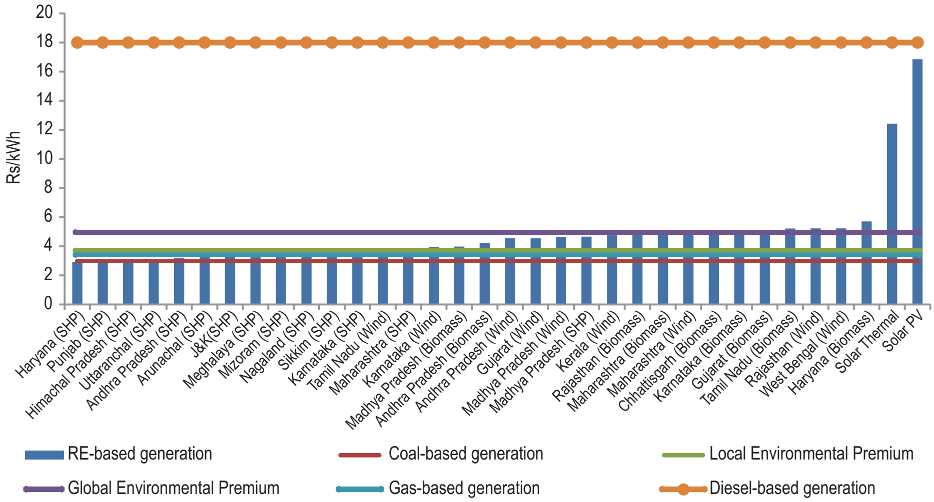
Source: Authors.

are 334 lives saved/million tons of carbon abated, or $58/ton (at the 1995 exchange rate and 1995 prices) of carbon emissions reduced in monetary terms. A one-ton reduction in carbon emissions is thus associated with a reduction in local pollutants worth about $58 in 1995 dollars ($93 in 2008 dollars). The local environmental premium thus amounts to Rs 0.66/kWh.

Generating electricity from renewable sources implies that an equivalent volume of coal used to generate the same amount of electricity is not burned. The pricing of CO_2 emissions in the European Union at $10/ton presents the financial price and the lower bound of valuation. This price reflects a limited market, in which modest targets for reducing CO_2 from large combustion sources in the European Union are set. It is not the cost of a ton of CO_2 in terms of damage caused or a measure of the price at which a ton of savings of CO_2 generated from the project would sell. The cost of a ton of CO_2 in terms of damage caused is considerably higher than $10. It is more appropriate to use the unit damage values arising from CO_2: $32/t$CO_2$ has been employed in this report as the global value of carbon emissions.[9] The global environmental premium thus amounts to Rs 1.22/kWh. However, the global environmental benefits may not be fully translated into monetary terms if there is a global climate agreement.

Small hydropower is the most economically viable form of renewable technology, with an average economic cost of Rs 3.56/kWh. This resource is the most attractive in Haryana, Punjab, Himachal Pradesh, Uttaranchal, and Andhra Pradesh, where the cost is less than the average cost. With the exception of Andhra Pradesh, these states are located in the north. Together they have unharnessed potential of about 5 GW (figure 2.2). At this cost of generation, small hydropower is competitive with the avoided cost of

Figure 2.2. Economic cost of generating power using renewable energy, by state (Rs/kWh)



Source: Authors.

coal-based generation, highlighting the need to address institutional barriers for small hydropower in these states, including through integrated approaches to evacuation infrastructure development and clearances (elaborated on in chapter 3).

The average economic cost of generation is Rs 4.6/kWh for biomass and Rs 4.9/kWh for wind. These costs are competitive with gas- and diesel-based generation. However, the availability and price fluctuations of biomass under a regulated market pose a significant risk to scale-up. The economic cost of biomass-generated power ranges between Rs 3.9–Rs 5.7/kWh. The generation cost of wind is highly sensitive to the capacity utilization factor, which is low (about 23 percent). The economic cost of wind power ranges between Rs 3.8–Rs 5.2/kWh. A substantial proportion of wind capacity (about 37 GW) is in the four states of Andhra Pradesh Gujarat, Karnataka, and Tamil Nadu.

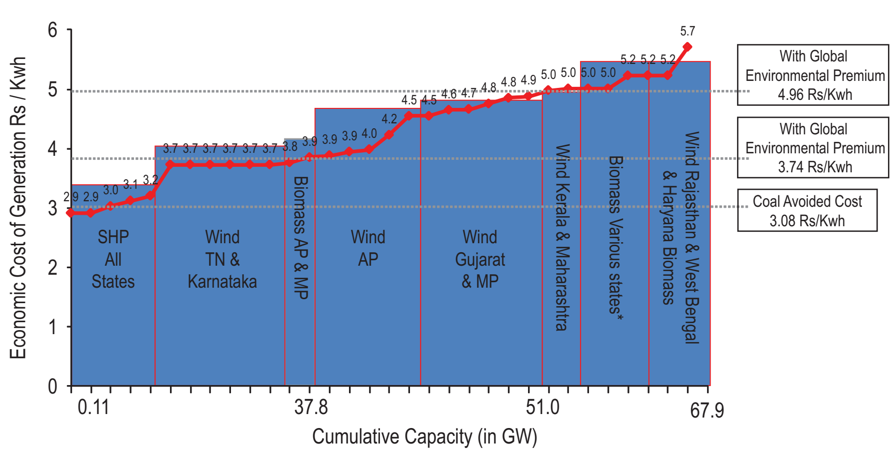
Solar power is the most expensive renewable resource. Unit costs are estimated to be Rs 12/kWh for solar thermal and Rs 17/kWh for solar photovoltaic—comparable to or lower than the cost of diesel-based generation.[10] Solar technologies become even more competitive when the associated environmental externalities of diesel-based generation are taken into account.

The high cost of production reflects the high capital cost and low plant-load factor compared with other renewable technologies. The capital costs of generating 1 MW of power are Rs 170 million (with a plant- load factor of 19 percent) for solar photovoltaic and Rs 130 million for solar thermal (with a plant-load factor of 23 percent). However, the economics of solar power are expected to improve significantly over the next two decades.

The economy can afford to supply about 3 GW of renewable capacity at minimum avoided cost of Rs 3.08/kwh, all of it from small hydropower. The renewable energy supply curve intersects the local environmental benefits curve (the cost of coal generation + the local environmental premium) at 9 GW and the global environmental curve (the cost of coal generation + the local environmental premium + the global environmental premium) at 62 GW, suggesting the attractiveness of renewables when avoided cost, including the environmental premiums, is considered (figure 2.3). About 90 percent of cumulative renewable capacity of 68 GW in wind, biomass, and small hydropower is available when the local and global environmental premiums of coal are brought into consideration. Therefore, development of a substantial volume of renewables is economically justified within the context of an aggressive low-carbon strategy in which environmental impacts are added to the alternative or avoided cost of energy generation. The total cumulative capacity in wind, small hydropower, and biomass is available at less than Rs 6/kwh. This cost, though higher than coal- or gas-based generation, is still about one-third the cost of diesel-based generation. Solar is still not economically viable in India unless compared with the avoided cost of diesel-based generation.

The availability of renewable capacity is sensitive to changes in the cost of coal-based generation. The renewable energy supply curve is based on the assumption of an imported coal cost of Rs 3.08/kWh, which is a proxy for the market price. This cost is not significantly higher than the regulated domestic cost of coal-based generation (Rs 2.98/kWh). As the government moves toward aligning domestic prices to market dynamics, it is expected that there will be an increase in cost, implying a competitive advantage to renewable energy. If the cost of domestic coal–based generation rises 10 percent (to Rs 3.3/kWh), about 5 GW of renewable energy will be available; 61 GW can be exploited if all environmental benefits are considered. If costs rise 20 percent (to Rs 3.6/kWh), 5 GW will be available (67 GW if environmental premiums are factored in). The rate used to discount economic flows of renewable energy also affects the volume of renewable capacity. With a discount rate of 5 percent, about 4.4 GW of renewable capacity will be available and 54 GW can be harnessed if all environmental impacts are considered on top of the avoided cost of coal-based generation.

Figure 2.3. Economic competitiveness of wind, biomass, and small hydropower



Source: Authors.
Note: The economic costs of generation include all capital, operational, and financial expenses and exclude all taxes and subsidies.

