Report on India's Renewable Electricity Roadmap 2030

Toward Accelerated Renewable Electricity Deployment

NITI Aayog
Government of India

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SHAKTI
SUSTAINABLE ENERGY FOUNDATION

RAP™

February 2015

Report on India's Renewable Electricity Roadmap 2030

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Acronyms

AD	Accelerated Depreciation
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CEA	Central Electricity Authority
CECRE	Control Centre of Renewable Energies [Spain]
CERC	Central Electricity Regulatory Commission
CREZ	Competitive Renewable Energy Zones
CSS	Cross Subsidy Surcharge
CUF	Capacity Utilization Factor
DCR	Domestic Content Requirement
Discom	Distribution Company
EIA	Environmental Impact Assessment
FiT	Feed-In Tariff
FY	Financial Year
GBI	Generation-Based Incentive
GDP	Gross Domestic Product
Genco	Generation Company
GETCO	Gujarat Energy Transmission Corporation Limited
GOI	Government of India
GW/GWh	Gigawatt(s)/Gigawatt Hour(s)
HNW	High Net Worth
IEA	International Energy Agency
IFC	International Finance Corporation
IPP	Independent Power Producer
IREDA	Indian Renewable Energy Development Agency
ISTS	Interstate Transmission System
JNNSM	Jawaharlal Nehru National Solar Mission
kWh/kWh	Kilowatt(s)/Kilowatt Hour(s)
LAA	Land Acquisition Act
LDC	Load Dispatch Centre
MoEF	Ministry of Environment, Forest and Climate Change
MoF	Ministry of Finance
MoP	Ministry of Power
MNRE	Ministry of New and Renewable Energy
Mt	Million Tonnes
MU	Million Units = One GWh
MW/MWh	Megawatt(s)/Megawatt Hour(s)
NAPCC	National Action Plan on Climate Change
NEM	Net Metering
NHPC	National Hydroelectric Power Corporation Limited
NLDC	National Load Dispatch Centre
NMP	National Manufacturing Policy
NSM	National Solar Mission (same as JNNSM)
NTPC	National Thermal Power Corporation Limited
O&M	Operation and Maintenance
OA	Open Access
PFC	Power Finance Corporation, Limited
PGCIL	Power Grid Corporation of India, Limited
PJM	PJM Interconnection [US]
PM	Particulate Matter
POSOCO	Power System Operation Corporation, Limited
PPA	Power Purchase Agreement
PRI	Pancahyati Raj Institutions
PUCT	Public Utilities Commission of Texas [US]
PV	Photovoltaics
RD&D	Research, Development and Deployment
RE	Renewable Electricity
REC	Renewable Electricity Certificate
RECAI	Renewable Energy Country Attractive Index
REMC	Renewable Energy Management Centre
RES	RE Sources
RGO	Renewable Generation Obligation
RPC	Regional Power Committee
RPO	Renewable Purchase Obligation
SERC	State Electricity Regulatory Commission
SEZ	Special Economic Zone
STU	State Transmission Utility
Transco	Intra-state Transmission Company
TW/TWh	Terawatt(s)/Terawatt Hour(s)
TYNDP	Ten Year Network Development Plan [European Union]
UC	Unit Commitment
UI	Unscheduled Interchange
UMPP	Ultra-Mega Power Plant
VGF	Viability Gap Funding
VRE	Variable Renewable Energy

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Foreword

The rapid adoption of renewable energy to power India's growing economy at a price that consumers can afford and on a scale large enough to make a major dent in shortages was the challenge confronting the India Renewable Energy Roadmap Initiative, a project commissioned in November 2013 by the Planning Commission, the predecessor institution of NITI Aayog. The project was in turn guided by a Steering Committee. The charge was to determine what changes would have to be made to the Indian power sector to make rapid deployment of renewables successful. The broad and deep stakeholder process used by the Roadmap Initiative brought the experience and concerns of government officials, regulators, grid operators, electric utilities, renewable energy developers, investors, and industry, consumers, the finance community and other key players to bear on this question. The resulting Report on **"India's Renewable Electricity Roadmap 2030"** identifies legal, institutional and policy changes that will be needed to successfully adopt renewables on a large scale.

Meeting a large segment of the power needed for India's growing economy with RE could potentially bring vast benefits: additional power with no fuel costs and positive impacts on air quality and water use. The resources are abundant in India. The Roadmap Initiative identifies obstacles to this goal of large-scale RE. while suggesting solutions. For example, RE is cost-effective over the life of projects but more capital-intensive than conventional power plants. India's finance mechanisms can adapt. RE resources are abundant but locally variable; aggregating and managing RE for its most efficient and economic use will require updated grid operations.

The report makes specific policy recommendations. I compliment the Steering Committee and the Roadmap Initiative team on their careful consultation with stakeholders and experts, and their articulation of complex dynamics and challenges into useful findings and recommendations. I hope that the report will help inform contribute to policy changes that would put India on the path to rapid scaling-up of renewable energy.

(Arvind Panagariya)

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Preface

In November 2013, the NITI Aayog (erstwhile Planning Commission) initiated a stakeholder-driven analysis of the opportunities and barriers to rapid deployment of renewable electricity. Entitled **"Report on India's Renewable Electricity Roadmap 2030"**, the process was facilitated by the NITI Aayog in conjunction with its role of co-leading the 21st Century Power Partnership (21CPP), a multilateral effort of the Clean Energy Ministerial (CEM) that serves as a platform to advance the large-scale deployment of renewable energy. The Initiative was guided by a Steering Committee led by then-Member (Energy), Planning Commission of India. Members of the Committee included Secretaries from key Ministries (Power, New and Renewable Energy, Finance, and Environment and Forests), Chairpersons from key central level agencies (Central Electricity Authority, Power Grid Corporation of India Limited), and Energy Secretaries from two representative states (Tamil Nadu and Rajasthan).

The NITI Aayog's operating agent for the 21CPP, the Confederation of Indian Industry (CII), and the Roadmap Initiative's knowledge partners, the Shakti Sustainable Energy Foundation and the Regulatory Assistance Project, constituted the RE Roadmap Initiative team. The team implemented a comprehensive stakeholder-driven "roadmap" exercise to answer the question: "How must the Indian power system evolve if India chooses to put RE at the core of the future system, rather than at the periphery?"

The Initiative team conducted extensive conversations with close to 250 stakeholders including the steering committee members, Chairpersons and senior staff of central and state electricity regulatory commissions, Energy Secretaries of states, managing directors of generation, transmission and distribution companies, grid operators and managers, power planning agencies, civil society, industry, finance, developers, and bilateral and multilateral institutions in twelve states and in Delhi. The bulk of these interviews were conducted during the first three months of 2014. The initial results were presented to the steering committee in April 2014. Over the next six months, the Initiative's findings and subsequent recommendations in draft form were sent or presented to over 100 individuals, groups and institutions, as well as international experts, for response.

The **"Report on India's Renewable Electricity Roadmap 2030"** summarizes both the process and the results of the stakeholder exercise. It presents the opportunities and barriers to RE as reflected by stakeholder input and provides a summary of the rationale as well as benefits and costs of RE within the context of the Indian power system. Then, drawn from stakeholder input and international experience, the paper suggests a framework for an integrated policy strategy for rapid RE implementation that complements both the existing and planned conventional power projects. The framework includes:

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- A new comprehensive National RE Law and/or Policy and its components
- Support mechanisms to ensure timely implementation
- Grid reforms to ensure smooth integration of RE

Given the complexity of the challenges and the wide consultation undertaken, both in preparing the draft report and soliciting feedback on the policy recommendations, the report has now been finalised – almost a year after the Initiative was begun. In the meantime, it is worth noting that some of the policy suggestions made in the draft report have been taken up by the Government for consideration. Many have contributed in varying degrees in preparing this report. It is my pleasure and also my privilege to thank all the Members of the Steering Committee for their guidance and for sparing their valuable time towards the finalization of this report.

I am also thankful to the members of the Renewable Electricity Roadmap Initiative team including Rajesh Menon, Soma Banerjee, Rasika Chandihok, and Kumar Vipul of CII; Deepak Gupta and Disha Agarwal of the Shakti Sustainable Energy Foundation; and Robert Lieberman, Ranjit Bharvirkar and Catherine Murray of the Regulatory Assistance Project. The team was assisted by Mahesh Patankar and Meghana Rao of MP Ensystems Ltd., and Hugo Chandler and Nick Gibbins of New Resource Partners. My thanks to them as well.

I also want to thank Sh. Rajnath Ram, Joint Advisor, NITI Aayog, for facilitating communication among key team members. Finally, my thanks to Sh. Anil Kumar Jain, Advisor (Energy), NITI Aayog, who has been a driving force and constant motivation behind this initiative, and without whose untiring and focused efforts, the process would not have even been initiated.

Furthermore, this report is meaningful primarily due to the participation of over 250 policy makers and stakeholders who shared thoughtful insights and suggestions. It should be noted that the RE Roadmap Initiative's stakeholder process took place under a variation of the Chatham House rule. Under this rule remarks were noted but not attributed. As a result the list of stakeholder participants at the end of the report includes only the names of the agencies, organizations and companies involved; no individuals are named. This rule allowed for very frank and robust conversations with people who care deeply about India's future power trajectory. I thank them all for their time and inputs.

(Sindhushree Khullar)

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Executive Summary

"We should not get into the mindset that RE is the intruder and conventional energy is the main player. Why not consider RE to be main occupants of the 'house' and then work out the rest of the system around RE, essentially, because RE is the future?"

— Former Member (Energy), erstwhile Planning Commission of India

For decades, as demand for power has grown, India has added large-scale conventional power resources. Now, with solar and wind power and other renewable electricity (RE) resources becoming commercially available in the marketplace, there are additional choices available to policymakers and stakeholders concerned with the technical, economic, and environmental characteristics of a future power system that keeps pace with economic growth.

One of India's major advantages today and going forward is that its RE potential is vast and largely untapped. Recent estimates indicate that India's solar potential is greater than 10,000 GW and its wind potential could be higher than 2,000 GW.

To fully take advantage of India's RE potential over the next few years, however, will require new initiatives from central and state governments — beyond policy and programs currently in place — to support the engagement, participation, and new behaviors of power sector stakeholders including RE industry and developers, grid operators, public and private finance, consumers, and others.

Renewables are different than power technologies of the past. Most renewables have zero fuel costs but they are more capital-intensive than conventional fossil power plants. India's renewable resources are abundant, but the output of wind and solar photovoltaic is variable, and in the case of wind in particular, subject to uncertainty. To capture the benefits, India would need to raise the necessary capital, and get comfortable with managing the variability and uncertainty of renewable energy generation. The enormous benefits RE brings — zero fuel, electricity prices free from volatility and external influence, reduced imports, dramatically reduced pollution and water use — will not be had without significant effort. NITI Aayog's initiative – The India Energy Security Scenarios 2047 (IESS 2047) – would be useful in illustrating the costs and benefits of adopting high RE targets to meet India's growing energy demand.

To help policymakers identify these new approaches, a stakeholder-driven analysis of the opportunities and barriers to rapid deployment RE was initiated at the request of the Government of India in November 2013.

The resulting process and its findings have significant relevance in the current scenario, when the Government of India has enhanced its aspirations multifold – amending them from 20 GW of solar power (by 2022) to 100 GW (by 2019) and from an additional 15 GW of wind power (during 2012-17) to an additional 40 GW (by 2019).

The Process

Given this backdrop of benefits and challenges, the Government of India's erstwhile Planning Commission, in its role as co-leader of the 21st Century Power Partnership (21CPP)[i], initiated the "RE Roadmap Initiative". It requested that the Confederation of Indian Industry (CII), in conjunction with knowledge partners the Shakti Sustainable Energy Foundation (SSEF) and the Regulatory Assistance Project (RAP), serve as the Initiative team and

i The 21st Century Power Partnership (21CPP) is a multilateral effort of the Clean Energy Ministerial (CEM) that serves as a platform to advance the large-scale deployment of renewable energy. While the erstwhile Planning Commission served as co-leader of the 21CPP on the international platform, CII served as operating agent to the 21CPP in India.

conduct a stakeholder-driven "roadmap" exercise to answer the question: "How must the Indian power system evolve if India chooses to put RE at the core of the future system, rather than at the periphery?"

A steering committee for this exercise was created, led by then-Member (Energy) and composed of Secretaries of Ministry of Power (MoP), Ministry of New and Renewable Energy (MNRE), Ministry of Finance (MoF), Ministry of Environment and Forests (MoEF), Central Electricity Authority (CEA), Power Grid Corporation of India, Ltd. (PGCIL), and the Energy Secretaries of Tamil Nadu and Rajasthan.

The analysis, findings and practical "next-step" policy recommendations that follow are based, in large part, on broad and robust open-ended conversations conducted under the "Chatham House Rule" with over 250 power sector stakeholders from 13 states, and from central or pan-India institutions.[ii] The stakeholders included the steering committee members, chairpersons/members and senior staff of central and state electricity regulatory commissions, energy secretaries of states, managing directors of generation, transmission and distribution companies, grid operators, power sector planning agencies, grid managers, civil society, industry and finance, developers, and bilateral and multilateral institutions.

Initial interviews and small group conversations were conducted throughout the country during December 2013 through March 2014. Preliminary findings were presented to the Steering Committee in April 2014, then circulated and commented upon by close to 100 stakeholders and domestic and international experts. The draft policy recommendations drawn from the Roadmap Initiative process went through an iterative process from August through October 2014 as the Roadmap Initiative team solicited feedback from diverse stakeholders and domestic and international experts, both through correspondence and in-person.

Structure of the Report

The objective of this document is to capture and synthesise the inputs of stakeholders in the renewables sector — at national and state levels in India as well as internationally — as to what should be done differently to drive a dramatic scale-up of renewable energy, particularly solar photovoltaic and wind power. Blended with these inputs are a large number of international experiences. These serve sometimes to contrast Indian experiences with those elsewhere, and at other times to provide alternative perspectives on addressing a particular challenge.

The diverse and deep experiences of the 250 stakeholders allowed the Initiative process to delve into a comprehensive consideration of RE issues and opportunities. Their responses and observations have been organized into eight specific themes that focus on identifying changes in power sector governance, management, structure, and power systems themselves that would be prerequisite to the large-scale, cost-efficient, reliable deployment of renewable electricity.

Chapters 1 and 2 set the scene for the discussion of the overarching issues that are discussed in depth in Chapters 3 to 8.

Chapter 1 provides the context, including targets for deployment, and lays out a systematic approach to assessing the relative benefits, costs, and risks of renewable energy.

Chapter 2 discusses key policy tools currently in place and visualises how these may evolve as renewable energy reaches higher penetration levels.

Chapter 3 begins the discussion of specific areas that are being looked at by stakeholders up and down the country, beginning with supply chain aspects of renewable energy deployment, including manufacturing, the adequacy of human resources, and research and development.

Chapter 4 moves on to an assessment of investment in renewable energy markets to date, including sources of investment, private and public sector roles, and how greater private investment in particular can be stimulated.

Chapter 5 covers an area that is often overlooked in strategic analysis of this kind: risks at the level of the individual project, from siting to grid connection, and a number of performance risks.

Chapter 6 takes the completion of a variable RE power plant as its point of departure, and asks how a sufficiency of buyers can best be assured for the electricity generated.

Chapter 7 then considers the transportation of electricity to the consumer, through the transmission and distribution networks, and how these may be planned for greatest efficacy.

ii Under the Chatham House Rule, anonymity is maintained to encourage the frank exchange of views. As a result, the 250+ stakeholders who participated in the RE Roadmap Initiative are not named and no comments are attributed to individuals. However the various institutions, agencies and companies their perspectives are derived from are listed at the back of this report.