Box 2.4. Definition of financial cost and benefit

The levelized financial cost represents the cost developers face in undertaking a renewable energy project. The total financial cost, inclusive of taxes and exclusive of subsidies and customs duty savings, is defined as the sum of operating and financial charges. The total financial cost is discounted using a rate of 16–17 percent (depending on the technology used) over the life of the asset. The taxes levied on developers are the corporate tax rate of 33.99 percent and the minimum alternate tax of 16.99 percent. For all technologies, a 10-year tax holiday for corporate tax rate applies. Developers are required to pay these taxes only after the initial period of development is completed.

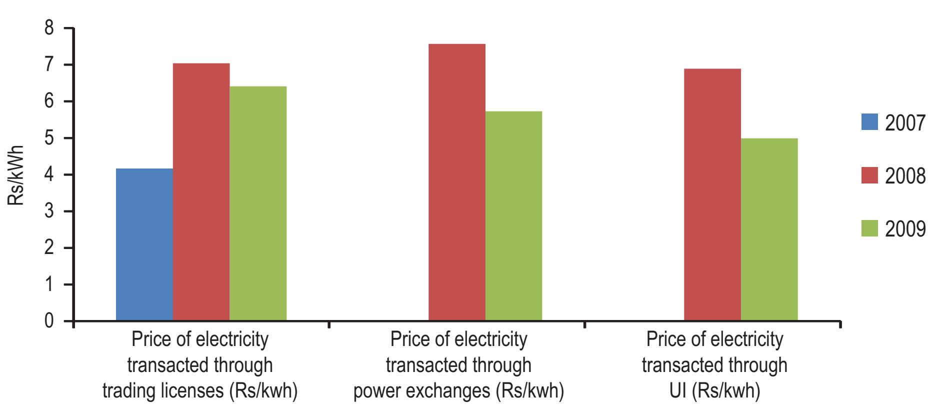
Although the tax rate is similar across technologies, the unit burden of taxes differs depending on the capital cost, which ranges from Rs 0.09/kWh for biomass to Rs 1.8/kWh for solar photovoltaic. Subsidies for renewable energy come in various forms, such as accelerated depreciation for wind and solar development and generation-based incentives in wind power and capital subsidies for small hydropower and biomass, with special consideration for the states of Himachal Pradesh and Uttaranchal. Subsidies can range from Rs 0.02/kWh for biomass to Rs 0.98/kWh for solar *photovoltaic*. In addition, customs duty savings are provided for wind (Rs 0.21/kWh) and biomass equipment (Rs 0.14/kWh).

Source: Authors.
Notes: a. CERC Notification No. Eco 2/2008-CERC for guidelines on tariff determination
b. The developers are required to pay the minimum alternative tax even in the tax holiday period

Viability of Renewable Energy Generation from the Perspective of the Utility and Developer

The financial opportunity cost of developing renewable energy includes both the long-term cost of procuring power and short-term trading prices (box 2.4). A "short-term" transaction refers to contracts of less than a year procured through interstate trading licenses and directly by distribution licensees, power exchanges (the India Energy Exchange and Power Exchange of India Ltd.) and unscheduled interchange charges.[11] As of 2009, the short-term market represented about 8 percent of total energy generated in India.[12] The short-term trading cost is estimated at Rs 5/kWh–Rs 6.4/kWh, depending on the method used to procure power (figure 2.4).

Figure 2.4. Short-term traded cost of electricity, 2007–09

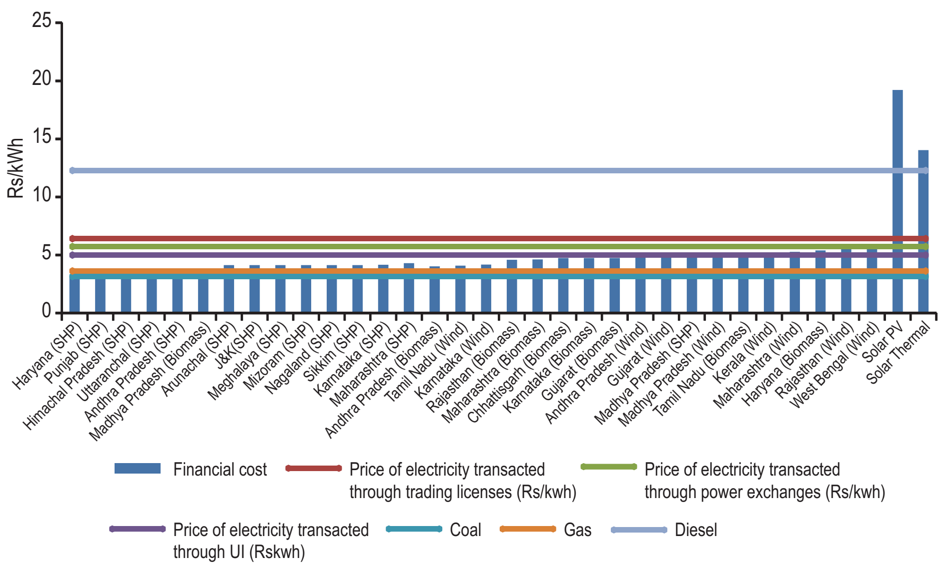


Source: CERC.

From the utility's point of view, buying renewable energy makes business sense only when compared with short-term power purchase cost. The cost of buying renewable energy at feed-in tariffs is significantly lower than any of the short-term methods of procuring power. The severe energy shortage in many Indian states has forced utilities to buy short-term power at often very high prices. The gamut of renewable energy in wind, biomass, and small hydropower will be available at below the lower bound of short-term prices. However, the bulk of power procurement still remains with PPAs with primarily coal- and gas-fired plants. The opportunity cost with which the utility chooses to compare its renewable energy expenses depends on the individual energy mix and future business plan. The prices facing the utilities are Rs 3.14/kWh for coal-based, Rs 3.6/kWh for gas-based, and Rs 12.3/kWh for diesel-based generation, inclusive of financial transfers (figure 2.5). At the cost of coal-based generation, renewable capacity is not available. About 5 GW of capacity is available at the cost of gas-based generation; the capacity of wind, biomass, and small hydropower is available at the cost of diesel-based generation. Solar power is not financially viable at any opportunity cost and requires additional support from the government. The JNNSM aims to provide that support by introducing several incentives, including bringing cost of solar energy to parity with grid costs. The utilities will need to be incentivized to ensure that investments in renewable energy make sound business sense.

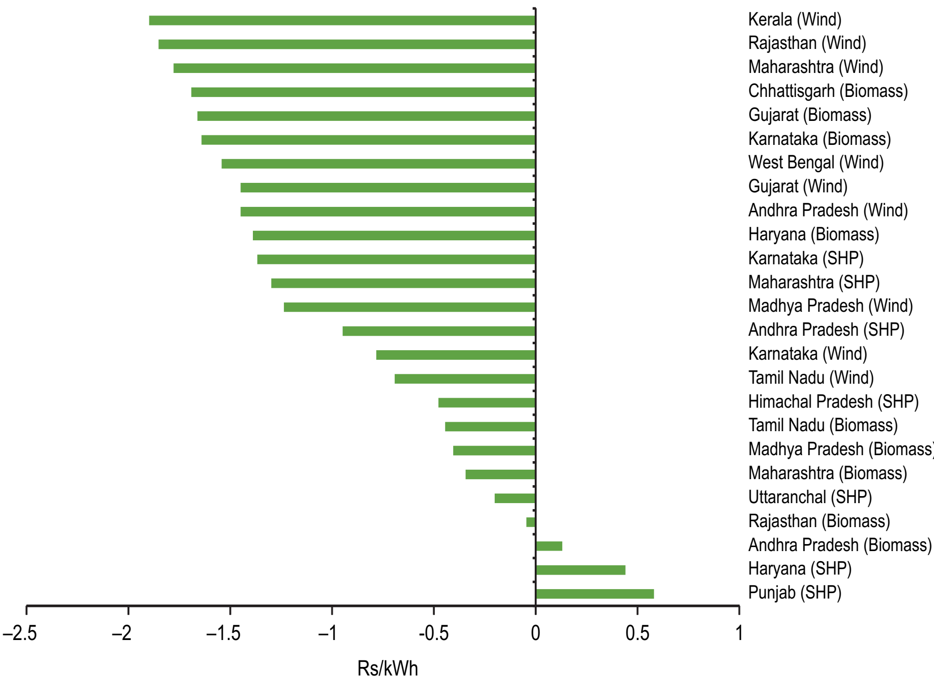
From the developer's point of view, financial barriers remain. In most cases (exceptions include Haryana and Punjab in small hydropower and Andhra Pradesh in biomass), tariffs are lower than the cost of production, in some cases by more than Rs 1/kWh (figure 2.6). Tariffs have to be more competitive to enable more private players to participate in the market for renewable energy generation.

Figure 2.5. Financial cost of renewable energy from the utility's perspective, by state



Source: Authors, based on data from CERC.

Figure 2.6. Gap between cost and tariffs of renewable energy, by state and energy source



Source: Authors calculations based on SERC tariff orders.

Achieving the government's goal for the next decade will require an annual subsidy of $1 billion–$6 billion, depending on choices made. This may change as the renewable energy certificate trading mechanism evolves. There is still significant scope for improving the bankability of renewable energy to attract developers to invest in renewable energy. To reach the goal of installing 40 GW of additional capacity of renewables in the next 10 years, the government could provide subsidies to achieve parity between the cost of renewable energy and coal-based generation (table 2.1) A back-of-the-envelope estimation is made by identifying the size of subsidy required to bring levelized cost of

Table 2.1. Resources required to achieve 40 GW of renewable energy

Scenario	Fuel mix (for 40 GW)	Total subsidy required (over 10 years)	Annual subsidy required
1	Wind (25 GW), SHP (5 GW), Biomass (10 GW)	Rs 777 billion	Rs 77 billion ($1.7 billion)
2	Wind (25 GW), SHP (15 GW)	Rs 450 billion	Rs 45 billion ($1 billion)
3	Wind (15 GW), SHP (20 GW), Biomass (5 GW)	Rs 493 billion	Rs 49 billion ($1.1 billion)
4	Wind (5 GW), SHP (5 GW), Biomass (10 GW), Solar PV (10 GW), Solar Thermal (10 GW)	Rs 2.98 trillion	Rs 0.29 trillion ($6 billion)

Source: Authors.

renewable energy to avoided cost (at a coal-based generation price of Rs 3.08/kWh). The amount is equal to the up-front capital subsidy or net present value of generation-based incentives. The estimated resource requirement ranges from Rs 450 billion (about $10 billion) for low-cost renewable energy but low diversity of renewable energy sources to Rs 2.9 trillion (about $64 billion) for high-cost renewable energy with significant diversity of renewable energy sources. Provision of low-cost renewable energy is not prohibitively expensive when spread over 10 years, with an annual bill of about $1 billion (table 2.1).

Notes

1. Energy Technology Prospective 2008, IEA.
2. Energy Technology Prospective 2008, IEA.
3. World Energy Outlook 2009, IEA.
4. Awerbuch, S., and M. Berger, 2006 "A Portfolio Approach to Energy Planning in Mexico." Draft report. *Instituto de Investigaciones Eléctricas*, Cuernavaca, Mexico.
5. Energy Technology Perspective, 2008; IEA, 2009.
6. Awerbuch, S., 2006, "The Value of Renewable: Portfolio Diversification, Energy Security, and Free Hedging." Paper presented at the International Grid-Connected Renewable Energy Policy Forum, February 1–3 Mexico City.
7. http://assets.wwfindia.org/downloads/re_thinking_coal_s_rule_in_india.pdf.
8. Bussolo, Maurizio, and D. O'Connor, 2001. *Clearing the Air in India: The Economics of Climate Policy with Ancillary Benefits*. Technical Paper 182. Paris: OECD Development Centre.
9. Markandya, A., B. G. Armstrong, S. Hales, A. Ciabai, P. Criqui, S. Mima, C. Tonne, and P. Wilkinson, 2009. "Health and Climate Change 3: Public Health Effects of Strategies to Reduce Greenhouse-Gas Emissions: Low-Carbon Electricity Generation." *Lancet* 374 (9706): 2006–15.
10. The National Solar Mission (2009) projects a 50 percent reduction in the capital cost by 2012. Such a scenario may render solar projects economically competitive, with a cost lower than that of diesel-based generation.
11. CERC 2010, *Annual Report: Short-Term Power Market in India*, New Delhi.
12. The development of a competitive power market was one of the cornerstones of the Electricity Act 2003, which facilitated trading at various levels.

CHAPTER 3

What: Establishment of an Enabling Environment for Renewable Energy Development

This chapter provides an overview of the legal, regulatory, and institutional framework in India and reviews unresolved issues raised in extensive discussions with representatives of industry, regulatory authorities, and other stakeholders. It presents 10 main barriers for developing renewable energy and 10 possible solutions. It indicates how the government could create a more conducive environment to attract private investments in renewable energy and examines how the strength of India's dynamic private sector could be better leveraged to meet its ambitious renewable energy goals. The chapter concludes by prioritizing proposed interventions and indicating a way forward.

In recent years India has established an overarching policy and institutional framework. However, multiple regulatory and institutional overlaps have led to ineffective coordination that has resulted in continuing implementation gaps. The barriers that hold back renewable energy development relate to three broad areas: the financial viability of renewable energy projects, the lack of soft and hard support infrastructure, and regulatory and process delays, which increase transaction costs.

Addressing financial issues requires streamlining financial incentives, moving to a market-based approach for setting tariffs, addressing concerns about financing renewable energy projects, creating new long-term funding sources, and most important, tapping into the private sector's willingness and ability to pay for renewable energy generation. Investments in support infrastructure need to be made to ensure timely transmission evacuation and access infrastructure, provide quality and easily accessible resource information, and catalyze the development of industry supply chains. Policy implementation must be made effective on the ground, and the capacity and capability of state nodal agencies should be strengthened to facilitate renewable energy development and reduce the cost of doing business for renewable energy investors. These efforts could be implemented in a gradual, risk-tolerant approach with emphasis on quick wins. Pilot programs could be launched around the idea of renewable energy parks, which could create integrated infrastructure for investors in renewable energy resource–rich areas.

The Current Operating Environment

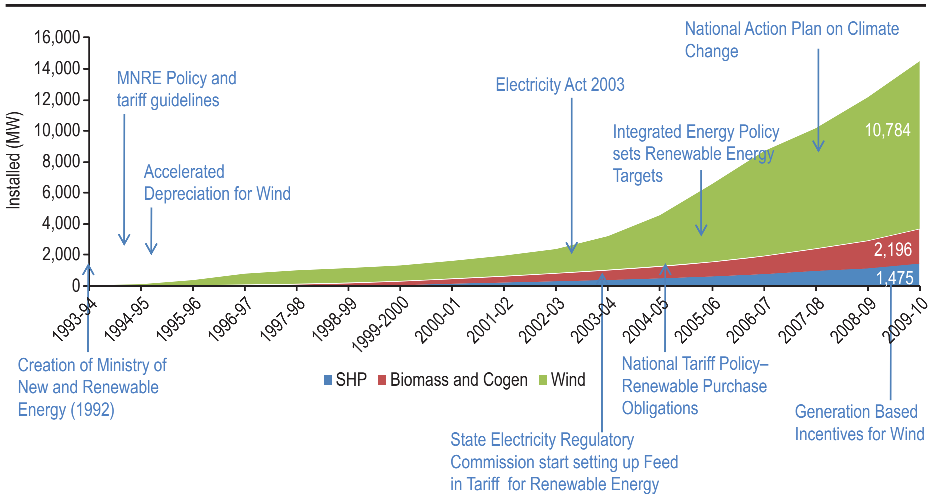
India has already put in place significant policy, regulatory, and financial incentives to encourage renewable energy development. The landmark Electricity Act 2003 aimed at fostering competition, private investment, and power for all. De-licensing generation and allowing open access probably had the greatest impact on jump-starting renewable energy development. The act explicitly recognized the role of renewable projects for supplying power to the utility grid as well as in stand-alone systems. It provided an overall framework for preferential feed-in tariffs and quotas for renewable energy. It also introduced a host of important reforms, such as allowing captive generation, establishing provisions for power trading, and allowing phased open access to both transmission and distribution. All these steps had a substantial impact on attracting private investment into the power sector. As a result, renewable energy capacity grew dramatically.

Subsequent initiatives, such as the National Tariff Policy 2005, articulated the government's vision of universal provision of "power to all" by 2012 and an increase in per capita consumption to 1,000 kWh by 2012.[1] The two policies established a strong framework for both supply-side incentives with preferential feed-in tariffs and demand-side stimulus with RPOs.

A number of dedicated institutions were created to facilitate development of renewable energy. On the institutional side, the MNRE has been playing a key role in catalyzing all aspects of renewable energy development, from resource mapping to R&D investment and promotional projects. On the financing side, the India Renewable Energy Development Agency (IREDA) has a long track record of providing financial support to renewable energy projects. Agencies for promoting renewable energy have been set up in most states as well. Although there are gaps in these institutions like inadequate capability at state nodal agencies and lack of adequate renewable energy financing, a nascent institutional infrastructure does exist for renewable energy on which future development can be built.