Chapter 8 discusses system operational aspects: how the often-cited issues of variability and uncertainty in the output of wind and solar photovoltaic power plants could be managed reliably.

Finally, Chapter 9 outlines a small number of specific near-term steps that the Government of India, state governments, and stakeholders could take to begin the power sector retooling process that will accelerate deployment of RE in India.

Findings

The RE Roadmap Initiative's broad stakeholder process held under the Chatham House Rule allowed for frank and thoughtful conversations about the opportunities and barriers to RE as seen by diverse policymakers and stakeholders in India's power sector. The results were enriched by consideration of international experience (successes and setbacks), and by feedback from international experts. Although there was not complete consensus, there was significant agreement on the challenges and obstacles facing a rapid scale-up of RE in India and the principles that would be the foundation for any solutions.

Stakeholder interviews and international experience identified four areas where new policy and programs would be useful.

There will, of course, be many specific alternative approaches and strategies to achieving successful RE policies. But there was significant agreement that the five core principles discussed below must be at the heart of any of those new efforts. These principles were synthesized from the best thinking of Indian stakeholders and international experts:

- **Treat RE as a resource of national and strategic importance**
- **Mandate RE as a significant component of the power sector**
- **Take an integrated approach to power sector planning, including generation, transmission, and distribution**
- **Make buyers indifferent between conventional and RE resources until grid parity is achieved**
- **Give small-scale/distributed RE, close to end users, priority equal to large-scale/centralized RE**

Key Findings

The stakeholder interviews and international experience identified four areas where new policy and programs would be useful. These include the need for:

- **A Comprehensive National Policy Framework for RE**
- **Willing and Credit-Worthy Buyers (i.e. Discoms) for RE**
- **Smoother RE Project Development Environment**
- **Updated Grid Planning and Operation**

The principles described above are the foundation for the recommendations that follow. Drawn from stakeholder input and international experience, the paper suggests a framework for an integrated policy strategy for rapid RE implementation that complements both the existing and planned conventional power projects. The framework includes:

- A new comprehensive **national RE law and/or policy** and its components
- **Implementation support mechanisms**
- Reforms to ensure smooth **grid integration** of RE
- Energy access and **off-grid RE** considerations

Policy Recommendations

National RE Law and/or Policy

A comprehensive, transparent, long-term, and definitive legislative/policy framework for RE should be implemented by amending existing laws/policies (e.g., address electricity-related aspects from the Electricity Act) and/or creating a new laws/policies (e.g., dedicated to renewable energy as whole). RE could be considered a "resource of national and strategic importance" as it addresses several fundamental national objectives such as energy security, reduction of the trade deficit, enhanced land/water availability for non-energy purposes (e.g., agriculture), cutting-edge industrial and RD&D (research, development and deployment) growth, increased employment, and others. Some essential features of a potential RE policy/legislative framework are presented below:

Targets

The law/policy should establish national RE targets that would incorporate an appropriate but measurable metric (e.g., generation, capacity, share of consumption, etc.) to monitor progress in achieving the targets. All states would be equally responsible to meet a common national uniform target. The law/policy should include appropriate "sunset" provisions that would allow regular opportunities to update the law/policy in light of the evolving set of issues pertaining to RE. The rationale for setting the targets should account for the various benefits and costs described above.

Financial Support Required for Achieving Targets

The law/policy should clearly identify the source, level, and distribution mechanism for financial support for reducing the incremental cost of RE (includes both generation and integration costs) to the ultimate buyers as compared with the already subsidized fossil fuel-based generation.

Integrated Energy Resources Planning

Comprehensive and analytically sophisticated planning exercises should be undertaken routinely in order to assess the benefits and costs of various aspects of the electricity sector, including supply-side resources (e.g., coal, hydro, gas, nuclear, RE), the transmission and distribution networks and their operation, and demand-side resources (e.g., energy efficiency, demand response, etc.). These planning exercises should explicitly and systematically account for various risk factors such as fuel availability, fuel costs, and other possible benefits and costs.

Programmatic Approach

The new requirements for the entire power system consist of a portfolio of two complementary policy approaches:

- A restructured and enforceable RPO that incorporates a mandatory national uniform obligation on all bulk buyers (i.e. discoms and open access consumers). The RPO mechanism can be structured to allow all possible generation project developers — e.g., pure-RE developers, discoms, consumers, etc. — to participate in the growth of RE capacity. As the cost of RE continues to fall, the RPO mechanism allows for an increasing share of RE in future consumption.
- A mandatory net metering (NEM)/feed-in tariff (FiT) for behind-the-meter RE generation (e.g. rooftop solar photovoltaic). This requirement would apply to all distribution service providers. Electricity generated under the NEM/FiT would count toward the RPO. The NEM/FiT mechanism encourages the addition of RE generation close to the point of use thereby minimizing the costs of transmission and distribution and associated losses.

Key Policy Recommendations

National RE Law and/or Policy

Establish targets

Identify financial support required for achieving targets

Undertake integrated energy resources planning

Take a programmatic approach

- **A restructured and enforceable RPO**
- **A mandatory net metering (NEM)/feed-in tariff (FiT)**

Support Mechanisms for Compliance and Timely Implementation

"One-Stop Shop" for standardized contracting

Financial support and disbursal mechanism

Streamlined project development

Low-cost financing

RE Grid Integration and More Efficient Grid Operation

Upgrade grid technology

Upgrade grid operation protocols

- **Grid Codes**
- **5-minute Scheduling and Dispatch**

Expand balancing areas

Promote flexible demand and supply resources

Support Mechanisms for Compliance and Timely Implementation

With strong policy/legislation in place, the focus on implementation support will be even more desirable. The government, at both the central and state levels, will need to support compliance with mandatory requirements regarding RE on the power system through the following functions. Preferred approaches are described below; alternatives are described in the full document.

"One-Stop Shop" for Standardized Contracting: Streamlining the contracting process (e.g., standardization of contracts), and making available relevant information (e.g., that could lead to a more transparent price discovery process) in a centralized manner could significantly reduce contracting-related transaction costs and project risks. This could be achieved by establishing a new CERC-regulated intermediary institution that centrally procures RE from developers at an auction-price and sells to bulk buyers.

Financial Support and Disbursal Mechanism: A uniform, simple financial support and disbursal mechanism targeted to buyers that is transparently designed and provides certainty over a reasonable period of time could significantly help in expediting RE growth. The financial support could be disbursed through the new Intermediary Institution — described previously — that ensures that bulk buyers are indifferent between new RE and new fossil fuel-based generation.

Streamlined Project Development: One of the major constraints on rapid RE development is the lengthy and costly project development process that includes investment-grade RE resource assessments, access to land (either acquisition or leasing), supporting infrastructure development (roads, water, transmission interconnections, etc.), and so on. A newly formed states-center committee should lead the facilitation process to reduce soft costs in project development (e.g., siting, permitting, supporting infrastructure) with technical and logistical support from the Intermediary Institution described above. This is largely aimed at de-risking the sector and fast-tracking RE deployment.

Low-cost Financing: RE technologies, unlike fossil-based energy technologies, have high capital costs but very low operating costs spread over 25-30 years. Thus, the cost of finance (currently ranging from 12–14% in India) forms a significant component of the power tariff from these sources. Buying down the rate of interest for RE projects would reduce tariffs and hence scale up demand for RE. The cost of finance in any country is typically driven by multiple factors and hence, it is neither desirable nor possible to make interventions in financial markets. The interventions thus have to be sector (RE) specific. Further, it is desirable to reduce cost of capital at multiple stages viz:

Stage 1: Reduce the risk perception of the sector by de-risking and hence manage/reduce investors' return expectations (both debt and equity).

Stage 2: Increase the quantum of money available and reduce the cost of access to such money

Stage 3: An existing central-government entity (e.g. IREDA, PFC) could pool various sources of funds including commercial (banks, FIs, MDBs' lines of credits, etc.) and non-commercial (National Clean Energy Fund {NCEF}, grants, subsidies, Corporate Social Responsibility money, etc.) capital from domestic as well as international sources. This pool of funds could be administered and managed to lend debt (and even part equity, if possible) at lower interest rates.

RE Grid Integration and More Efficient Grid Operation

Finally, in addition to strong policy/legislation and supportive deployment environment, grid interconnection and integration of RE is equally critical. Technically, RE is typically described as an intermittent source of electricity. Intermittency consists of two distinct aspects:

Table ES1

RE Grid Integration and Efficient Grid Operation Strategies

Strategy	Impact on Uncertainty	Impact on Variability
One-time		
Upgrade grid technology	Minimize	Manage
Upgrade grid operation protocols	Minimize	Manage
Expand "Balancing Areas"	Minimize	Minimize and manage
Upgrade grid planning practices	Minimize	Minimize
Ongoing		
Balancing resources – estimation, procurement, dispatch	Manage	Manage

- "Predictability/Uncertainty" refers to the lack of accurate knowledge about future RE generation (e.g. sudden drop in wind power), which is not very different from fossil fuel- based generation/ transmission systems (e.g. an unforeseen failure of a fossil-based generator or a transmission line).
- "Variability" is the known natural variation in RE generation (e.g., wind peaking during monsoon and reduced availability in other seasons), just as exists on the demand side currently (e.g., low demand at midnight and high demand during late afternoon).

Internationally — where RE accounts for increasingly large shares of power system generation — various changes to grid design, technology, and its operation have been implemented that allow successful grid integration, i.e. minimizing and/or managing the variability and uncertainty aspects of RE. Many of these strategies are inherently useful for improving the overall efficiency of grid operations and reducing overall costs to consumers whether RE accounts for a large (more than 25%) share of the generation mix or not. Some of these changes are one-time changes while others would evolve over time as load shapes and the resource mix continue to change. These strategies are summarized in Table 1 below. The rest of this section describes these strategies in more detail.

These strategies can be classified into following sub-categories, in roughly ascending order in terms of cost per kWh.

- ***Upgrade grid technology:*** System operators at all levels (i.e. state, regional and national) should have visibility of the grid status in neighboring balancing areas and also the ability to easily coordinate with them. Most of the transmission companies (i.e. central and state transmission utilities) and Load Dispatch Centers (LDCs) (i.e. POSOCO and State LDCs) have initiated grid technology upgrades in recent times. These initiatives need to be significantly ramped up to deploy sensors for generating real-time high geographic resolution data on grid conditions. These data generation sensors need to be coupled with sophisticated analytical engines that provide the necessary information for grid operations. Centralized RE forecasting mechanisms need to be tightly integrated with system operations. Lastly, advanced decision-making and control systems need to be implemented that enable system operators to respond significantly faster to changed grid conditions.

- ***Upgrade grid operation protocols:*** Various aspects of system operations need to be updated. These include but are not limited to:
    - *Grid Codes:* System operators around the world – especially those encountering a high share of RE on their grid – are continually updating their grid codes to ensure that RE additions do not affect the grid adversely, and to explicitly acknowledge attributes unique to RE generators and, consequently, require appropriate capabilities
    - *Scheduling and Dispatch:* Through both practice and theory, it has become evident that grids that are operated in a manner where scheduling and dispatch are implemented over short time durations (e.g., as low as five minutes) have significantly lower overall costs to consumers as the need for ancillary resources decreases. Currently, in India, scheduling occurs on a day-ahead basis while dispatch occurs on a 15-minute basis. System operations technologies and protocols need to be updated to enable five-minute scheduling and dispatch of all resources connected to the grid and automated incorporation of RE forecasts. This will also lower ancillary service requirements.
- ***Expand balancing areas:*** It has been seen globally that larger balancing areas (or the ability to coordinate among balancing areas) have significantly lowered the overall cost to consumers as ancillary services requirements are reduced substantially. Currently, balancing areas in India — specifically, states — neither have the visibility of their neighbors' grid condition nor the ability to coordinate with them. A single national-level load dispatch center that is nonprofit, independent, and regulated by CERC is sufficient for managing the entire national grid.
- ***Promote flexible demand and supply resources:*** Power systems, especially those with a high share of RE, require access to sufficient flexible resources (e.g., demand response, gas turbines, hydroelectricity, etc.) to ensure continued stability of the grid at each moment. Currently, there are no mechanisms in India to ascertain the amount of balancing resources needed and how these can be procured and dispatched. Grid simulations that are used to identify resource pools (both built and un-built), specifically for providing various types of flexible resources including ancillary services, should be conducted routinely. Procurement mechanisms need to be implemented to ensure these resources are connected for use in assuring grid stability. Finally, mechanisms for fair price discovery and compensation of flexible resource providers (e.g. ancillary services) need to be established. The relevant LDC should be made responsible for procuring ancillary services to ensure grid stability. The procurement process should be similar to the usual competitive bidding process used by discoms for procuring energy. The compensation could be cost-plus as approved by the relevant regulatory commission and paid by all the buyers to the LDC.

Energy Access and Off-Grid RE

One-third of India's population does not have access to electricity. Most of the discoms are struggling to provide the minimum lifeline supply of one unit per household per day to the rural areas.

The scope of this RE Roadmap Initiative did not include an extensive consideration of the challenges of energy access or off-grid RE generation dynamics. However, stakeholders concerned with these issues indicated that RE sources could rapidly bridge India's energy access challenge in a cost-effective manner. RE could also accelerate achievement of India's universal service obligation, a mandate outlined in the Electricity Act 2003.

Some policy approaches to these ends were put forward during this Roadmap Initiative, although there was general agreement that these issues require their own in-depth stakeholder process.

For the record, these are the basic energy access and off-grid RE concepts that were suggested. In addition to the current grid extension programs of the Government of India, which are time- and resource-intensive, state utilities (and state governments) should be actively engaged and held responsible for:

- Immediately providing stand-alone off-grid systems in remote rural areas for home lighting and running other basic appliances. Over time, these systems could play the same role as that of rooftop systems in urban areas.
- In parallel, developing district and block-level plans for providing electricity through deployment of micro-grids or mini-grids using RE resources.

The creation and sustenance of the proposed systems would require new business models and private sector participation. Enabling policy and regulatory frameworks should be created at the central as well as state levels. The business models, policies and regulations thus formulated must allow for integration of these stand-alone and/or mini-grid systems with the larger grid system once the distribution grid reaches the inaccessible areas.

Summary and Conclusion

"…Why not consider RE to be main occupants of the "house" and then work out the rest of the system around RE, essentially, because RE is the future?"

This was and remains the key and critical question. For a hundred years, conventional fossil-fueled power plants were at the core of power systems around the world. Those systems had particular engineering and technical characteristics, and, for decades, operating and governance institutions have been created, designed, and operated to support a system with those characteristics.

But renewables are different. For India to capture the benefits of renewables as "the main occupant of the house" will require the rethinking and reengineering of institutions, the redefinition of policies, the re-tuning of power grids and systems, and the replacement of old habits with new ones.

A rethink is unavoidable: renewables are different from the power technologies of the past. The enormous benefits they bring — zero fuel, electricity prices free from volatility and external influence, reduced imports, dramatically reduced pollution and water use — will not be had without significant effort.

Most renewables have zero fuel costs but they are more capital-intensive than conventional fossil power plants. India's renewable resources are abundant, but the output of wind and solar photovoltaic is variable, and in the case of wind in particular, subject to uncertainty. To capture the benefits, India would need to raise the necessary capital, and to get comfortable with managing the variability and uncertainty of renewable energy generation.

The policy framework summarized above and described in Chapter 9 would facilitate that rethinking; it was based on extensive inputs from stakeholders and international experience and specifically designed to overcome the barriers to success and meet the renewables challenge.

To that end, then, both the purpose and the best use of this RE Roadmap Initiative report will be to assist policymakers and stakeholders to grasp what is at stake, and what needs to be done to make a successful choice in favor of renewables at scale.