The impact of various policy and regulatory initiatives has been mixed. Of India's numerous policy and financial incentives, two have had the clearest correlation with installed capacity. The wind sector–specific efforts of the mid-1990s, including accelerated depreciation, preferential tariffs, and resource mapping initiatives, and the landmark umbrella Electricity Act 2003 have had the most tangible impact on the industry growth (figure 3.1). The link between other initiatives and sector growth is less clear.

Figure 3.1. Key legislation and increases in renewable energy capacity, 1993/94–2009/10



Source: PwC analysis for World Bank.

Table 3.1. Status of renewable purchase obligations, by state (2008–09)

State	RPO target (percent)	Actual renewable energy purchase (percent)	RPO met
Andhra Pradesh	5	4.5	No
Chhattisgarh	10	3.8	No
Gujarat	2	2.1	Yes
Haryana	3	0	No
Karnataka	7–10	9.	Yes
Madhya Pradesh	10	0.1	No
Maharashtra	5	3.1	No
Punjab	1	0	No
Rajasthan	6.25–6.75	7.	Yes
Uttarakhand	5	1.3	No

Source: RPO regulations and state tariff orders.

In 2009, significant policy initiatives were launched to address the gaps in two of the most important policy support instruments, the feed-in tariff, and the RPO (table 3.1). A key issue for the industry has been the lack of uniformity in feed-in tariffs across states. There is an urgent need for adequate capital cost benchmarks, periodic indexing of input prices, and harmonization of investment assumptions used to arrive at acceptable returns for renewable energy investors. In 2009 the CERC feed-in tariff regulation published a uniform feed-in tariff determination methodology for each renewable energy technology, based on market benchmarks of capital and operating costs, along with explicit price escalation factors.[2]

Another significant step was the introduction of the REC trading mechanism across states.[3] The CERC has notified regulations in respect of RECs. Once RECs become a functional and tradable instrument in India, it is likely that SERCs may recognize trading in them as one way of meeting an RPO. A few SERC orders already do so. REC trading can help overcome geographical limitations on renewable energy development, allowing deficit states to meet their RPO target from renewable energy resource–rich states while at the same time allowing the development of more cost-effective renewable energy sites (least-cost sites) across states regardless of state-level RPOs. This important policy enabler has an opportunity to create an integrated market for renewable investment across the country and to allow investments to flow freely across states to the most economically attractive resources.

The multiplicity of laws, regulations, and agencies governing the renewable energy sector makes integrated intervention difficult and undermines investor confidence. No single law governs the development of the renewable energy sector in India. Seemingly unrelated regulations—such as the Forest Conservation Act 1978, the Water Act 1972, the Air Act 1980 for prevention and control of pollution, and the Environment Protection Act 1986—all have a direct impact on how renewable energy projects are developed. In the absence of unified national legislation, multiple laws and policies govern development, often creating delays and conflicts. A single agency or institution often becomes a bottleneck, creating problems for the entire project development cycle.

Development of the renewable energy sector also depends on multiple institutions, which are empowered under different laws and often lack coordination. These institutions include the Ministry of Power, the MNRE, the CERC and SERCs, state governments, state nodal agencies, and regional electricity corporations (table 3.2). The lack of coordination among them leaves critical implementation gaps. The Ministry of Power is responsible for national electricity policy and national tariff policy, both of which play a key role in promoting procurement of renewable energy–based power. The MNRE has a direct mandate for renewable energy in all policy and programmatic aspects. The SERCs, which have the most direct impact on feed-in tariffs, RPOs, and open-access charges, are loosely bound by the directives and guidelines of the CERC. All central agencies have a state counterpart, which has the final say on how renewable energy projects are developed. Progress on the ground depends mainly on state-level policies on feed-in tariffs and RPOs, evacuation, clearances, open access, and facilitation from state nodal agencies. More often than not, one or more of these elements becomes a bottleneck in developing renewable energy projects.

Table 3.2. Roles of state and central government agencies in policy development, regulation, and promotion of renewable energy

Level	Central government (Ministry of Power/ Ministry of Finance)	MNRE	CERC
Central	• Develops national electricity tariff policies, which also cover renewable energy • Provides fiscal incentives for promoting renewable energy	• Develops national renewable energy laws • Sets technical standards for renewable energy • Conducts resource assessments for renewable energy; supports R&D in renewable energy technologies • Promotes effective use of information technology for renewable energy, manages database • Reviews renewable energy programs to understand their effectiveness and efficiency	• Sets guidelines for feed-in tariff design for different renewable energy technologies • Regulates the regional electricity corporation mechanism • Regulates interstate open access, and third-party sales
State	State government	State nodal agency	SERCs
	• Develops state- level renewable energy policy • Provides fiscal incentives for promoting renewable energy sources	• Conducts resource assessments for various renewable energy sources • Allocates renewable energy projects and progress monitors • Provides facilitation services to project developers —IREDA personnel escort project developers to various government departments with the objective of facilitating and streamlining clearances • Facilitates clearances and land acquisition • Creates awareness and educates the masses about adoption of renewable energy • Maintains database on renewable energy sources	• Develops feed-in tariff methodologies for different renewable energy technologies • Determines RPOs and enforcement mechanism • Sets regulations on intrastate wheeling, open access, and third-party sale

Source: PwC analysis for World Bank.

Creating a national renewable energy law and crafting an integrated policy would enable a coordinated national economic perspective and would help drive focus from fragmented uncoordinated state policies. It would also help provide better clarity on the rules of the game, the requirements to be followed, and the roles and responsibilities of different institutions involved in the development of renewable energy sources. Although doing so would not directly eliminate many barriers, it would set the stage and provide additional comfort to investors, particularly new entrants.

The Proposed Operating Environment

The barriers to an attractive operating environment for renewable energy development can be categorized into three broad groups: financial viability issues, regulatory hurdles, and lack of support infrastructure (table 3.3).

Table 3.3. Renewable energy barriers and suggested solutions

Type of barrier	Remaining issues	Suggested solutions
Financial viability	• Skewed financial incentives for facilitating investments in renewable energy • Too many incentive programs • Failure to adequately address utilities' long-term financial concerns • Failure to develop least-cost resources first • Inadequate long-term funding sources	• Provide streamlined, market-based government interventions • Create national renewable energy fund to mitigate impact on utilities • Enable direct purchase and distributed generation of renewable energy • Facilitate financing of renewable energy
Support infrastructure	• Inadequate evacuation and access infrastructure • Lack of good-quality data • Underdeveloped industry value chain	• Make renewable energy evacuation a high transmission priority • Introduce and enforce "take or pay" for renewable energy generation • Invest in high-quality, integrated resource monitoring systems • Catalyze R&D and supply chain innovations and investments
Regulatory approvals	• Delays in clearances and approvals • Long development cycle • Land and resource acquisition issues	• Move to unified, light-touch regulation for renewable energy • Strengthen state nodal agencies and state regulators

Source: Authors.

Issues related to financial viability

Renewable energy technologies require large initial capital investments, making the levelized cost of generation higher than it is for many conventional sources. Five barriers have a direct effect on the cost of renewable energy and the purchasing power of buyers.

- *Skewed financial incentives for facilitating investments in renewable energy*. The cost-plus approach to tariff setting, along with the technology-specific focus, has led to incentives that hinder the effective economic development of renewable energy resources in India. For instance, the combination of accelerated depreciation and a cost-plus mindset has failed to encourage cost competition in the wind sector. In contrast to most global markets, in which feed-in tariffs fall over time, tariffs in India have risen. This is a critical issue, as wind is one of India's most abundant and dominant renewable energy resources. Capital costs for wind plants rose from Rs 4/MW in 2003 to Rs 6/MW in 2008, despite technology improvements and adequate scale.[4] Feed-in tariffs for small hydropower producers do not adequately compensate for the high resource and other operational risks investors are likely to face over the 35-year investment time horizon assumed in CERC guidelines. Small hydropower is the only renewable energy resource for which the financial costs are higher than economic costs (because of unfavorable taxes and subsidy scheme). Many states are willing to pay well above Rs 4/kWh for wind electricity, while they can develop small hydropower for Rs 3/kWh. In a number of states small hydropower tariffs are even lower than tariffs for new coal- or gas-powered plants.

- *Too many incentive programs*. India offers every possible type of incentive, including feed-in tariffs; generation-based incentives; RPOs; central, state, and regional capital subsidies; accelerated depreciation; and tax incentives. The incentives are offered by different central and state agencies. Some have formulas that base the subsidy on nonlinear functions. The effect is unintended overlaps, reduced transparency and fiscal discipline, unnecessary complexity in claiming subsidies, and ineffective leverage for the amount spent on renewable energy development. An integrated and coordinated approach for financial incentives is urgently needed.
- *Failure to adequately address utilities' long-term financial concerns*. The regulatory framework is designed to allow the pass-through of renewable energy costs to consumers in the form of tariff revisions. However, it is contingent on utilities meeting the targets (for example, for loss reduction) set by the regulator. If the utility is unable to achieve a target, it tends to be saddled with losses that are not included in the average cost of power supply. Utilities also suffer when consumer tariffs are not revised on a yearly basis but the renewable energy feed-in tariffs are, leaving the utilities to make up the differential. Given cross-subsidies from high-tension industrial and commercial customers to certain consumer categories (such as agriculture and low-volume households), industrial customers look for ways to purchase cheaper power through third-party sales or captive generation. This, in turn, forces utilities and regulators to constrain open access in order to ensure that the utilities retain their paying consumers and remain financially secure. As a result, utilities have limited incentives to go out of their way to encourage renewable energy development.
- *Failure to develop least-cost resources first*. In some states, wind is more developed than less expensive sources of power, such as small hydropower and biomass. Solar power, the most expensive source of power in India, gets more attention and investment than much less expensive sectors, such as small hydropower and biomass.
- *Inadequate long-term funding sources*. There is real concern about the bankability of renewable energy projects because of high (real and perceived) risks by financiers. Tariff regulations lack an appropriate mechanism to minimize the risk of uncontrollable factors, such as biomass availability and price variation and hydrological and meteorological risks in small hydropower, wind, and solar. For instance, in small hydropower, high nontariff barriers—such as difficulties in obtaining clearances, the poor quality of project information, and hydrological risks—make the project risk very high for financiers. There is also often a mismatch between the tenure of available funds and the cash flow of renewable projects. In some cases (for example, solar energy), financiers are also reluctant

to accept the technology risk, possibly because they are unable to evaluate technical feasibility. This problem both limits access to finance and introduces a bias toward investment in fossil fuel–based technologies, whose risks are more easily understood and mitigated. As a result, most projects are financed on the promoter balance sheet and not on a project finance basis. In many cases, project developers have to assume the refinancing risk, making it difficult for new entrants and small- to medium-size developers to raise finance.

Issues related to support infrastructure

To catalyze investments in remote and renewable energy–rich areas, the government needs to remove "soft" and "hard" infrastructure bottlenecks facing the private sector. Three major barriers need to be addressed.

- *Inadequate evacuation and access infrastructure*. The lack of adequate evacuation infrastructure and grid interconnections is one of the biggest barriers to harnessing renewable energy potential. Economically attractive potential for wind and small hydropower in Andhra Pradesh and coastal Tamil Nadu, small hydropower in north and northeast India, and wind in Madhya Pradesh or West Bengal remains untapped because of lack of adequate grid evacuation capacity and approach roads. Experience in India and other countries suggests that grid evacuation infrastructure is critical to the success of renewable energy projects. This is true for both large projects that sell power generated to the grid and small distributed-generation projects for which access to the grid improves financial viability and reduces risks of projects by acting as a reliable back-up sink and source of power. Transmission bottlenecks inhibit use of RECs to facilitate interstate power trading and boost the development of renewable energy.
- *Lack of good-quality data*. Although the MNRE has invested heavily in collecting renewable energy data, lack of good-quality data remains a big problem. Even basic data on the actual generation volume of renewable energy by technologies are not available in the public domain. A number of state nodal agencies are not able to establish and maintain a technical library, a data bank, or an information center or collect and correlate information regarding renewable energy sources. Information is not updated frequently, and in certain cases (for example, biomass), it is outdated. The Biomass Atlas prepared by the Indian Institute of Science Bangalore in 2000 under funding by MNRE, often does not accurately reflect developable energy potential if biomass resources and in many areas cannot be used even as an indicative estimate by developers.[5] Over the past decade, the pattern of alternative usage has been altered significantly, affecting the estimate of biomass surplus and in turn the potential of biomass-based power projects. Wind data are inaccurate because of lack of adequate investment in improved and multi-year measurements on sites. As a result, the plant capacity factor for many wind plants is lower than what was envisaged at the design stage. Similar problems exist with hydrology data. There is also a strong need to integrate these data resources and present them to potential developers in a user-friendly way.

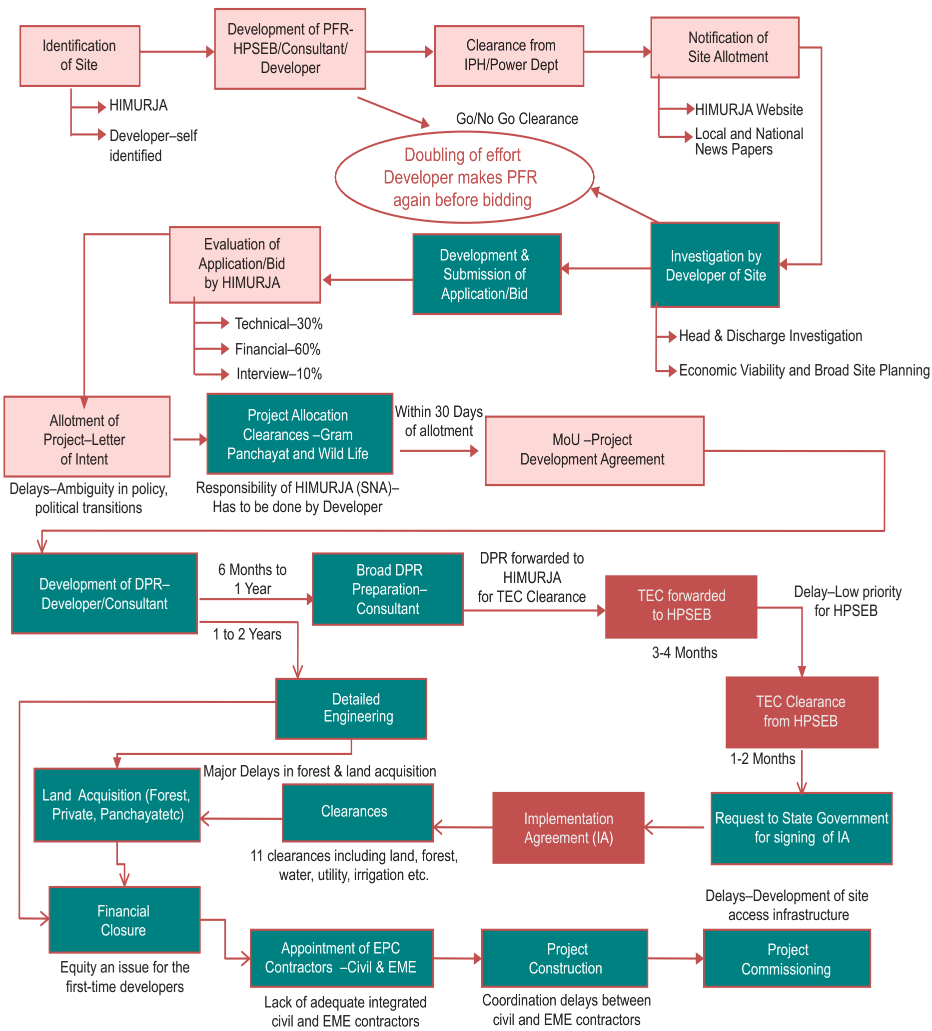
- *Underdeveloped industry value chain*. A strong domestic sector can accelerate renewable energy development, as seen in the wind sector. All other major renewable energy sectors (solar, biomass, small hydropower) suffer from lack of strong indigenous supply chains. The solar sector needs strong local R&D and manufacturing to bring down costs over the long term. The JNNSM intends to introduce incentives for facilitating local manufacturing and R&D. Small hydropower and biomass also face significant supply chain and industry development challenges. Because of limited and inconsistent market demand, small hydropower producers face significant capacity constraints and lacks standardization, which can cut costs significantly. Perhaps the most affected sector is biomass. Biomass fuel input prices rose from Rs 300–Rs 400/metric tons in 2000 to Rs 1,500–Rs 2,000/metric tons in 2009, effectively choking off the highly promising sector.[6] In the absence of an organized market for biomass or captive fuel supply arrangements, biomass plants are at the mercy of middlemen, who add a substantial markup to farm prices and change prices speculatively based on plant production.