Introduction

Today, India's 260 GW of installed electric generating capacity is significantly higher than its nearly 140 GW of peak demand. In fact, India's coal generation capacity alone is higher than the country's peak demand. And yet, paradoxically, shortages and blackouts are endemic.

The reality is that many of India's shortages and blackouts are the result of insufficient fuel availability and high costs. Conventional coal-fired power plants constituted a major share of the new capacity built between 2005 and 2014. Despite estimates that India has huge reserves of coal, the country's ability to mine that coal and move it around the country is constrained. Further, unlike domestic coal, the price of imported coal is unregulated; its price is set in the international market which can be quite volatile. Imported coal in the recent past has been significantly more expensive than Indian coal. Distribution companies (discoms) that buy electricity from plants fired with imported coal face significant and unpredictable upward pressure on tariffs. Some utilities have tried to avoid these high costs by simply not buying imported coal or power fueled by imported coal, even when the result is local shortages and rolling blackouts.

For decades, as demand for power has grown, India has added large-scale conventional power resources. Now, however, with solar and wind power becoming commercially available in the marketplace, there are additional choices available to policymakers and stakeholders concerned with the technical, economic, and environmental characteristics of a future power system that keeps pace with economic growth.

One of India's major advantages today and going forward is that its RE potential is vast and largely untapped. Recent estimates show that India's solar potential is greater than 10,000 GW and its wind potential could be higher than 2,000 GW.

The truly good news from a policymaker and stakeholder perspective is that the costs of generating RE have fallen steeply in the past decade. Within a few years, it is likely that subsidies for RE will no longer be necessary as it will be available at the same or lower cost than power from the more traditional fossil fuel-based plants. In fact, in India today:

- new wind projects at the point of generation are cheaper than the comparable costs of power from new imported coal-based projects;
- solar photovoltaic generation costs are cheaper than the cost of natural gas-based generation;
- roof-top solar photovoltaic systems costs is cheaper than the cost of existing tariffs for large commercial and industrial (C&I) consumers and even high-use residential consumers in some states; and
- new rooftop solar costs are already significantly lower than the cost of diesel back-up generators and battery-inverter systems used by many consumers.

As renewable technology continues to improve and the costs continue to fall, forecasters worldwide believe that these positive trends for RE are likely to continue.

Another attribute of RE is, unlike conventional fossil-based power plants which take from six to ten years to be operational, RE generation can be built quickly – thus matching supply and demand quickly, and simultaneously reducing the risks to buyers and sellers. In addition, international research has indicated that the cost of integrating and managing the intermittency that comes with RE generation – depending on the system size and its composition – can range from negligible to moderate.

Under any scenario, billions of rupees' worth of new power plants and new transmission lines will be built by 2030. This new infrastructure should be built with a high RE generation mix in mind. Any new investment in new infrastructure, be it new generation or transmission, should accommodate a high RE generation mix. New generation should be from flexible resources that can complement RE's availability and transmission will have to be designed to allow not only for the transfer of power from RE-rich areas to RE-poor areas, but also for more cost-effective system balancing.

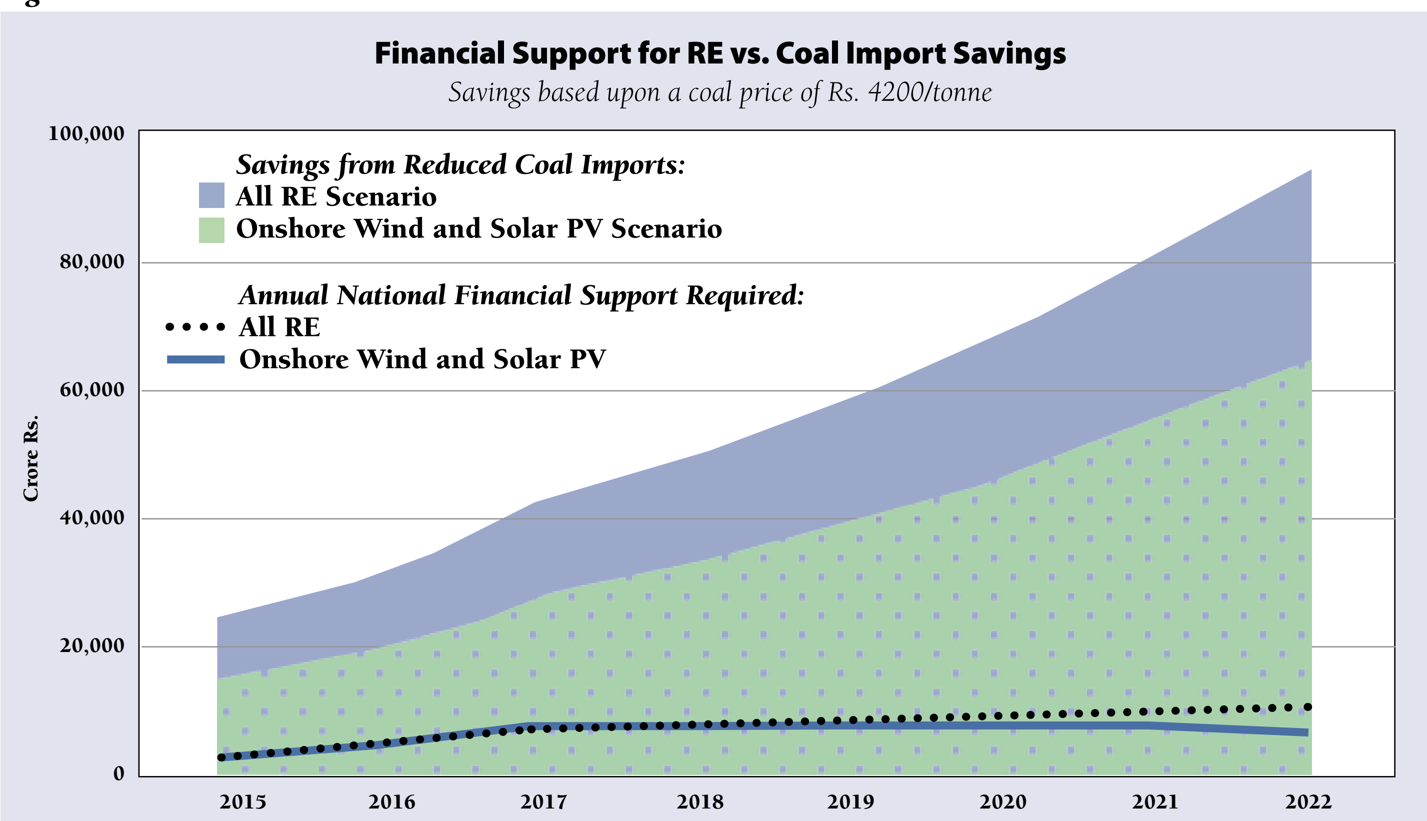
However, from a broad public policy perspective, the major benefit of a more rapid transition to RE lies perhaps less in the direct consumer impact and the impact on the power system itself. Dwarfing those will be the positive effect on India's macroeconomic circumstances as tapping into abundant indigenous renewable resources avoids revenue outflows for expensive imported fuels. At the current time – without innovative policy changes – India is facing a rapidly rising and volatile imported coal bill far into the future. As of 2013, India's erstwhile Planning Commission forecasts that Indian coal imports for electricity generation are expected to rise from 90 million tons in 2011-2012 to 250 million tons of coal in 2022,[1] draining about Rs. 1,05,000 crores (Cr.) from the Indian economy.[2]

Reaching 20% RE (by energy) by 2022 will dramatically reduce the coal import bill in 2022. According to preliminary analysis carried out by the Roadmap Initiative team, for as little as Rs. 7,000 crores in 2022, electricity buyers in all states can be made indifferent between RE and conventional sources. Juxtaposed with that investment, the coal import bill in 2022 will fall by more than Rs. 60,000 Cr. See Figure 1, below.

In order to realize RE benefits, a successful RE strategy for India will need to be integrated with and complementary to existing and planned fossil-based power projects. Consequently, it will require new thinking, a probable reengineering of institutions, the redefinition of policies, the retuning of power systems, and the replacement of old habits with new ones. A new way of thinking is unavoidable: RE is different from the power generation technologies of the past (e.g. thermal, hydro, etc.). Current infrastructure and policies are set up to fit the requirements of fossil energy resources, not RE, and a system that utilizes increasing amounts of RE can only be achieved by significant efforts and retooling of the power system.

The above benefits come with certain challenges. RE is relatively more capital-intensive than conventional power plants. The output of wind and solar photovoltaic

Figure 1-Intro



1 http://planningcommission.gov.in/plans/planrel/12thplan/pdf/12fyp_vol2.pdf; pages 133 and 160

2 Assuming imported coal price to be at Rs. 4200/tonne

3 Uncertainty in RE generation is, typically, reduced significantly through implementation of appropriate forecasting techniques. The impact of residual uncertainty and variability in RE generation is addressed through a portfolio of strategies targeted to the design and operation of the power system.

generation is variable and uncertain.[3] Thus, to capture the benefits, India would need to make available the necessary capital, and get comfortable with managing the variability and uncertainty of RE generation in conjunction with the existing and planned fossil fuel-based and large power plants.

How to begin that process of retooling is the purpose of this exercise and document.

Roadmap Process

It was against this backdrop of benefits and challenges that the Government of India's erstwhile Planning Commission, in November 2013, requested that the Confederation of Indian Industry (CII) in conjunction with the Shakti Sustainable Energy Foundation (SSEF) and the Regulatory Assistance Project (RAP), conduct a stakeholder-driven "roadmap" exercise to answer the question: "How must the Indian power system evolve if India chooses to put RE at the core of the future system, rather than at the periphery?" A steering committee for the exercise was created, led by then-Member (Energy) and composed of Secretaries of Ministry of Power (MoP), Ministry of New and Renewable Energy (MNRE), Ministry of Finance (MoF), Ministry of Environment and Forests (MoEF), Central Electricity Authority (CEA), Power Grid Corporation of India, Ltd. (PGCIL), and the Energy Secretaries of Tamil Nadu and Rajasthan.

Both the purpose and the challenge of this road map exercise have been to assist policymakers and stakeholders to grasp what is at stake, and what they would need to do in order to make a choice in favor of RE at scale, successful.

The analysis and practical "next-step" policy recommendations that follow are based, in large part, on broad and robust open-ended conversations conducted under the "Chatham House Rule" with over 250 power sector stakeholders from 13 states. The stakeholders included the steering committee members, chairpersons/members and senior staff of central and state electricity regulatory commissions, energy secretaries of states, managing directors of generation, transmission and distribution companies, grid operators, power sector planning agencies, grid managers, civil society, industry and finance, developers, and bilateral and multilateral institutions.

Initial interviews and small group conversations were conducted throughout the country during December 2013 through March 2014. Preliminary findings were presented to the Steering Committee in April 2014, then circulated and commented upon by close to 100 stakeholders and domestic and international experts. The draft policy recommendations drawn from the Roadmap Initiative process went through an iterative process from August through October 2014 as the Roadmap Initiative team solicited feedback from diverse stakeholders and domestic and international experts, both through correspondence and in-person.

Outline of Report

The report and its findings find much more relevance in a scenario when the Government of India has enhanced its aspirations multifold – from 20 GW of solar power (by 2022) to 100 GW (by 2019) and from an additional 15 GW of wind power (during 2012-17) to an additional 40 GW (by 2019).

In the following chapters, stakeholder responses have been organized into eight detailed and specific themes that focus on identifying changes in power sector governance, management, structure and power systems that would be prerequisite to the large-scale, cost-efficient, reliable deployment of RE. Where appropriate, examples of international experience (successful and otherwise) relevant to the issues raised have been added. In the final chapter, the intent is to outline a small number of specific near-term steps that the Government of India, state governments and stakeholders could take to begin the power sector retooling process described in the background document.

Chapters 1 and 2 set the scene for the discussion of the overarching issues that are discussed in depth in Chapters 3 to 8. Chapter 1 provides the context, including targets for deployment, and lays out a systematic approach to assessing the relative benefits, costs, and risks of renewable energy. Chapter 2 discusses key policy tools currently in place and visualises how these may evolve as renewable energy reaches higher penetration levels.

Chapter 3 begins the discussion of specific areas that are being looked at by stakeholders up around the country, beginning with supply chain aspects of renewable energy deployment, including manufacturing, the adequacy of human resources, and research and development.

Chapter 4 moves on to an assessment of investment in renewable energy markets to date, including sources of investment, private and public sector roles, and how greater private investment in particular can be stimulated.

Chapter 5 covers an area that is often overlooked in strategic analysis of this kind: risks at the level of the individual project, from siting to grid connection, and a number of performance risks.

Chapter 6 takes the completion of a variable RE power plant as its point of departure, and asks how a sufficiency of buyers can best be assured for the electricity generated.

Chapter 7 then considers the transportation of electricity to the consumer, through the transmission and distribution networks, and how these may be planned for greatest efficacy.

Chapter 8 discusses system operational aspects: how the often-cited issues of variability and uncertainty in the output of wind and solar photovoltaic power plants could be managed reliably.

Finally, Chapter 9 outlines a small number of specific near-term steps that the Government of India, state governments and stakeholders could take to begin the power sector retooling process that will accelerate deployment of RE in India.

Each chapter draws attention to power system aspects that are sometimes unique to the Indian case, sometimes ubiquitous, but always germane when considering the large-scale deployment of variable renewable electricity technologies such as wind and solar photovoltaic. They then proceed to discuss issues that are particularly problematic, and options for their resolution as proposed by stakeholders or suggested by international experiences. The chapters are rounded off with a short summary of key issues.

While this report makes an effort to suggest steps for issue resolution, we must specify one thing that has become clear during this process: there is no single answer on which all agree. All over the globe, policymakers, power sector stakeholders and participants are struggling to re-invent and re-imagine their institutions and their behaviors to adapt to the unique technical and economic characteristics of renewable resources. Progress is being made as increasingly large amounts of RE are coming on line in China, Europe, and North and South America. Since no one is developing RE the exact same way, there are many examples to consider and lessons to be learned. India will develop a portfolio of policies and strategies that work in the India context.

What is also clear is that the choice to make RE a significant component of India's evolving power system will require new, domestically-driven solutions, informed by both Indian and international experience.

The report is written for the informed policymaker and sector stakeholder. Technology and technical aspects of all kinds are discussed using non-technical language wherever possible, to ensure accessibility for a wider audience.

1. Bringing RE into the Heart of Indian Electricity Systems

"We should not get into the mindset that RE is the intruder and conventional energy is the main player. Why not consider RE to be main occupants of the "house" and then work out the rest of the system around RE, essentially, because RE is the future?"

— Former Member (Energy),
India's erstwhile Planning Commission

There is resounding consensus among all the stakeholders that renewable electricity (RE) will play a major role in the future of the Indian electricity system. However, it is less clear what that will mean in terms of:

- RE share of electricity, and when it will be achieved;
- The cost to society as a whole, and how those costs should be allocated; and
- What the key barriers are to accelerating RE deployment, and the solutions to them.

1.1. Context

The key difference between conventional generation (e.g., coal, natural gas, nuclear, hydro) and a system based on renewable energy (e.g., wind, solar) is the need for raw fuel that in turn necessitates a complex, reliable, and expensive upstream infrastructure for its production and transportation to generator site. In order for it to function, the physical, economic, and institutional aspects of not only the power grid, but of this entire upstream infrastructure as well, must work in sync. In some ways, the impact of limitations and/or failures of upstream infrastructure can be compared in importance to the complexities of managing variable RE, and yet are usually not considered in the context of power sector planning.