The Failure of Current Processes

Many steps have been taken to simplify and streamline the regulatory process, but they often fail to function well in practice. For instance, the experience with single-window clearances has been generally disappointing, with market players referring to them as “one-shop stops” rather than “one-stop shops.” Important issues related to land and resource acquisition and delays in regulatory clearances are throttling renewable energy development.

Delays in clearances and approvals and the long development cycle represent major obstacles. Mechanisms such as single-window clearances, facilitation by state nodal agencies, and simplified regulation for smaller renewable energy projects have not worked well. In some cases multiple bottlenecks have been replaced by single, larger, and more powerful roadblocks. Significant delays are still the norm. Developers and financiers cite administrative hurdles and delays as one of the biggest concerns holding back renewable energy investment. For example, more than 60 percent of project cycle time in small hydropower projects is spent getting various government clearances. Clearances must be obtained from (i) wildlife, fisheries, *panchayat*, irrigation, public health, revenue department; (ii) SERC (for PPAs); (iii) forest—state and central, pollution control board, industrial license, labor permits, state transmission utilities; (iv) distribution companies’ approval for interconnection and for usage of explosive for excavation; and (v) state nodal agencies (for implementation agreement, infrastructure permission), techno-economic approval from state utility and transfer of land in case land is to be procured in tribal areas. A typical small hydropower project takes four to eight years from conception to commissioning in India—two to four times as long as in China or Sri Lanka. Such a long cycle commissioning timeline is common in practice even though the state agencies project an average period of just six months for obtaining all clearances. Examination of the project allocation and development cycle for a small hydropower project in the Himachal Pradesh highlights the areas where potential problems and issues can and do come up in project development and commissioning (figure 3.2).

Figure 3.2. Project allocation and development cycle of small hydropower project in Himachal Pradesh



Source: PwC compilation based on stakeholder discussions.
Note: SNA/SREDA: state nodal agency or state renewable development agency (HIMURJA in Himachal Pradesh); PFR: prefeasibility report; DPR: detailed project report; HPSEB: Himachal Pradesh State Electricity Board (state utility); IPH: (state) Department of Irrigation and Public Health; MoU: Memorandum of Understanding; TEC: techno-economic clearance; IA: implementation agreement; EME: electromechanical equipment.

Land and resource acquisition issues also represent obstacles. Small hydropower and wind are site specific; access to land can therefore be a big issue. Speculative blocking by unscrupulous middlemen has is widespread, leading to unsustainable price increases. There is a need to facilitate transparent, fair, and timely acquisition of land. In the case of hydropower, water rights are a national property. Consequently, there are extensive delays in allotting sites and difficulties determining appropriate price. SREDA/ state nodal agencies, which have primary responsibility for resolving these issues, lack adequate resources and have limited importance within the state government hierarchy. Although states can acquire land under Section 4 of the Land Acquisition Act, state administrations are reluctant to use this route, because of political considerations and the low priority state governments give to renewable energy projects.

What Can Be Done?

Although these barriers are common in other countries, in many cases no readymade solutions can be imported and applied to India. In areas related to the strength of the private sector in wind and some of the broad policy and programmatic support for renewable energy, India is actually a leader. It could also become a pioneer in coming up with new solutions.

Several actions could be taken to address financial viability and bankability issues. The first would be to provide streamlined, market-based government interventions. India has been using a number of market- based government interventions to promote different renewable energy technologies. There is a need to simplify the numerous and overlapping financial incentives and put them on a sound economic and market foundation. The following actions could be lead to a cogent set of synchronized and simplified policies that provide comprehensive solutions to the high financial generation cost of renewable energy:

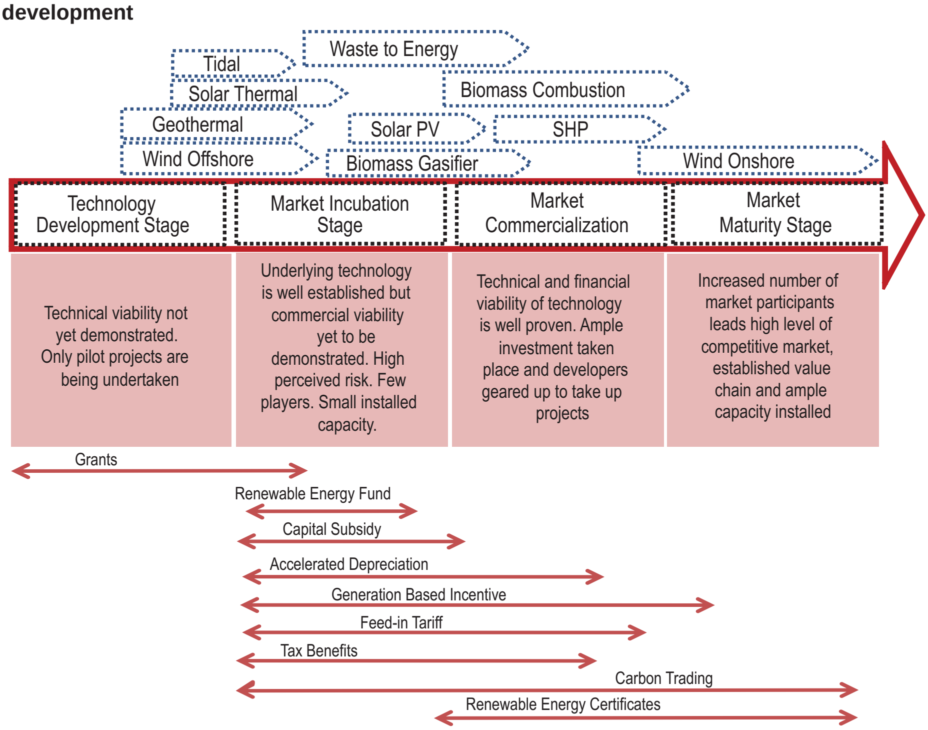
- Set, and make mandatory, short- and long-term national targets for renewable energy, as suggested by the NAPCC. Long-term targets can be based on the potential identified by the renewable energy supply curve that corresponds to the economic cost of power. The NAPCC target of increasing purchased renewable energy by 1 percent every year for the next decade is a good start.
- Establish coherence in the underlying principles and approach in breaking down the national RPO target into statewide RPOs. (GDP could be a good choice of allocation factor.) These targets should be made mandatory and enforced. SERCs should be responsible for monitoring annual compliance with RPO targets by state distribution utilities; penalty mechanisms should be introduced as a deterrent for noncompliance. A common, strictly enforced RPO target would provide utilities with incentives to develop least-cost resources first. Technology-specific RPOs may not be necessary unless there is a specific objective of the government to promote a particular technology. (The JNNSM's mandating that SERCs fix a percentage for the purchase of solar power is one example of a technology-specific RPO.)
- Allow states and utilities to move to a technology-neutral feed-in tariff based on the economic avoided cost of power generation, including premiums for local externalities. The feed-in tariff can be revised downward after meeting the RPO. Experience from Germany, Spain, and the United States suggests that this approach can accelerate investment in renewable energy. Avoided cost tariffs have a strong financial and economic rationale, as it may help address the financial concerns of utilities on renewable energy procurement and help bring in the least expensive renewable generation sources first.
- Eliminate all other technology-specific incentives, including capital subsidies and accelerated depreciation. States can use price discovery bids to identify additional generation-based incentives necessary to support specific technologies.

Competitive procurement of renewable energy is in line with the objectives of the national tariff policy, which states that procurement of power from nonconventional sources shall be done as far as possible through competitive bidding. Some states have started piloting the award of small hydropower projects based on a competitive bidding process. The Ministry of Power and the MNRE could jointly develop competitive procurement approaches and bidding documents for implementing this initiative. This market mechanism would also provide a strong economic rationale for additional subsidies, avoid issues related to cost benchmarking and indexing, and encourage cost competition and market innovation. Because some incentives, such as capital grants and tax breaks, are effectively paid for by the central budget, it is important to ensure that states are adequately compensated. The international experience on introduction and utilization of policy instruments in renewable energy market development is presented in box 3.1.

Box 3.1. Stages of introduction and use of policy instruments

International experience indicates that appropriate introduction and utilization of policy instruments at relevant stages of renewable energy development is critical for the sector's development. The appropriate stage for introducing various policy instruments in the sector's development cycle and the current positioning of various technologies in India are shown in figure below.

Figure: Applicability of policy instruments at various stages of renewable energy market development



Source: PwC analysis for World Bank.

Create a national renewable energy fund to mitigate the impact on utilities. Moving to an avoided cost mechanism should reduce the financial impact of renewable energy procurement on utilities. However, capturing the value of externalities and providing generation-based incentives to meet technology-specific RPO targets would require additional subsidies that might need to be financed by a national or state fund. The use of market-based competitive price discovery and least-cost REC trading across states should reduce the extent of subsidies. India could use the recently established National Clean Energy Fund, which finances research and innovative projects in clean technologies, as a vehicle to accumulate and channel renewable energy subsidies and reduce the financial burden on utilities. The fund could be financed through budget allocations, redirection of various renewable energy subsidy funds, or a small national green cess on electricity. Existence of fully financed national fund to subsidize RE would remove market uncertainty and make states and utilities more willing to implement renewable energy goals in practice. (A similar fund established by China as part of its 2005 renewable energy law to fund wind feed-in tariffs increased installed wind capacity by a factor of 20 in less than five years.[7])

Enable direct purchase and grid-connected distributed generation of renewable energy. India needs to move away from using government or utility subsidies as the only way of supporting the higher financial costs of renewable energy. Although the proposed streamlined financial incentive program could reduce renewable energy subsidies, the limited budget allocated to states for renewable energy cannot by itself dramatically accelerate the pace of renewable energy development. Renewable energy is more competitive than several coping alternatives, but market-based mechanisms to integrate renewable energy into the power sector are missing.

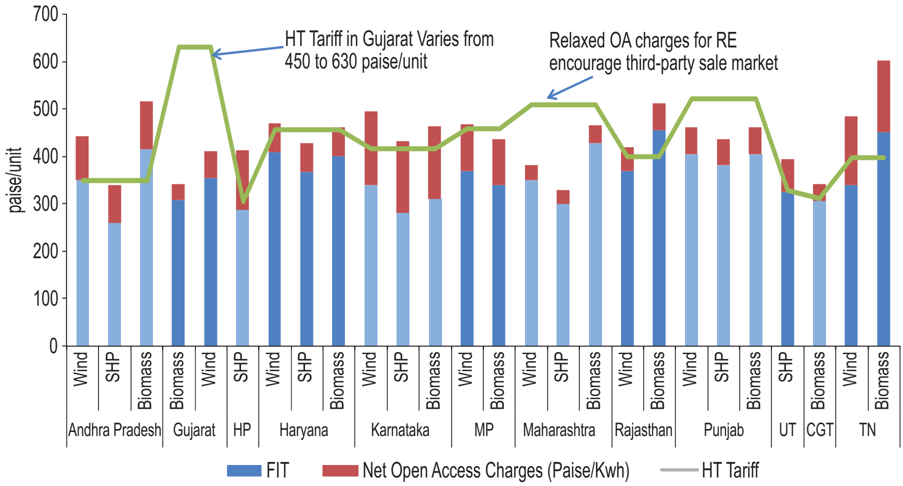
Two important steps can be taken to enable private sector solutions. First, open access must be made to work. Most states have been reluctant to allow open access to consumers and third- party sales by captive generators out of concern about losing large high-paying consumers and the resultant impact on utility finances. The high incidence of cross-subsidy surcharges and wheeling charges imposed on the direct sale of power to consumers reduces the competitiveness of renewable energy in an otherwise potentially high- demand market. To promote renewable energy, the government should remove the cross-subsidy surcharge for open access in order to create a level playing field for competitive market development (box 3.2). While there may be practical difficulties in doing the aforesaid, doing so would help high-paying consumers replace diesel with renewable energy sources. It would also create competitive pressure for utilities to improve the quality of supply. Also, with the mechanism in place, it is anticipated that this would be simplified as that would allow the separation of green attribute from the electricity component.

Second, the government should promote new models for allowing renewable energy developers to recover higher generation costs directly from customers. India could consider promoting widespread use of rural distribution franchises that meet their power requirement using their own local renewable energy plants.[8] Commercially operated private franchises that generate power locally using renewable energy could address the power supply shortage and significantly improve service to rural areas. Locally based small-scale renewable energy generation can ensure that power is actually fed to local areas rather than diverted to meet urban demand. This approach could also reduce the

Box 3.2. Attractiveness of renewable energy projects for developers

States have adopted incentives—such as allowing concessions in open access, cross-subsidies, and wheeling charges—to encourage developers of renewable energy projects. The most important factors determining the viability of such a business model is the level of the incentive and the relationship between the HT tariff, the feed-in tariff, and net open access charges levied in the state, as presented in the figure below.

Figure: Relationship between HT tariff, the feed-in tariff, and net open access changes, by state



Source: Forum of regulators and state tariff orders.

Karnataka and Tamil Nadu have high net open access charges because of high cross-subsidy surcharges and low relaxations. The high level of net open access charges may discourage further investment in these states, both of which have strong potential for renewable energy. Among states with low net open access charges (Gujarat, Haryana, Maharashtra, Punjab, and Rajasthan), only three (Gujarat, Punjab, and Maharashtra) have competitive third-party sale in all Renewable Energy technologies. In Gujarat and Maharashtra, almost all renewable energy developers have the opportunity to sell at prices that are higher than the feed-in tariff. Biomass developers in Madhya Pradesh and Punjab also have such opportunities.

Source: PwC Research for World Bank.

need for renewable energy subsidies, as higher cost renewable energy generation could be largely mitigated through the avoidance of transmission costs and improved efficiencies in private franchises, which, as experience shows, results in substantial reductions in technical and collection losses as well as distribution overheads.

In order to provide additional incentives to utilities, the renewable energy supplied directly to consumers using open access and distributed generation will be credited toward utilities' RPO targets. This could be done by facilitating the financing of renewable energy projects, in three ways:

- The perception of risk by commercial banks in the renewable energy sector could be addressed by increasing the awareness and building the capability of banks as well as through partnerships with major Indian business schools to train future financiers and bankers.

- New sources of long-term funding needs could be found for renewable energy projects. IREDA, a focused renewable energy financial intermediary, could become a wholesaler, playing a catalytic role in leveraging more funding from domestic and international markets. IREDA needs to explore new instruments, such as green bonds, new equity, and synthesized products, with which to raise financing and enable risk sharing and mitigation in renewable energy projects.
- A national partial risk guarantee facility, which could be managed by IREDA or private sector financial institutions, could address specific renewable energy project risks, such as refinancing, construction financing, off-take by utilities, resource availability, and technology. International financial institutions could be asked to backstop such a facility if the intention is to attract global financiers and developers.

Investments must be made to support infrastructure in the sector. Renewable energy evacuation should be made a high-transmission priority, given the same focus as village electrification. It should have dedicated funding as part of existing programs like RGGVY or through new green funds. Although the new Indian Electricity Grid Code (IEGC) announced in April 2010 by the CERC will help facilitate development of renewable energy by specifying the technical and commercial aspects for integration of these resources into the grid, some additional actions could be taken to improve transmission development in renewable energy:

- The IEGC mandate states that interstate transmission system planning and development should take into account the needs of renewable energy sources and the renewable capacity addition plan (as issued by the MNRE). To make this goal a reality, all state transmission utilities should be mandated to prepare a comprehensive five-year transmission plan with appropriate consideration of renewable generation projects based on load flow studies and location of generation projects. State nodal agencies should take a lead role in coordinating and providing information to state transmission utilities on new renewable energy generation capacity.
- The cluster approach for the development of wind, solar, and small hydropower (river basin–wide) could be used to pool power from pockets of renewable energy–abundant areas and develop transmission capacity.
- State transmission utilities should be required to provide renewable energy evacuation to all projects or aggregated projects with more than a certain specified MW output.
- State transmission utilities should be allowed to use different mechanisms to recover costs for establishing transmission lines for renewable energy-rich areas. For large conventional plants, the timing and quantity of power transmitted is certain, allowing for predicable cost recovery for transmission lines. Multiple small-scale renewable energy plants do not provide for certain cost recovery. Utilities should therefore be allowed to pass on to the rate base transmission investments that are built to catalyze new renewable energy projects in resource-rich areas.
- Introduce and enforce "take or pay" for renewable energy generation. One hundred percent of the available capacity of renewable energy should be dispatched, without being subjected to merit-order dispatch. A long-term take-or-pay contract would make it incumbent for utilities to dispatch renewable

energy. The freeing of renewable energy projects from this merit-order dispatch principle is a welcome step under the new IEGC.[9] The take-or-pay agreement, if part of a PPA, would insulate developers and investors from issues of grid access. The terms of the PPAs and the feed-in tariff should be harmonized. At least 12- to 15-year PPAs should be required to provide confidence to developers and financiers. New technologies, such as solar thermal, may require even longer term PPAs. Mandating such PPAs would reduce regulatory uncertainty, create appropriate incentives for location and operation, and allow for efficient system operation. A take-or-pay regime would have to be enforced by the regulator, and the utilities would have to be properly compensated through tariffs. In a number of countries, including Armenia, Denmark, Sri Lanka, and some U.S. states, long-term PPAs and take-or-pay or must-run regulations are the norm.