1.1.1. Rapid Demand Growth and Chronic Supply Shortages

India's present peak demand for electricity is 135 GW and is expected to grow to about 200 GW by the end of financial year (FY) 2016/17, that is, the end of the 12th Plan period, and to 283 GW by FY 2021/22 (the end of the 13th Plan period).[1] The Compound Annual Growth Rate (CAGR) underlying the growth in electricity requirement – both energy and peak demand – is approximately seven percent over the period 2016/17 to 2031/32. For the sake of comparison, this rate of growth is three to four times greater or more than currently observed and expected in developed countries, and approximately on par other developing economies.

This rapid growth is driven by both increasing consumption by customers who are connected to the electricity grid and the number of customers who are likely to get connected to the grid in the near future. The increased consumption is primarily a consequence of increasing population and economic growth that is expected to occur.

Not only is the demand for electricity growing, the load profile is also changing as greater income leads to increased purchases of appliances – especially for space cooling – that has a significantly different load profile from historically common loads such as lighting.[2] Other changing factors such as the composition of economic activities (e.g., shift from industrial to services), hydrology (e.g., falling groundwater tables coupled with droughts), and others, also have significant implications for the load profile. In Table 1 the growth of the electricity system – both in terms of supply and demand – are shown for each five-year plan period.

Energy access and unmet demand continue to handicap fundamentally India's goals for economic growth, improvement of living standards, and the achievement of other social goals (e.g., education), especially in the rural areas. There is a huge opportunity cost because of the lag before the supply-demand gap is bridged conclusively.

1 18th Electric Power Survey.

2 See: http://www.gbpn.org/sites/default/files/08.India_TechnicalReport_0.pdf.

Consumer response to this lack of access and unreliability of electricity supply ranges from expensive investments in backup supply (e.g., batteries and diesel generators) to the foregoing of productivity and a better quality of life.

The centralised large-scale power generation paradigm has not met the full needs of Indian society, and stakeholders indicated that the prospects of its doing so in the near future are dim. In sharp contrast, the modularity, scalability, and greater speed of deployment of RE technologies relative to the conventional generation may have the potential to address this supply-demand gap in a much shorter time frame.

According to the Statistical Year Book 2014, the overall rate of electrification in 2011 was 67 percent, with 93 percent of urban and 55 percent of rural households having access to electricity. The level of electrification of households varies significantly across various states in urban areas (80 percent in Uttar Pradesh to 99 percent in Sikkim), but especially in rural areas (10 percent in Bihar and 23 percent in Uttar Pradesh to 97 percent in Himachal Pradesh).

Furthermore, even if households have access (i.e., there is a connection with the grid), the availability of power is significantly limited to as low as only a few hours during the day. The Government of India (GOI) reports low per capita consumption (eight units/month) for as much as 67 percent of the rural households that are electrified, which indicates that a significant amount of demand is unmet owing to limited availability and poor power quality.[3]

The central government continues to provide financial support (e.g., APDRP, R-APDRP, RGGVY) alongside ongoing state government-led programmes for extending the grid to all households. However, stakeholders questioned whether, even when the grid is extended to all households, there would be sufficient energy available for all those connected households.

The recent rapid decrease in the costs of modular energy generation technologies such as solar photovoltaics (PV)

Table 1

India's Growth in Capacity, Electrification, Network, and Consumption (1947-2013)

As On/During Financial Year Ending With	Intalled Capacity (MW)	No. of Villages Electrified	Length of T & D Lines (Ckt. kms.)	Per Capita Consumption (kWh/year)
31.12.1947	1,362	N/A	23,238	16.3
31.12.1950	1,713	3,061	29,271	18.2
13.03.1956 *(End of the 1st Plan)*	2,886	7,294	85,427	30.9
31.03.1961 *(End of the 2nd Plan)*	4,653	21,754	157,887	45.9
31.03.1966 *(End of the 3rd Plan)*	9,027	45,148	541,704	73.9
31.03.1969 *(End of the 3 Annual Plans)*	12,957	73,739	886,301	97.9
31.03.1974 *(End of the 4th Plan)*	16,664	156,729	1,546,097	126.2
31.03.1979 *(End of the 5th Plan)*	26,680	232,770	2,145,919	171.6
31.03.1980 *(End of the 2 Annual Plans)*	28,448	249,799	2,351,609	172.4
31.03.1985 *(End of the 6th Plan)*	42,585	370,332	3,211,956	228.7
31.03.1990 *(End of the 7th Plan)*	63,636	470,838	4,407,501	329.2
31.03.1992 *(End of the 2 Annual Plans)*	69,065	487,170	4,574,200	347.5
31.03.1997 *(End of the 8th Plan)*	85,795	498,836	5,141,413	464.6
31.03.2002 *(End of the 9th Plan)*	105,046	512,153	6,030,148	559.2
31.03.2007 *(End of the 10th Plan)*	132,329	482,864	6,939,894	671.9
31.03.2012 *(End of the 11th Plan)*	199,877	556,633	8,726,092	883.6
31.03.2013 *(End of the 1st yr. of 12th Plan)*	223,344	593,732	8,970,112	917.2

Source: Central Electricity Authority

3 GOI 12th Five Year Plan, Volume II, Economic Sectors, p 131.

as compared with more expensive conventional diesel generators has allowed entrepreneurs (such as Mera Gao Power, SunEdison, Azure, and so on) to explore off-grid distributed micro-grid electricity supply models for rural areas, in Bihar and Uttar Pradesh, for example.

Electricity supply has fallen short of consumer demand chronically, both in terms of energy and peak power needs. Figure 1 shows the shortage situation over the last three decades. Furthermore, stakeholders have pointed out that, given highly unreliable supply to a large portion of the population, peak demand estimates may underestimate significantly the true level; consumers facing highly unreliable supply are unlikely to have invested in appliances even if they can afford them.

The power shortage problems arise not only from the electricity generation aspect of the supply system but also from the upstream infrastructure that was described earlier. Official reports and stakeholders both indicated reduced availability of coal (average plant load factor for coal was 68 percent in 2013) and hydro, and lack of natural gas as the key reasons behind the lower generation.

Some of these factors are being addressed, with mixed results. Constraints on domestic production of fuel such as coal and natural gas has led to increases in imports, especially of coal. However coal-fired power has still been constrained by the various circumstances associated with imported fuel (e.g., high prices relative to domestic sources, trade deficit, currency fluctuations, import infrastructure). Other factors such as a lack of transmission capacity among the regions may also have reduced the ability of the existing fleet to meet demand. Recently new transmission capacity has been added, which has enabled the synchronisation of the southern region with the rest of the country in a single unified grid. Other factors have still not been resolved to the satisfaction of relevant stakeholders (e.g., affordably priced domestic natural gas).

In contrast, RE capacity additions have demonstrated relatively short lead times in construction, and once constructed do not rely on upstream supply of fuel, water, and so on. Indeed, for these reasons perhaps, several major power plant developers (e.g., Tata, Reliance, Coal India Ltd., NTPC) – both government- and privately owned – have begun to diversify toward RE projects, and have even canceled some planned investments in coal generation.

1.1.2. Implications of Importing Fuel

Increasing domestic energy resources, including those with no fuel costs (e.g., RE), is a powerful concept that resonated with stakeholders. Dependence on imported coal exposes India to risks of volatile prices, foreign exchange rate risks, competition with other importers, and the domestic needs of the source countries.

The lag in domestic production has resulted from a variety of factors: inefficient production of coal from existing mines, delays and major issues in the allocation of coal blocks to mine developers, delays in land acquisition, and transport constraints (e.g., lack of both railway tracks and sufficient rolling stock). Domestic coal production (with a CAGR of 4.6 percent over FY 00/01 to FY 11/12) has not been able to keep pace with demand (CAGR of 6.4 percent over 2002 to 2013) or generation (CAGR of 5.3 percent over FY 00/01 to FY 11/12). India imported 38 million tonnes (Mt) of coal in 2007, rising to 105 Mt in 2012, and it is projected to rise to 185 Mt by the end of the 12th Plan in 2017.

In 2013 alone, the total additional coal import bill

Figure 1

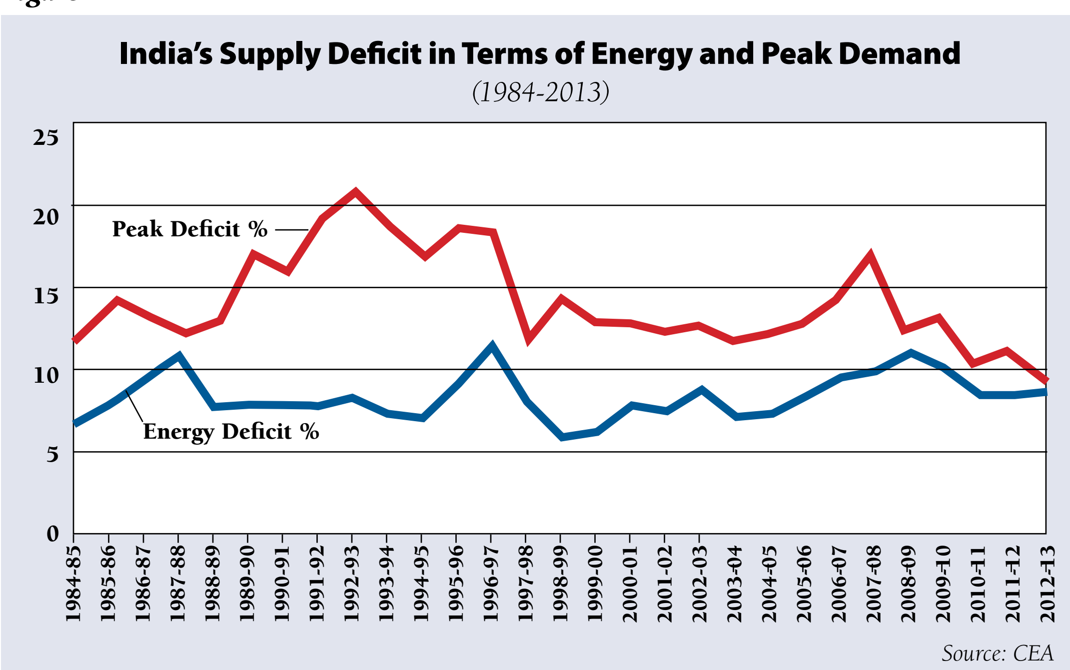
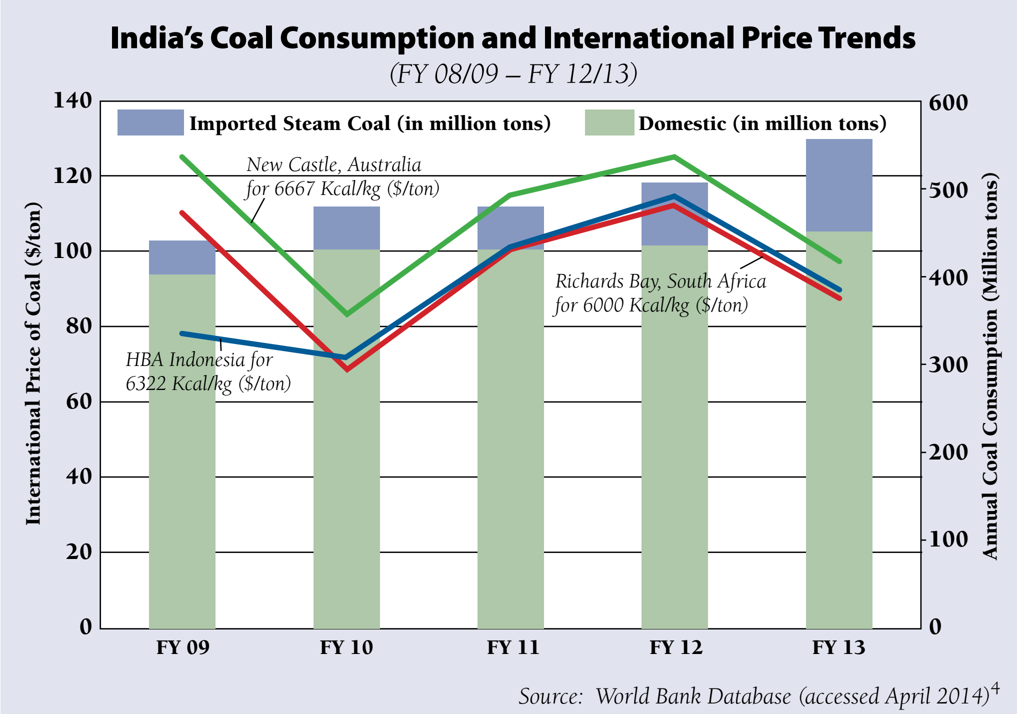


Figure 2



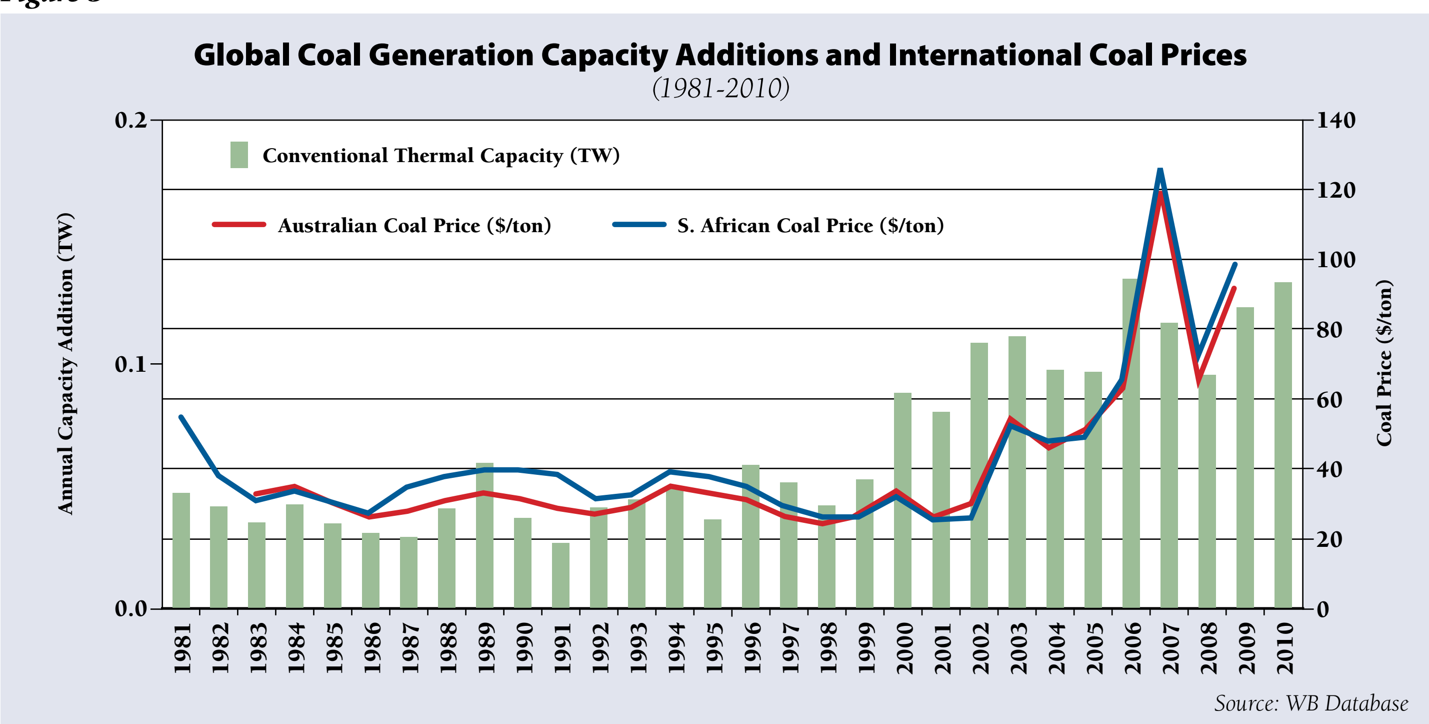
Source: World Bank Database (accessed April 2014)[4]

below USD 40/tonne. However, after 2000 average annual additions in global coal generation, capacity almost tripled to 110 GW. Simultaneously international prices started to increase rapidly, became increasingly volatile, and spiked above USD 120/tonne in 2008. The increase in capacity additions was largely a result of the the growth in electricity demand, especially in China and India. Whether the era of stable and low international coal prices returns or not depends on the speed and size of new coal supply coming online, globally, to meet the expected growth in coal demand.

Policymakers will need to account for the risks associated with international coal prices and trade deficit issues if they expect to depend on increased imports. Furthermore, policymakers will have to account for the corresponding impact on the trade balance and its implications for the overall fiscal policy of the country. Stakeholders described

was in excess of USD 10 billion. International coal prices are a function of the policies of coal exporting countries, and international supply and demand. Between 1981 and 2000, annual global capacity additions averaged 40 GW and international coal prices were stable, remaining mainly

Figure 3



Source: WB Database

4 See: http://data.worldbank.org/topic/infrastructure.

the positive impact of increased RE on India's current account deficit as a huge benefit, with resulting beneficial linkages to the cost of finance in the country, resources for government programmes, and many other ripples through society.

Stakeholders also consistently mentioned energy security as a major concern. They recognised the trade-off between energy security and the price tag of that security. If, in addition to the import of oil, India is now to rely increasingly on other nations (e.g., Indonesia, Australia, South Africa, the United States) to meet its electricity needs, then foreign policy engagements with these countries will need to reflect this. Domestic policy shifts in these countries may have implications for the availability of coal for export to India. For example, in recent years, several new coal export terminals were being considered in northwestern United States. However, domestic resistance to building these export terminals has led either to outright cancellations or to significant delays. In Indonesia, the government unilaterally changed its coal pricing policy linking it to the international price, thereby directly undermining the viability of coal-based projects (e.g., over 8000 MW of capacity at Mundra in Gujarat) that were already under construction, as fuel cost is not passed through to consumers.

Finally, stakeholders identified the geographic and physical diversity of RE resources as an opportunity to improve the resiliency of the grid. This is reflected in international experiences such as recent terrorist attacks on critical grid infrastructure in California, and natural disasters such as hurricanes in the United States.

It should be noted that stakeholders advocated for investment in domestic RE manufacturing as an important component of an RE strategy to grow Indian high-value exports and contribute to improvement in India's balance of trade (discussed in Chapter 3). There was also interest in domestic content requirements to reduce imports of RE supply chain elements.

1.1.3. Environmental Impacts

One stakeholder said that *"renewable energy is always talked about as marginal. We make small efforts and say we are doing our part. But are we leaving the world a better place?"* Several other stakeholders also insisted that environmental benefits must be considered when comparing RE to other power options.

Both power generation and the upstream extraction and infrastructure of coal and gas are responsible for a wide range of environmental impacts, while competing with other users for two key resources: water and land. Environmental impacts have major implications for humans as well as the flora and fauna of India and elsewhere. In this densely populated and highly agriculture-dependent country, water and land are scarce resources, the use of which should be carefully assessed. It should be noted that some stakeholders indicated that the environmental impacts and water/land requirements of RE power plants should also be systematically assessed and mitigated if need be. The environmental impacts of coal-/gas-based generation can be broadly classified as:

- **Air:** CO_2 (climate change), SO_2 (key ingredient for formation of acid rain), NO_X (key ingredient for formation of ground-level ozone formation), Particulate Matter (PM2.5 and 10), trace elements such as mercury/arsenic and the like.
- **Water:** thermal pollution, acid rain (indirect SO_2 impact), ash ponds leaking into water bodies (e.g., several incidents in the United States), use of toxic chemicals to treat coal before use in power plants (as in a recent incident in West Virginia in the United States).
- **Land:** ash ponds, mountain-top removal and dumping of waste in valleys (as in West Virginia in the United States), permanent destruction of forests in mining areas for railway lines and power projects (e.g., in the process of storing coal).

1.1.4. Water Availability

Water availability must also be considered while assessing the implications of the withdrawals for power generation. WRI (2013) estimated the water stress (i.e., ratio of water withdrawals to water availability) for all countries, and determined that India was already categorised as high stress (i.e., 40 percent to 80 percent ratio) along with regions such as Middle East and Southeast Asia, Australia, and North Africa.[5] The main user of water in India is agriculture, which accounts for approximately 85 percent of the freshwater use.

The problem of water scarcity is exacerbated by the geographic concentration of the coal-based generation capacity. Figure 4 presents the geographical distribution of coal plants in India relative to the level of water scarcity in each location. The United Nations (2014) indicates that more than 80 percent of the capacity is located in either water-

5 See: http://www.wri.org/blog/world%E2%80%99s-18-most-water-stressed-rivers. Accessed July 2014.

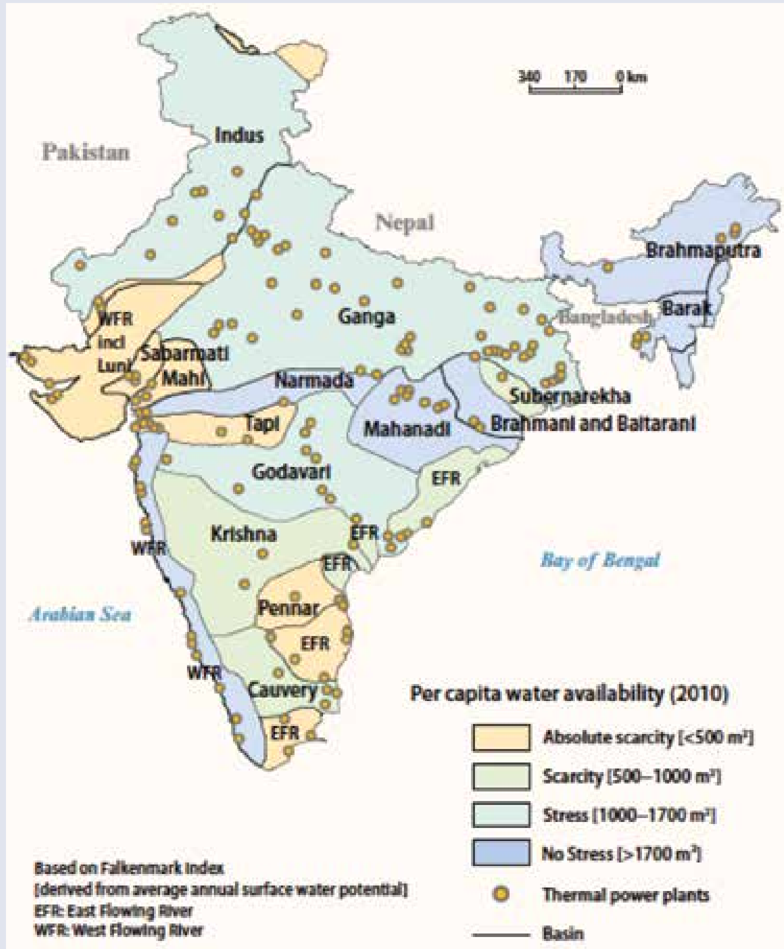
scarce or -stressed regions of India.

The high priority accorded to agriculture in India is expected to lead to conflicts with the needs of planned generation capacity. Some examples of these conflicts as mentioned in media reports are as follows (excerpted from UN, 2014):

- In Madhya Pradesh, power cuts were imposed to alleviate the water shortage in the region in 2006 (*Hindustan Times,* 2006).
- In Kerala, power cuts were imposed to deal with water scarcity in 2008 when monsoon rainfall was 65 percent less than normal (*Thaindian News,* 2008).
- In Orissa, farmers protested against the increasing rate of water allocation for thermal power generation and industrial use. In response to the protest, the state government decided to give conditional permission to construct a thermal power plant that had applied to use seawater for cooling purposes rather than river water to avoid placing further pressure on the Mahanadi River basin (UNEP Finance Initiative, 2010).
- Opposition to Adani power projects is growing in Nagpur. The local community believes that this power plant poses a threat to the Pench Tiger Reserves and endangers drinking water and irrigation water availability (*The Times of India,* 2011).
- All six units of the Parli thermal power plant in the Beed district of Maharashtra were shut down because of a severe water shortage in the Marathwada region. The plant had previously received water from the Khadka dam, but the supply was stopped because the water in the dam had almost dried up (NDTV, 2013).

Figure 4

The Water Stress Level of Major River Basins and the Distribution of TPPs



Source: UN (2014).

The discussion above has primarily been about the water use of thermal power plants. On the other side of the coin, coal-fired generators may also be negatively impacted by inflows of water at an undesirable temperature, causing shutdowns in several recent instances.[6] Such occurrences happen during the higher temperatures of summer, when typically demand for electricity is the highest, creating potentially major problems for the grid as a whole. According to the *Statistical Year Book of India (2014)*, the ambient water temperatures of most rivers in India have been increasing steadily over the last decade, from 35.25° C in 2001 to 36.63° C in 2011.

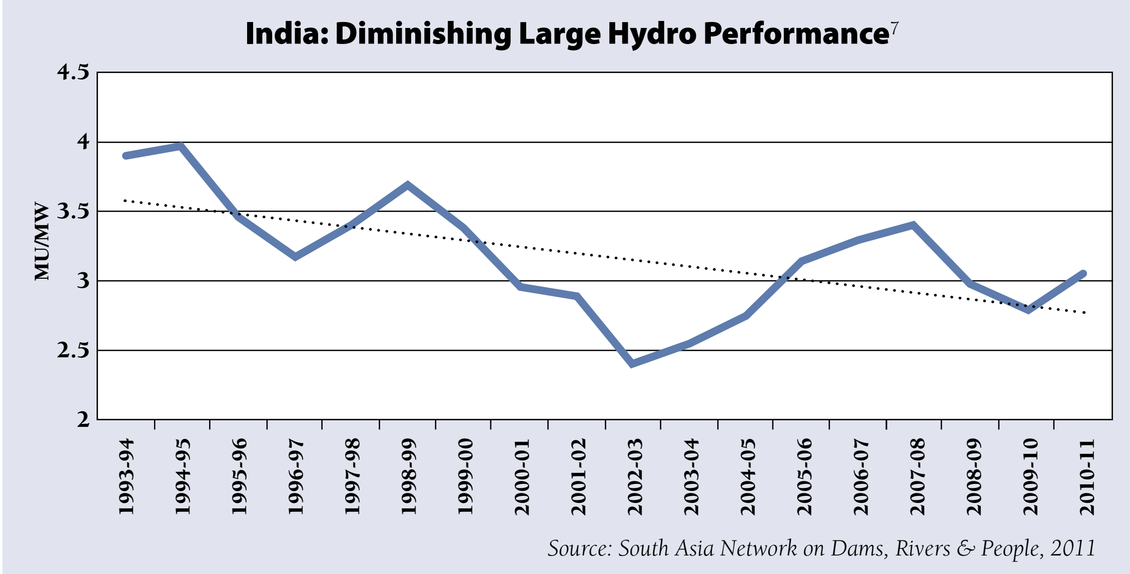
In addition, because of the precipitation patterns and the condition of the hydroelectric power projects in India, overall electricity performance has decreased from 3.9 MU (GWh)/MW in FY 93/94 to 3.05 MU/MW in FY 10/11. During this period, in several years the performance dipped well below 3 MU/MW to as low as 2.4 MU/MW in FY 02/03 (Figure 5).

Although power planning has not systematically accounted for cumulative water requirements of thermal capacity, in relation to water availability, the issue is certainly a top concern of Indian industry. Results of FICCI's 2012

6 Union of Concerned Scientists, 2013.

survey of Indian industry indicate that 66 percent of survey respondents said that "water availability is impacting business today" and 87 percent think it will impact within the next 10 years.

Figure 5



Source: South Asia Network on Dams, Rivers & People, 2011

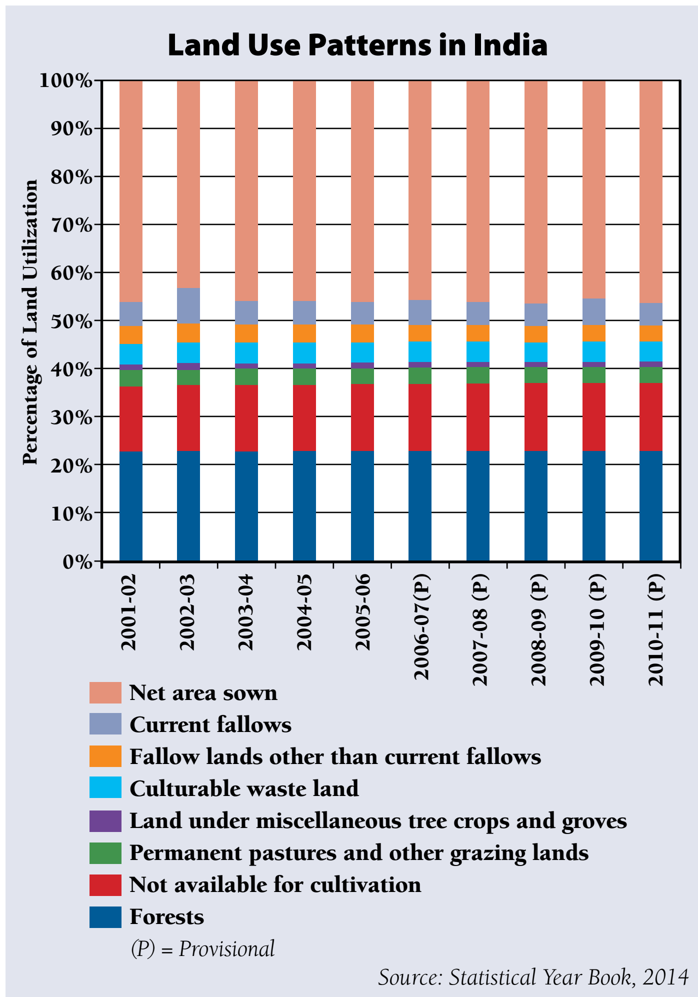
1.1.5. Land Availability

As for water, one of the main uses of land is agriculture, followed by forests, with a very small amount of land available designated as fallow (Figure 6). The proportional uses of land vary greatly across India. The typical land area of a wind farm in India is 9 MW/km2. However, although this appears high relative to, for example, a thermal power station, only a fraction of it is disturbed (less than three percent), and at that only temporarily, during the construction phase. An even smaller fraction is permanently used (less than one percent), mainly for the roads that maintenance crews need during the operational life of the wind farm.

In the case of solar PV, the land requirement in India is approximately 35 MW/km2. However, solar PV is a highly modular and scalable technology that can be installed in sizes ranging from a few square feet to hundreds of acres, and can be integrated among other land uses. For example, systematic assessment of rooftop solar PV potential for a dense city such as New York is as high as approximately 5000 MW and can account for a third of the peak demand of the city.

A comparison with thermal power land use should include upstream infrastructure and the disposal of effluents. Although exercises such as the Central Electricity Authority (CEA) (2007) have systematically estimated land requirements for coal-based electricity generators in India, there is little systematic analysis in India, or elsewhere, of land requirements for extraction and transport.

Figure 6



Source: Statistical Year Book, 2014

1.1.6. Limited Institutional Coordination

Key stakeholders highlighted an existing lack of coordination among the important institutions responsible for achieving the accelerated deployment of RE in India.