- Investment should be made in a high-quality, integrated resource monitoring program. Known gaps in existing programs need to be addressed. For instance, the Biomass Atlas needs to be updated to reflect changes in agriculture output and alternative economic uses. The assessment should take the economics of developing these resources and financial viability into consideration. The biomass potential from forests and wasteland should be considered as exploitable potential only after the costs of plantation, collection, and extraction are quantified. In addition to geographic information system (GIS)–based surveys, there is a need to asset the resources at the state, district, and *taluka* levels, through field surveys and consultations with farmers and other stakeholders. New wind measurement norms need to be adopted. (For example, number and pattern of meteorological masts to obtain accurate assessment data.) These data should be monitored for at least two seasons and additional investments to cover unmapped potential, assessing biomass potential from energy plantations in wastelands and India's vast offshore wind potential, are required. The country also needs precise solar radiation data, especially to support the National Solar Mission, efforts for which are underway by the MNRE. The MNRE could in addition, support establishment of national and state-level renewable energy information systems that provide integrated and easily accessible public information. State nodal agencies, in conjunction with the CERC and SERCs, could lead this effort. The database should be easily usable and provide up-to-date information.
- R&D and supply chain innovations and investments should be catalyzed. Although R&D initiatives should ideally be driven by the private sector, the state could play an important catalytic role in accelerating investments in innovations and new domestic capacity. For instance, the JNNSM has laid out a policy to provide public funds to promote R&D and local manufacturing for solar energy. Similar efforts could be made for other technologies. For instance, investments in off-shore technology could facilitate development of the wind sector. The MNRE could encourage technology development based on important local investments leveraged by small grants, cost-shared grants, or both for wind and biomass. Long-term capacity- building investments also could be made, such as increasing collaboration with leading international universities to develop postgraduate-level or specialist renewable energy engineering courses and of-

fering fellowship programs to allow more senior engineers to study abroad. Equipment standardization and low-cost design could reduce the costs of local hydro equipment, as they have in China. The biomass sector probably receives the most attention, given its untapped potential and opportunity for providing stable alternate income streams for farmers. India should simplify rules for captive crop generation and deregulate energy plantations on wastelands to alleviate the fuel supply shortages.

The government could help reduce the cost of doing business for renewable energy projects by taking three main steps:

- Move to unified, light-touch regulation for renewable energy. Like information technology and cellular telephony, clean technology and renewable energy have the potential to be a transformative growth industry. To realize this potential, India needs to streamline bureaucratic processes for clearances and approvals. The single-window approach has not worked, largely because of the reluctance of various agencies to delegate power. An alternative would be to pilot a "no objection"–based approval process. Such a process would require officials to explicitly reject an application and provide written explanations for the reasons they did so; unless rejected, an application would automatically be considered approved. States such as Punjab have adopted a single-window clearance and fixed time limits (45 days) within which clarifications, comments, or objections to projects need to be sent to the state nodal agency; absent such comments, the state nodal agency grants all clearances to the project. Promising approaches like special purpose vehicle–based project predevelopment can be widely adopted. Government-created special purpose vehicles can offer a package of clearances for multiple renewable energy projects, which could reduce transaction costs and encourage large investors. To prevent speculative land grabbing, the government could indicate its willingness to use Section 4(1) of the Land Acquisition Act to ensure transparent, fair, and timely acquisition of land required for small renewable energy projects. In Gujarat, where the state nodal agency administers the functions of the land allocation committee and coordinates with other departments to ensure the smooth transfer of land to renewable energy project developers, land acquisition has worked relatively well. Similar efforts by state governments are needed to ensure time-bound allocation of sites and to streamline approval process.
- Strengthen the SREDA and state regulators. SREDA or state nodal agencies are supposed to play a leading role in helping renewable energy projects through the regulatory maze, but few have the resources, capability, or authority to do so. A comprehensive capacity-building program on emerging regulatory, legal, and financing issues to facilitate grid-connected renewable energy should be structured. International experience suggests that local agencies need help conducting resource assessments, providing support for investment projects, developing demonstration projects, setting local standards, and building awareness of programs. State nodal agencies also need resources and training to work with other state agencies to ensure speedy clearances of renewable energy proj-

ects. Sharing of best practices from other states in India and other countries could be very helpful.

- Strengthen the ability of state nodal agencies to provide assistance to local project sponsors. Such agencies should be able to disseminate and process technical information to overcome information barriers, provide predevelopment assistance, and set up local development and demonstration projects. The MNRE, with IREDA's assistance on financing issues, could take the lead in developing and implementing such a program.

Challenges and Opportunities

Any discussion of radical new approaches to achieve an order-of-magnitude change in renewable energy should first recognize the existing risks. The poor financial state of and lack of incentives faced by utilities as well as the weak institutional capacity of public sector institutions, especially at the state level, are among the key risks that will have to be carefully managed. Concerns from key stakeholders should be listened to and addressed to head off implementation resistance, which rendered previous reform attempts ineffective. Implementation will have to be gradual in scale and sequencing and tolerant of the chance of failure.

Early adoption of "quick wins" could build momentum for high-effort, high-impact structural reforms. Some solutions take substantial time to design and implement and may require considerable resources. Achieving and demonstrating some quick results is important to gain political support for longer-term solutions. Policy initiatives such as enforcement of state-level RPOs could provide an immediate boost to the sector. Initiatives on financial sector capability and awareness building, strengthening of state nodal agencies, and investment in high-quality resource information system can also be implemented relatively quickly.

Perhaps the best way to create substantive change is to implement comprehensive pilot models in a few states. One potential quick win that could yield high impact would be to create renewable energy parks, which can serve as integrated implementation platforms on which the solutions could be tested and refined. Such parks could be established as joint national and state government initiatives in a few selected pilot states. They could serve as concentrated zone of renewable energy development, including generation and/or manufacturing. The central government could commit substantive financial and administrative resources to attract states rich in renewable energy resources. The states could be selected based on their demonstrated commitment for such a program, including co-financing and capacity to implement.

Creating renewable energy parks could accelerate development of resources and address multiple issues comprehensively. India is already familiar with special economic zones and technology parks, which create an enabling environment to promote certain industries. Renewable energy parks are a good example of private-public partnerships that allow aggregation of projects, create economies of scale, and enable the formation of supporting supply chains. Such parks can be attractive to both small and large players. They can offer ready-to-bid project pipelines; provide prefeasibility studies, including resource assessment data; access to land and transmission infrastructure; and preferential open access policies. They can be used to craft simplified light-touch regulations, including accelerated environmental and social clearances and package clearances. IRE-

DA could pilot new risk guarantee and financing schemes, and state and central funds could catalyze R&D and supply chain innovations in renewable energy parks. Examples include solar, wind, or river basin–based special purpose vehicles for small hydropower projects. Initially, the parks would require specific kick-off grants or subsidies from the MNRE and other agencies, which could be recovered from developers as projects reach critical mass. The parks could serve as testing grounds for new policies, which if proven successful could be then replicated across the country.

The ideas proposed in this study are meant to provoke substantive discussions among key stakeholders to establish customized solutions for India. Creating a consultative forum to bring together developers, corporations, utilities, consumer groups, and regulators to debate and pilot broader initiatives can facilitate India's journey toward a more secure energy future.

Notes

1. World Energy Outlook 2007.
2. http://www.cercind.gov.in/Regulations/CERC_RE-Tariff-Regualtions_17_sept_09.pdf.
3. The CERC notification (Terms and Conditions for Recognition and Issuance of Renewable Energy Certificate (REC) for Renewable Energy Generation Regulations 2010 ("the REC Regulation"), January 14, 2010. Available at: http://www.cercind.gov.in/Regulations/CERC_Regulation_on_Renewable_Energy_Certificates_REC.pdf.
4. The estimation of capital cost in this study is based on PricewaterhouseCoopers' review of SERCs' wind tariff orders for about 50 wind-based power projects in India (UNFCC). The data collected in 2008—09.
5. Assessment by MNRE through the Indian Institute of Science.
6. PwC market analysis.
7. Chinese_Renewables_Status_Report_2009 REN21.
8. Distributed generation and supply franchises model discussed in World Bank report for the Ministry of Power.
9. For the first time, the new IEGC recognizes renewable energy sources, subject to specific conditions to be "must run" power plants that would not be subject to merit order dispatch.

ECO-AUDIT

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