7 See: www.sandrp.in.

Under Entry 38 of List III of the Seventh Schedule of the Constitution of India, electricity is a concurrent subject: both state and central governments have jurisdiction. Despite the ongoing efforts of relevant institutions at the centre and state levels, the alignment between state and central governments, and effective coordination, is still a work in progress. Alignment and coordination among states is also limited; regional approaches to addressing various policy issues have typically been facilitated by the central government instead of being initiated directly by the states concerned.

Within central government a large number of ministries are responsible for the various aspects related to electricity. These include the Ministry of Power (MoP), Ministry of New and Renewable Energy (MNRE), Ministry of Coal, Ministry of Finance, Ministry of Environment and Forests, Ministry of Petroleum and Natural Gas, Ministry of Railways, Ministry of Shipping, NITI Aayog, and others.[8]

The MoP encompasses several key institutions relevant for RE, including the Central Electricity Authority, PowerGrid Corporation (PGCIL), Power System Corporation (POSOCO), National Thermal Power Corporation (NTPC), National Hydro Power Corporation (NHPC), and others. Within ministries that make policy and administer the sector, various subordinate institutions own assets. For example, institutions under MoP, which is responsible for administering the Electricity Act of 2003, include PGCIL, which owns the interstate transmission grid; POSOCO, which is the sole system operator of the interstate grid; NTPC, which owns more than 40 GW of thermal generation capacity; NHPC, which owns approximately 6 GW of hydroelectric capacity; and Coal India, which produces 81 percent of all the coal produced in India.[9] These could potentially lead to inherent conflicts of interest. Similar conflicts of interest can also occur at the state level.

The most relevant departments within state government include energy, the designated/nodal agency, land/revenue, the pollution control board, and others. In most states, the energy department owns the holding company that in turn owns generation, transmission, trading, and distribution companies that serve the state.

State-owned generation companies (Gencos) were historically the primary developers of generation capacity. In recent times, however, the role of national government companies such as NTPC and NHPC has increased, and in the future the main developers of capacity are expected to be mostly from the private sector. The state government owns the intrastate transmission and system operation. The state-owned distribution companies (Discoms) also largely own the distribution sector, with a few small service territories being served by private companies and city governments.

As a whole the entire power sector in India is dominated in terms of direct ownership by the central and state governments. In contrast, the entire RE generation capacity has been developed and owned by private companies, whereas approximately two-thirds of conventional capacity is still owned by state and central governments. This may simply be the result of historical ownership trends, RE being developed more recently, during a period in which private ownership is more dominant.

Although various laws, policies, and the nascent regulatory framework continue to move the operation of the power sector toward commercial practises, political considerations continue to conflict with the commercial imperatives. Stakeholders noted that India will need to resolve the dilemma of whether to view the power sector commercially (i.e., with the fundamental objectives of cost recovery and return on investment) or as a social enterprise (i.e., with the fundamental objectives of achieving equitable/fair social and economic development).

Given that RE is a part of the power sector, the issues concerning the power sector as a whole will also affect RE. The rest of this report highlights some of the key institutional issues that need to be addressed in more detail. The following is a partial list of those issues as expressed by stakeholders:

- The actual supply chain underlying various energy resources – both RE and conventional (e.g., coal, natural gas) – is distributed across various line ministries, leading to major concerns about coordination among government policies (e.g., growth in coal production is significantly lower than growth of thermal generation capacity addition, leading to increased imports of coal).
- Although RE generation capacity targets have been included in the various five-year plans, so far they have not been developed in relation to the various macro-level policy concerns faced by India, such as energy security, trade deficit, environmental impacts, and others. No systematic assessment and comparison of risks, costs, and benefits is conducted across various energy sources using a common analytical

8 Since May 2014 a single minister heads MOP, MNRE and the Coal ministry.

9 See: https://www.coalindia.in/en-us/company/aboutus.aspx.

platform and through participatory process involving all relevant government and non-government stakeholders. Consequently, allocation of appropriate support mechanisms (e.g., financial incentives) for various energy sources is not explicitly synchronised from the perspective of addressing the main policy concerns listed above.

- The current process of developing RE projects consists of developers identifying project locations and then undertaking the various steps, such as procuring land, obtaining permits, interconnections, and so on from various agencies within the state and central government. This process varies significantly from state to state in terms of its effectiveness. There is no effort in streamlining this process and making it consistent across various states to reduce the "soft" costs. The reduction in project development risks would also reduce the cost of financing the projects and improve their viability. Development risk is discussed in greater detail in Chapter 5.
- The Electricity Act (2003) directs retail tariffs (i.e., costs faced by consumers) to reflect actual costs (i.e., costs of generation, transmission, and distribution), however, in reality consumer tariffs do not reflect costs. This has led to a chronic gap between the total revenues and costs of the distribution companies (mostly state-owned), which are also the primary interface between the consumers and the power sector as a whole. Both state governments and the central government either routinely or on specific occasions continue to provide direct financial support to distribution companies to bridge the gap between revenues and costs. This is discussed further in Chapter 6.
- None of the national or state generation planning exercises that have been conducted so far has estimated the level of "flexibility" required from the non-RE generators to minimise the cost of RE integration. The various RE grid integration strategies, such as reducing the variability and uncertainty of RE generation through aggregation over broader geographic regions (e.g., larger than states), have not yet been studied in the Indian context, which would require at a minimum coordination among a few states and ideally would be done at a national level. Similar concerns were raised about the limitations of current transmission planning exercises. This is discussed in greater detail in Chapter 7.
- Currently, almost the entire RE generation capacity is absorbed in the state where it is generated. There is no coordination with central government institutions, such as has occurred with conventional power ultra-mega power plants (UMPPs). Most RE projects are not selling to buyers outside their states, and hence the role of central institutions such as PGCIL and POSOCO is limited. As mentioned earlier, however, for achieving higher RE market penetration, RE will have to be sold across state boundaries, and therefore PGCIL and POSOCO are now planning to coordinate closely with their state-level counterparts and other state institutions.
- The cost of integrating RE into the grid (i.e., reducing the variability/uncertainty and balancing) is reduced significantly if the geographic area of the grid is large. This can be achieved either through allowing greater control over grid operations at a national level or through creating enabling frameworks (e.g., imbalance markets). Again, this requires a high-level of coordination among system operators, transmission planners, buyers, and regulators. Central government institutions such as PGCIL and POSOCO have a key role in operationalising this coordination. Central and state regulators, however, need to create regulatory and market frameworks to make this coordination happen.
- The lack of sufficient human resource capability and funds for the various activities required for supporting RE at all levels of the governments, even routine activities that support the power sector in general, is a major limitation faced by various government agencies (e.g., load dispatch centres [LDCs], regulatory commissions, planning authorities, and the like).
- Although MNRE oversees several RD&D institutes for research on RE, stakeholders indicated limited systematic and long-term coordination among various academic and research institutes that are not part of MNRE. Furthermore, the stakeholders also described the limited nature of interactions among the research community, industry, and policymakers.

Experiences within India and abroad show that systematic coordination and collaboration among all relevant entities, not just within the central government but also at the state level, can potentially lead to more robust support for RE development.

1.2. Analytical Framework for Identifying the Share of RE

The previous section touches on some of the overarching concerns with regard to the power sector, such as grid integration, the investment environment, and project development. These are not yet systematically assessed in planning activities in India, nor incorporated into both the macro- and micro-planning activities.

Fundamentally, these planning activities are expected to identify, quantify, and as far as possible, monetise the costs, benefits, and risks associated with various electricity sector components in a holistic manner. Not only should planning have to characterise the status, it should also attempt to forecast how the power sector could evolve, in terms of technology, economics, context, and other factors, in order to develop a set of potential outcomes that in turn contribute to the policymaking process.

For such outcomes to be most useful, the whole process must also strive to incorporate good governance principles.[10] It is also critical to develop long-term institutional capability to conduct these analytical exercises routinely (e.g., annually), supported by rigorous data compilation and methodological improvements.[11]

The analytical framework consists of three broadly defined components: macro-analysis, integrated power planning, and transmission and load flow analysis. Each of these components is typically assessed separately from a quantitative modelling perspective. It is important to note, however, that these three components are not always analysed independent of each other, as various analytical exercises may routinely combine different aspects from each component to advise the specific policy questions, for example, the combined analysis of specific pollutants (e.g., NO_X) and their impacts on the environment/human beings (e.g., ground-level ozone formation linked to asthma) and power sector operations.

The timeframe over which these types of analyses can be conducted range from short-term (e.g., next year) to decades. The longer the timeframe, the higher the uncertainty associated with various parameters (e.g., technology costs and performance, demand, consumer behaviour) that are used in the analysis. The short-term analysis typically focuses on increasing the accuracy of the simulated future, whereas the long-term analysis typically focuses on developing outcomes for distinct scenarios that allow policymakers to assess the direction of the changes subject to different assumptions and policy choices.

The macro-analysis is likely to include both quantitative and non-quantitative aspects, and hence has to rely on insights from various disciplines such as economics (micro and macro), atmospheric modelling, epidemiology, and so forth. The integrated power planning component typically and primarily relies on insights from the microeconomic discipline and statistical analysis (e.g., load forecasting), whereas the transmission planning and load flow analysis component primarily relies on insights from physics (especially electrical engineering) and to a lesser extent microeconomics. The macro-analysis component provides the broadest perspective of where various societal objectives interact with each other. Typically, the portfolio of electricity sources is established through a process of optimisation that attempts to minimise the direct costs of electricity, such as those of equipment procurement, construction of the power plant, and so on. However, societal objectives, such as maximising environmental protection, minimising imports, providing access to all those who are still not connected to the grid as soon as possible, and optimal use of water and land resources when other uses (e.g., agriculture) are included, have also to be met simultaneously with the objective of minimising the cost of electricity.

The macro-analysis approach attempts to optimise systematically and transparently the electricity portfolio, while ensuring that other societal objectives are considered. Some aspects of the macro-analysis may lend themselves much more easily to quantification and even monetisation (e.g., trade deficit). Others may be harder to quantify and monetise (e.g., water and land availability), and some may be impossible to even quantify, let alone monetise (e.g., energy security, economic growth). Even when quantification is not possible, effort must be made to at least clearly articulate the key costs/benefits/risks in a way that is useful for policymakers to use the outcomes of the analytical exercises.

In some ways, India's five-year planning process does consider many of these issues in its analytical work. The recent Energy Scenarios Planning tool developed and released by the NITI Aayog provides a platform that allows any user to understand the implications of selecting different

10 See, for example, the Transparency and Access to Information, Accountability and Redress, Participatory, and Capacity (TAP-C) principles articulated by Dixit et al (2007).

11 For example, the Energy Information Administration in the United States and ENTSO-E in the European Union.

portfolios to meet India's future needs. Several independent organisations – such as IRADE, TERI, Greenpeace (2013), WISE (2014) – have conducted fairly comprehensive analytical exercises of the type described here.

The integrated power planning component is one of the most commonly used analytical frameworks for establishing an electricity portfolio. As described earlier, in this framework the cost of electricity is minimised through the selection of appropriate supply-side (i.e., generation, transmission, and distribution) and demand-side (e.g., energy efficiency, demand response, "behind-the-meter" generation) resources. Typically, economic dispatch models are used for this type of analysis.

Examples of linkages between this component and the macro-analysis component include but are not limited to: environmental pollution reduction equipment costs added to generation costs (such as scrubbers for SO_2 reduction, Selective Catalytic Reduction (SCR) for NO_X reduction, CO_2 capture) and fuel availability and price (such as risks associated with reduced fuel availability for non-economic reasons, volatility in price of fuel).

A vast amount of literature exists on implementing integrated power planning exercises all over the world. It should be noted that as the share of RE continues to grow in different parts of the world, many of these integrated exercises are now systematically accounting for the unique characteristics of RE (e.g., variability and uncertainty of RE generation, and geographic and temporal constraints on RE availability).

The last component – Transmission Planning and Load Flow Analysis – refers to the actual physical/electrical analysis of the grid. Electrons flow according to the laws of physics. The policy choices made using the macro-analysis and integrated power planning frameworks must be simulated taking these laws into account, to ensure grid stability from a physical perspective.

The key linkages of this component with integrated power planning include but are not limited to: the generation mix connected to the grid and its operational characteristics; transmission capacity; and load profiles. Transmission companies and system operators typically and routinely commission these types of analyses when changes are being planned for the grid itself (e.g., transmission line additions) or to the resources connected to the grid (e.g., increased load or addition of a new generator). The geographic scope of these types of analyses are determined by institutional boundaries, such as the size of balancing areas and cooperation among neighbouring areas, and the design of commercial transaction mechanisms.

2. Choosing the Right Support Mechanisms

The share of renewable energy discussed by Indian government institutions, both in absolute terms and relative to other sources of electricity, has become increasingly ambitious over the years, ranging from:

- 2009: National Action Plan on Climate Change (NAPCC) target of 15 percent of total electricity consumption from RE by 2020
- 2010: National Solar Mission (NSM) target of 20 GW of solar by 2022
- 2013: PGCIL Desert Power 2050 estimate of 458 GW of wind and solar by 2050
- 2014: Discussions pertaining to a solar target of 100 GW by 2027
- 2014: Consultation pertaining to a National Wind Energy Mission in which a wind target of approximately 150 GW by 2027 is being discussed
- 2014: Estimate by the NITI Aayog's "heroic effort" scenario of 410 GW of wind and 420 GW of solar by 2047

Key questions face policymakers in the light of these ambitions, as well as the general perception among stakeholders that RE is more expensive than conventional alternatives:

- Whether or not to provide any support for RE?
- If so, what form should it take?
- What volume of support?
- What should the duration of such support be?

Policymakers grapple with these key questions in the context of wider energy objectives, including the provision of reliable and cost-effective access to all citizens, fair allocation of costs across various consumer segments, and fair returns on investments in energy provision to ensure long-term viability of the sector as a whole.

In addition, policymakers and stakeholders are beginning to articulate additional objectives such as minimising environmental impacts, minimising imports, and optimisation of use of land and water resources for electricity production relative to other uses (e.g., agriculture).

As discussed in Chapter 1, systematic analytical exercises can certainly assist policymakers in addressing these questions. Some of the insights yielded may even help to improve the overall efficiency of power sector operation irrespective of RE, for example, greater cooperation among balancing areas.

One of the key questions policymakers and stakeholders around the world have asked of proponents of renewables is "When does the support end?" The reality is that there is no single answer: it depends on an abundance of future factors, including future trajectories of costs of conventional fuels, technological and cost vectors for renewable technologies, and the speed, scale, and efficacy of grid modernisation and integration initiatives.

It is important for policymakers and stakeholders to understand that the operational changes identified elsewhere in this report (grid modernisation and integration, balancing areas and services) do not go away whether RE is at parity with conventional generation or not. In a system with large amounts of intermittent geographically dispersed renewables, those operational and management changes will be permanent and will continue to have to be compensated. It is also important to note that even power systems that consist only of conventional generation reserves are routinely maintained. The question is, what are the incremental changes associated with RE for a given system.

Fundamentally, the definition of parity depends on answering the question "Compared to what?" Parity is therefore discussed in different ways in different contexts. For example, on one hand, a commercial consumer in India facing a retail tariff of approximately 9 Rs/kWh will find rooftop PV (cost: approximately 8 Rs/kWh) to have already reached parity. Similarly, a distribution company trying to meet peak demand during summer afternoons when the wholesale market price or the cost of its marginal generator – typically, an open cycle gas turbine – is very high, may find PV to be at parity, as it is available exactly during the peak demand. On the other hand, cost of a new PV power plant when compared with the cost of an old, fully depreciated baseload thermal coal plant built at the mine-mouth and that is using low and fixed price domestic coal would lead one to conclude that parity has not yet been reached.

For utility-scale RE, parity (i.e., "grid parity") refers to the comparison with conventional generation at the bus-bar (i.e., at the interconnection with the high-voltage transmission level). The bus-bar cost can include different attributes, including levelised cost of energy, capacity value, and so on. Furthermore, the inputs to the bus-bar cost may have significant uncertainties associated with them (e.g., varying fuel costs, risk premium associated with lack of fuel availability, unscheduled outages, cash-flow, externalities, and the like). Typically, these could be very difficult to forecast and their implications can be highly contentious.

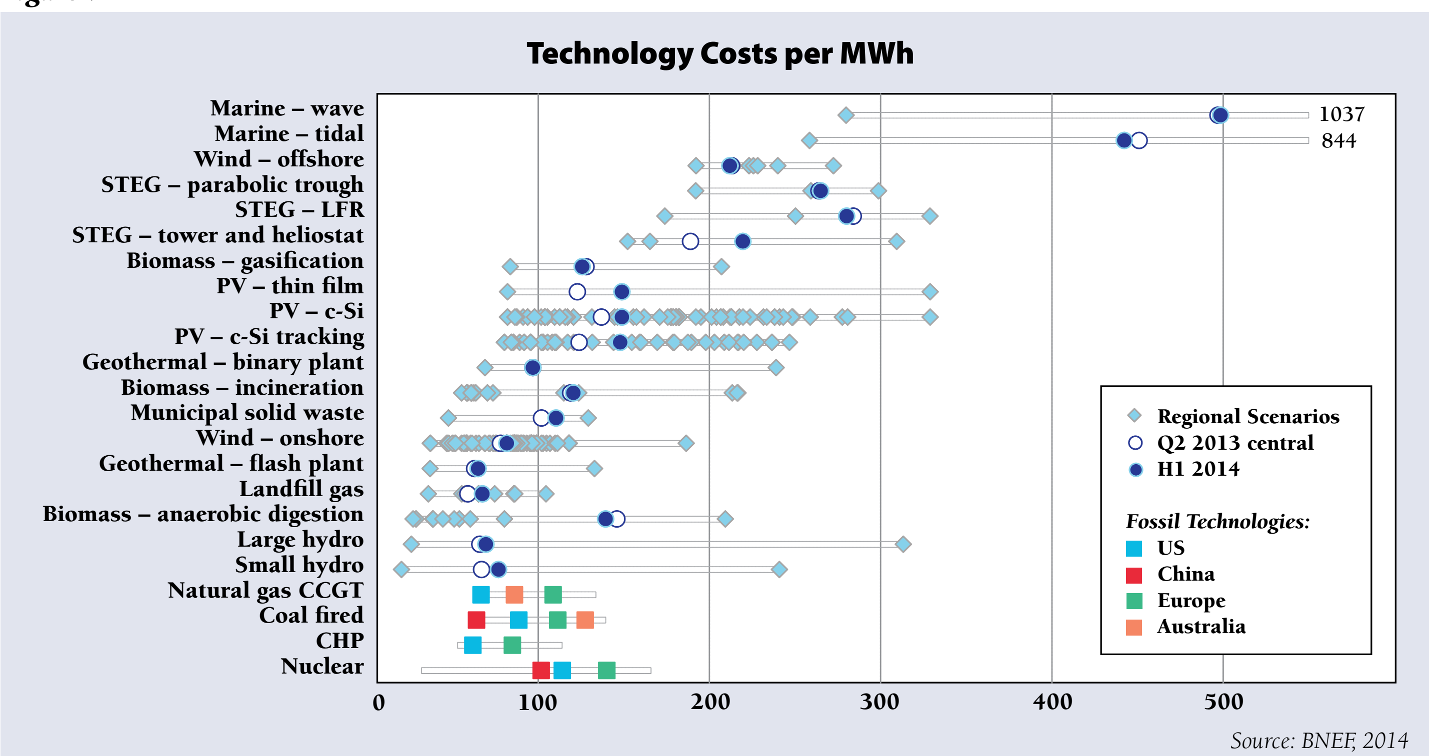
For distributed RE that is installed behind the meter, parity (i.e., "socket parity") would refer to the comparison with the retail tariff faced by the consumer. The retail tariff not only includes the bus-bar cost described above, but will also account for the cost of transmission and distribution and the technical losses of moving the power from the generator to the consumers. Furthermore, the retail tariff may include non-cost considerations, such as cross-subsidies from large consumers to small consumers. Consequently, retail tariffs often do not reflect the "true" cost of serving a consumer at any given point in time.

A key consideration for policymakers who are trying to address the questions listed at the beginning of this section is to establish the framework for comparing RE and conventional generation and then applying that framework at regular intervals to assess the situation over time, as the inputs to the analysis will keep evolving over time. As a snapshot and using a specific framework defined by Bloomberg New Energy Finance - Figure 7 presents a comparison – as of January 2014 – of the levelised cost of energy from various sources at a global level. Several observations can be made from these figures:

- The ranges of costs of both onshore wind and solar PV have started to overlap significantly with those of conventional generation such as coal-fired, natural gas combined cycle technology, large hydro, and so on; and
- Whether RE has reached grid parity at all depends on the region/country.

As of today, it is unclear whether grid parity for RE in general in India has yet been achieved, as systematic comparisons don't exist. Analysis of customer-sited solar PV installations suggests that "socket parity" may have been achieved for some customer classes in some states; see for example Bridge to India (2013). As many consumers in India use diesel generators and battery-inverter sets because of lack of reliable supply of grid-based electricity, rooftop

Figure 7



Source: BNEF, 2014

PV is already at a significantly lower cost compared with them. In the following subsections, background on existing support mechanisms and key concerns about them are discussed.

2.1. Existing RE Support Mechanisms

Historically, the central government (administered by MNRE and disbursed through the Indian Renewable Energy Development Agency [IREDA]) has offered two types of incentives for RE: Accelerated Depreciation (AD) and Generation-Based Incentive (GBI). In the second phase of the Jawaharlal Nehru National Solar Mission (JNNSM) that recently commenced, a new mechanism, viability gap funding (VGF), has been created for solar projects. Capital subsidy for biomass and small hydro also exists.

- AD refers to a tax-based incentive mechanism in which RE projects can take larger than normal depreciation benefits on their tax returns in the initial years of investment. Although this incentive is in place for solar power, it has now been cancelled for wind generation. However, discussions are underway to reinstate it.
- GBI provides wind electricity producers an incentive of Rs 0.5 per kWh fed into the grid for a period of not less than four years and a maximum period of ten years with a cap of Rs 100 Lakhs per MW. The total disbursement in a year will not exceed one-quarter of the maximum limit of the incentive (i.e., Rs 25 Lakhs per MW during first four years). The GBI scheme will be applicable for the entire 12th plan period having a target of 15,000 MW.
- Under the VGF mechanism, the tariff to be paid to the solar PV developer is fixed at Rs 5.45 per kWh. This tariff will remain firm for the 25-year project period. In case the benefit of accelerated depreciation is availed for a project, the tariff will get reduced to Rs 4.75 per kWh. The developer will be provided a VGF based on its bid. The upper limit for VGF is 30 percent of the project cost or Rs 2.5 crores/MW, whichever is lower. The developer must contribute its own equity of at least Rs 1.5 crores/MW. VGF is released in two tranches as follows: 50 percent on successful commissioning of the full capacity; the balance of 50 percent progressively over the next five years of operation, subject to the plant meeting output requirements.

The state regulator-led RE support mechanisms include:

- Renewable Purchase Obligation (RPO) and Renewable Energy Certificates (RECs): Fundamentally, an RPO is a requirement for an electricity purchaser (e.g., a Discom or an open access [OA] consumer) to procure a certain percentage of electricity from a specific source (e.g., RE) and recover the cost of that purchase through its regular ratemaking process. The source of funds for the incremental cost, if any, of RE as compared with conventional generation is the ratepayers. Currently, RPO levels are set by each State Electricity Regulatory Commission (SERC) independently, without formal coordination with other states or the central government. Levels therefore vary significantly across states (e.g., from 0.6 percent in Meghalaya to 10 percent in Karnataka and Himachal Pradesh for non-solar, and 0.05 percent in Tamil Nadu to 1 percent in Bihar/Gujarat). If obligated entities in the state are unable to procure a sufficient amount of RE to meet their RPO, they are expected to purchase RECs in order to meet their RPOs. The REC is a national market mechanism designed by the Central Electricity Regulatory Commission (CERC) and operated by POSOCO, the Indian Energy Exchange, and Power Exchange India.
- Feed-in tariffs (FITs) are preferential tariffs for procuring RE by Discoms that are established by a SERC through its usual regulatory process. The revenues to cover these costs incurred by the Discoms are part of the usual ratemaking process. Taken together, the RPO/REC and FIT mechanisms require Discoms to procure a specified percentage of electricity from a specific source at a specified cost. The incremental cost of RE, if any, would impose an additional burden on the ratepayers. Both the process (i.e., administrative, or competitive such as reverse bidding) and the level of FITs vary significantly across the various states. For example, in almost all the states except Rajasthan, the FIT for wind is set through an administrative process. In Rajasthan, a competitive bidding process was announced for establishing the price of wind. In most states, solar FITs are set through a competitive bidding process. There are various other types of direct and indirect financial incentives created for supporting RE in India that rely on tax and/or duty mechanisms, and vary by RE application (e.g., agricultural solar pumps, customer-side RE, and so forth).

2.2. Issues With Existing Support Mechanisms

Stakeholders presented diverse opinions on the RPO. At the national level, one of the key drivers behind RPOs as perceived by stakeholders is the NAPCC target, a national 15 percent of RE share by 2020 in energy terms. As discussed earlier, new targets are also being discussed that may be significantly larger than the NAPCC. However, neither the NAPCC nor the other targets are directly linked to the various state-level RPO targets in a legislative sense. Although several attempts continue to be made to harmonise the state-level RPO targets with the national targets, these have seen only limited success.

On one hand, RE-rich states indicated that they have already met or are close to meeting their RPO requirements, but are not keen on exceeding these requirements, citing grid integration concerns. Hence in some cases the RPO may in effect become a ceiling on deployment, rather than a stimulus.

Typically, the RPOs of RE-rich states are more aggressive and are at significantly higher levels, for example, as in Gujarat, Maharashtra, Tamil Nadu, and Karnataka. These states acknowledge that they have large potential for RE, but nevertheless find limitations on the extent to which RE power plants can be deployed with the intention of selling power to other states.

Meanwhile, RE-poor states are reluctant to set aggressive RPOs, as they feel that they do not have sufficient RE resources (especially wind), and/or that land acquisition is a major limitation (especially for solar). In most of the RE-poor states, there appears to be limited awareness of and willingness to procure RE from the RE-rich states.

Unlike conventional generation, wherein states have been routinely procuring power from other states and/or procuring fuel (e.g., coal) for their generators, it is not clear why they are reluctant to procure RE from other states. This fact fits well with the observations of stakeholders in RE-poor states, where it appears that RE generation needs to be physically located in the state, and that if there is limited availability of RE and/or land for developing RE, then the state should not have to achieve the ambitions of RE-rich states. There may be a fundamental misconception among some stakeholders that RPO is a generation obligation and not a purchase or procurement obligation.

Coal and wind resources are similar in the sense that both are geographically available in only specific locations. Hence, a similar approach to developing wind resources could be considered as for coal.

Some of the constraint on moving large amounts of RE from one state to another stems from the lack of sufficient transmission capacity, and a lack of appropriate grid integration mechanisms, although some stakeholders did question whether these usually accepted assertions were factually true or in fact misconceived.

Either way, in both RE-rich and RE-poor states, the perceived (if not real) higher cost of RE relative to conventional generation, coupled with the large fiscal deficits of Discoms, has in many cases led the latter to consider RE to be a less attractive proposition. Their chronic financial ill health (see Chapter 6) is the key reason SERCs in various states appear to be sympathetic to their position, and hence neither raise RPOs nor enforce them.

The REC mechanism is intended to provide a commercial platform to share the incremental cost of RE equitably across India consumers, because of this uneven dispersal of RE resources about the country. Similar mechanisms have been implemented in many other countries also. In the Indian context, however, this mechanism has not been successful to date for four key reasons:

1. RPO targets across states are not uniform and low RPOs create limited demand for RECs;
2. Enforcement of RPO targets is limited at best, which in turn limits demand for RECs;
3. Politically, the state-owned Discoms find it difficult to pay for an REC, which is perceived simply to be a "piece of paper" separate from the procurement of useful electricity, at a time when that procurement is insufficient to alleviate power shortages; and
4. Key stakeholders do not have a clear understanding about the reasons underlying the prices discovered in the REC markets.

In consequence, a large quantity of RECs remains unsold and the price languishes at the administratively determined floor price. The market is considered to be more or less defunct by many stakeholders. This situation has created a sense among the investment community that RECs are unlikely to improve the viability of RE projects until these issues are resolved.

Turning to concerns with the FIT, AD, GBI, and VGF mechanisms, opinions on their effectiveness fall into two camps:

- One set of stakeholders believes that the administratively set incentive levels (especially for wind) lead to windfall profits for RE producers, and that levels should instead be established through transparent and competitive mechanisms; and

- Another believes that RE is still in a nascent development stage, and that various risks (e.g., land, grid integration) have not yet been addressed sufficiently to allow for a shift to a competitive mechanism.

One major consequence of these diametrically opposed opinions is significant policy uncertainty as policymakers are swayed this way and that, which is a principal disincentive to private investors. In general, the opinions and experiences of stakeholders suggest that there is limited communication and coordination among the various relevant entities (SERCs, MNRE, the MoF, State Development Agencies/State Nodal Agencies, CERC, POSOCO, and so on) that are responsible for designing these mechanisms.

Comprehensive and systematic discussions may be necessary to answer the following questions:

- Are all the different mechanisms needed simultaneously?
- Should there be only one support mechanism across the country?
- Who should design the support mechanism, implement it, and administer it?
- What are the linkages of financial incentives to real and perceived barriers that they are attempting to address?
- What is the long-term viability of the existing sources of funds from which these incentives are drawn? If the viability of existing sources of funds is low, then what new/alternative sources can be considered?

The International Energy Agency (IEA) released an important report in 2011 that addresses the present range of options for support policy design. Deploying Renewables: Best and Future Policy Practices describes a number of principles to be borne in mind and highlights how mechanisms may evolve to better suit the maturity of the technologies they seek to stimulate.[12]

12 IEA, 2011.

3. Manufacturing, Human Resources, and RD&D

The global market for low-carbon and energy efficient technologies, including renewable energy technologies, is projected to nearly triple to USD 2.2 trillion by 2020.[13] Stakeholders raised this as a critically important issue around which India policymakers needed to engage.

In India and globally, renewable energy represents an opportunity not only to diversify the energy supply mix but also to support the growth of new and existing parts of national economies, with the benefits of industrial sector expansion and diversification, innovative research and development, and job creation.

As the renewable energy market expands in India, fed by a supportive policy framework, demand for related goods and services will ripple through the supply chain. This may lead to growth in domestic production, which can provide improved supply chain security.

Internationally, India has the opportunity to further grow its manufacturing base, taking advantage of factors such as low cost of labor and proximity to fast-growing Asian markets to expand domestic production and export income.

A key challenge for policymakers is and will remain the striking of a balance between the extent to which India seeks to manufacture for domestic and export to global markets, and the extent to which it should import the best available technologies and components from overseas markets. The resolution of this challenge will help India focus on manufacturing, as well as research and development policy, and extract the maximum possible value for the economy in terms of growth and job creation, while growing and sustaining a competitive renewable energy sector.

This chapter explores the current situation in India today as regards manufacturing, and the issues of import substitution and protection. It sets out the costs and benefits of domestic industry, and discusses research and development needs, as well as the need for skills and labor.

3.1. RE Manufacturing Today

Both wind and solar technologies are manufactured in India, although the extent to which their components are manufactured or assembled in India varies. In 2013, 700 to 800 MW of solar and 10,000 MW of wind manufacturing capacity existed.

Quite distinct pictures emerge of the present health, scale, and value of wind and solar manufacturing in India. This is a function of the relative maturity of each – wind deployment preceded that of solar power and in terms of deployment dominates the market – but it also reflects other issues, such as the global dominance in solar manufacturing of nations such as China, who over the last five years have reshaped the solar PV manufacturing landscape.

3.1.1. Manufacturing Challenges

An established and mature wind turbine-manufacturing sector has grown up in India in parallel with the deployment of wind projects across the country in the last eight to ten years. India is emerging as a major turbine manufacturing centre, and a diverse market of manufacturers has developed in recent years (Table 2). In 2012, 13 manufacturers were active, producing a range of different sized products, with an annual production between them of more than 9500 MW.[14]

Indian manufacturers are able to sell products into the global market for wind turbines and be competitive by taking advantage of lower manufacturing costs. Their export markets include South America, the United States, Europe, and Australia.

Wind power deployment faces challenges from several quarters, however, including:

- A recent fall-off in demand for turbines as domestic development rates have slowed following policy

13 UNEP, 2013

14 GWEC, 2012.

Table 2

Wind Sector Manufacturers Active in India (2012)

Manufacturer	Technology Rating (kW)	Drive	Speed	Generator	Class
Enercon	800	Gearless	Variable	Synchronous	II-S
GE Wind	1,500	Gear	Variable	DFIG	II A
GE Wind	1,600	Gear	Variable	DFIG	II
Suzlon	1,250/2,100	Gear	Fixed	Asynchronous	II A/III
Suzlon	1,500	Gear	Fixed	Asynchronous	III A
Suzlon	2,250	Gear	Variable	DFIG	II B
Vestas India	1,650/1,800	Gear	Variable	Asynchronous	II B/III A
RRB Energy	1,800	Gear	Variable	Asynchronous	II/III
Gamesa	850	Gear	Variable	DFIG	II A/III B
Gamesa	2,000	Gear	Variable	DFIG	II A/III A
Global Wind Power Limited	2,500	Gear	Variable	Synchronous	III A
Inox Wind Limited	2,000	Gear	Variable	DFIG	III B
Kenersys India	2,000	Gear	Variable	Synchronous	II A
Leitner-Shriram	1,350/1,500	Gearless	Variable	Synchronous	II A/III A
ReGenPowertech	1,500	Gearless	Variable	Synchronous	III A/III B
WinWinD	1,000	Gear	Variable	Synchronous	III B

Source: GWEC, 2012

shifts, particularly with the withdrawal of accelerated depreciation and the delay in reinstating generation-based incentives;
- A shortage of essential raw materials, notably fiberglass for blade construction, and rare earth materials used in controls;
- Dependence on overseas suppliers for critical components such as gearboxes and bearings, which are not produced domestically; and
- Logistical bottlenecks: access to suitable port facilities, and site access (particularly where larger wind turbines are involved, road infrastructure may be inadequate).

In aggregate, these factors have contributed to negative growth in wind manufacture in 2013. Stakeholders asserted that as much as three-quarters of Indian wind manufacturing was lying idle.

Solar manufacturing, in contrast to that of wind power, is at an early stage. It is more fragmented, and focussed mainly on the domestic market. According to stakeholders, solar manufacturing faces a number of challenges, including:

- Competition from overseas manufacturers, which benefit from aggressive support policies, such as those in China, where the sector is backed by direct and indirect subsidies. Chinese industry also benefits from long-term measures, such as stable power procurement processes.
- A global supply glut as a result of excess manufacturing capacity, and a growing disparity between the rate of installation and manufacture. In 2013, 28 to 30 GW of solar PV was installed, whereas up to 65 GW was manufactured, resulting directly in a decrease in PV panel prices and reduced manufacturing margins.

The solar PV manufacturing base in India is small and unable to benefit from economies of scale or the benefits of vertical integration found in Chinese and US manufacturing.[15] Indeed, vertically integrated Chinese manufacturers have been able to use their installation arms to exploit the

15 See Goodrich et al, 2013.

supply glut.

Stakeholders maintain that Indian solar PV suffers from a largely unsupportive policy framework, wherein price per MW must compete against other generation technologies of which the full costs are not recognised, such as the environmental costs of coal power.

Much Indian solar PV manufacturing is dated, meaning that its products are of comparably low efficiency and do not command the highest prices compared to competing nations that have recently invested heavily in modern facilities. This is a function of the infancy of the Indian market, which has not driven efficiency in the same way as witnessed in these more advanced markets. Stakeholders asserted that in 2013 as much as 80 percent of Indian solar PV manufacturing capacity was lying idle.

3.2. Support for Domestic Manufacturing

Stakeholders have suggested that one of the most productive ways of approaching policy support for Indian RE manufacturing is to consider the simple question of whether it is better for India to make or buy. Framing the debate in this way allows for a discussion focussed around the most efficient way for India to compete in RE manufacture and meet its own requirements. Implicit in this approach is a consideration of employment benefits, opportunities for export, energy security, as well as domestic energy intensity and best return on investment.

To date, both state and central government support has been focussed on building demand for manufactured goods and services, through such mechanisms as premium tariffs for electricity generation and accelerated depreciation benefits designed to reduce the tax burden of investors in such projects.

On the supply side, the renewable energy industry benefits, alongside other sectors, from a number of mechanisms that support manufacturing. Broadly speaking, such measures may fall into two categories: (1) those that encourage domestic manufacturing, and (2) measures that discourage foreign imports that might otherwise substitute for the former.

They include the subsidy to capital expenditure on manufacturing facilities, for example, through the Special Incentive Package Scheme and local content rules requiring that one or more components be sourced domestically. Most of the major initiatives derive from central government rather than the states, and their design is discussed briefly below.

Recent reporting suggests that more than 75 percent of existing Indian solar capacity is of foreign origin, despite a number of albeit rather fragmented policies aimed at encouraging domestic production.

It is worth noting at the outset that foreign companies are encouraged to operate in India; the emphasis is on local manufacturing, not local ownership. For example, 100-percent foreign direct investment is allowed in Indian renewable energy manufacturing facilities. As of June 2013, cumulative foreign direct investment in non-conventional energy source stood at approximately Rs 13 426 crores.

Some international wind companies with subsidiaries in India source over 80 percent of their components from Indian component manufacturers. Leading manufacturers like Suzlon, Vestas, and Enercon, and newer entrants such as Gamesa, GE, Siemens, Regen Powertech, and WinWinD, have set up production facilities in India.

Although largely a demand-side policy, focussing on premium tariffs for electricity production to achieve 22 GW of solar PV by 2022, the JNNSM also aims to create a strong manufacturing base for solar energy in India. Accordingly the JNNSM includes a requirement for the use of domestically produced raw materials, components, and products.

Wider, domestic-content requirements are designed to ensure that for any one solar project a 50-percent proportion of the components is sourced domestically. Although certain wind components – for example, those that are not manufactured in India – are eligible for rebates on import duty, local content rules render redundant the import of complete turbines. Every turbine installed in India must be tested and certified by the Centre for Wind Energy Technology, part of the MNRE. Failure to comply would disqualify the power plant in question from grid connection and financial incentives. Consequently, foreign manufacturers are obliged to establish a local manufacturing facility.

The Special Incentives Package Scheme was launched by the Department of Information Technology in 2007. The scheme allows for a capital dispersal, or equity stake, up to the value of 20 percent of capital expenditure (CAPEX). Although a small number of RE companies participate in the scheme, to date no dispersals have been made. A modified Special Incentive Package Scheme for 20 to 25 percent of CAPEX was announced in July 2012, but also has yet to have significant impact on manufacturing.

The National Manufacturing Policy (NMP) announced in November 2011 aims to raise the share of manufacturing in gross domestic product (GDP) to 25 percent, and in the process to generate 100 million additional manufacturing jobs by 2022. Although the policy is sector neutral, it does refer specifically to green technology. Even this classification is very broad, however. Nevertheless, the NMP identifies solar and wind energy as being of strategic significance alongside defense and telecoms, for example.

The NMP allows for the development of National Investment and Manufacturing Zones established via special purpose vehicles. These would be industrial towns with state-of-the-art infrastructure and zoned land-use, powered by renewable technologies.

3.2.1. Export Promotion

Indian manufacturers are engaging in the global market by taking advantage of lower manufacturing costs in India. Indian companies now export domestically manufactured wind turbines and blades to Australia, Brazil, Europe, the United States, and other countries.

Under the Special Economic Zones (SEZ) Act of 2000, SEZs are intended to provide speedy clearance, infrastructure support, fiscal incentives, and tax exemptions for increasing exports. Out of 588 SEZs formally approved, however, only two relate to export-oriented solar PV facilities, although these have had some success.

The Export Promotion Capital Good scheme, under which renewable energy qualifies, allows for renewable energy technology to be eligible for zero percent duty. Moreover, under India's five yearly export–import policy, green technology is listed as a Focus Product Scheme. This means that export of RE components or raw materials is entitled to a duty credit equivalent to two to five percent of the freight on board value of the exported material.

The export obligation – in brief, the required export volume to qualify for concessional duty rates – for specified "green energy technologies" under the Export Promotion Capital Good scheme has been reduced to 75 percent. This applies to solar cells, modules and components, biomass gasification and boiler equipment, wind turbines, electric vehicles, and waste heat boilers and recovery units.

3.3. Domestic Industry and International Competition

Discussion with roadmap stakeholders revealed awareness of a dichotomy between the importance of domestic industry and resulting macroeconomic benefits to India, on the one hand, and the need to maximise competition to deliver reliable and least-cost equipment on the other.

Belief in the relative value of these two effects seemed to be dependent on the type of stakeholder in question, each perceiving positive and negative impacts on his/her own position.

Those in favour of preferential treatment for domestic manufacture of one kind or another included:

1. Domestic manufacturers, including those who also develop power plants, who want strong support for domestic manufacturing, including the continuation or strengthening of Domestic Content Requirement (DCR) for power plant projects in order to build on or protect existing demand for their own production of components; and
2. Foreign manufacturers who have invested in manufacturing in India and who believe that the policy emphasis should be on building up an Indian industry, but not one based solely on indigenous technology, and who prefer a market offering incentive for local manufacture.

Those in favour of a level playing field between domestic and foreign manufacture included:

3. Foreign manufacturers, manufacturing overseas and then exporting to India, who would like access to the market to be on a completely level playing field, with no differentiation made among sources of components, to maximise competition to drive down costs; and
4. Developers, both domestic and foreign, who also believe the focus should be solely on maximising competition.

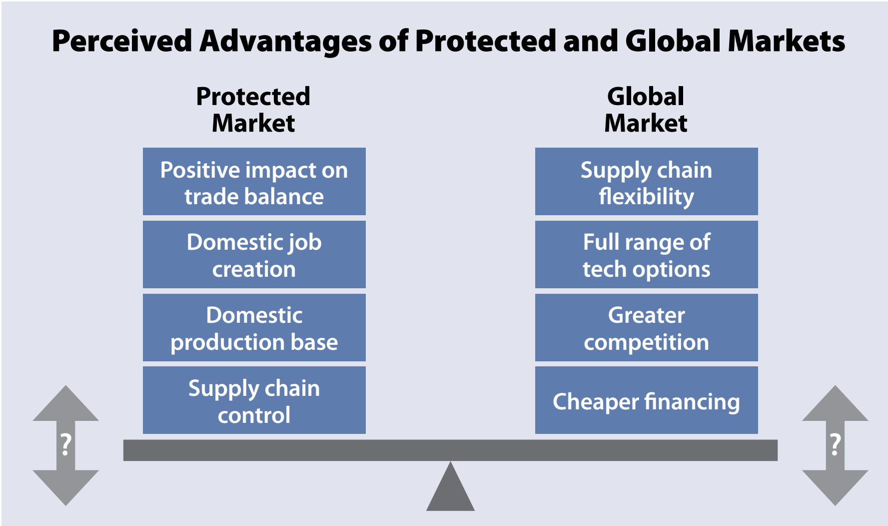
Identification of which of the two camps is correct is not within the scope of this roadmap, which is rather to highlight that both represent possible advantages and disadvantages. The following section presents how the relative costs and benefits might be weighed up.

3.3.1. Costs and Benefits of Nurturing Domestic Industry

Stakeholders raised positive and negative arguments for both the free competition approach, and the preference for developing a domestic market. These are captured in Figure 8.

As has been apparent in both the wind and PV markets in recent years, tightness of supply of components as opposed to inherent technology costs has a major effect on market prices of those components. This was apparent in the wind industry in 2004 to 2009 and in the PV industry when module prices dropped by a factor of five from 2008 to 2013.

Figure 8



Domestic supply may offer some insulation from this effect. However, if domestic manufacturing fails to keep pace with deployment, then import duties, for example, will exacerbate supply tightness as they reduce the options available to developers and manufacturers.

Local manufacturing may have a positive effect on the balance of trade. For example, US annual exports of solar products to India were worth USD 119 million before the NSM required domestic content in power plants under the scheme, but have fallen precipitously since then. This issue also spills over into wider trade relations among countries.

Further analysis should examine the expected total cost of renewable energy hardware needed to meet deployment targets. This will indicate, on the one hand if import is relied on, the potential resulting burden on the balance of trade, and on the other hand, the potential value to the Indian economy of building factories in India, in terms of GDP, employment, and technological innovation, for example.

The Indian solar PV market is expected to be worth some USD 11 billion by 2017.[16] On top of that there is the potential for exports to be considered. India is well located to serve as a hub for global export if the technology is of the highest standard.

There are also potential negative impacts of protecting domestic industry. If it is protected from international competition, this may translate into an unnecessary expenditure. Recent analysis of the effects of DCR under the NSM, by Bridge to India (2014), suggests that the overall cost may be 65 percent greater, amounting to an additional USD 1.1 billion, as domestic equipment is more expensive. This could be seen as a windfall to domestic suppliers, and a disincentive to reduce their costs.

Furthermore, DCR may protect less efficient technologies, in terms of reliability, capacity utilisation factors, and higher operation and maintenance (O&M) costs, which might otherwise be rooted out by exposure to the global market.

3.4. Human Resources Across the Value Chain

Investing in renewable energy technologies creates new employment opportunities. In 2010, more than 3.5 million people worldwide were estimated to be working, either directly or indirectly, in the renewable energy sector, and further growth is expected. Estimates suggest that by 2030, 2.1 million people could be employed in the wind sector and 6.3 million in the solar PV sector.[17] These jobs will be distributed across manufacturing, fabrication, installation, O&M, project development, and marketing.

For India, a 2009 MNRE study estimated that 42,000 people were either directly or indirectly employed in the wind sector, with high growth scenarios indicating that as many as 160,000 might be employed in the sector by 2020.

On-grid PV sector employment in 2009 was relatively small, estimated at 4000, but in reaching the 20 GW by 2022 target of Phase One of the NSM, employment levels could rise as high as 152,000. For the off-grid PV sector in 2009, employment numbers were thought to be 72,000, projected to reach 225,000 by 2022.[18]

In parallel with this predicated expansion of RE employment in India there is growing need for the right type of skilled manpower. Focus here is on the availability of skilled manpower, some of it specialist, attracting and retaining talent, training and capacity building those in the sector, and the necessary expansion of renewable energy curricula in universities, to ensure the sustained supply of manpower.

In this respect, analysis of the areas in which human resources are presently lacking in India may be needed to

16 World Bank, 2013.

17 UNEP, 2013.

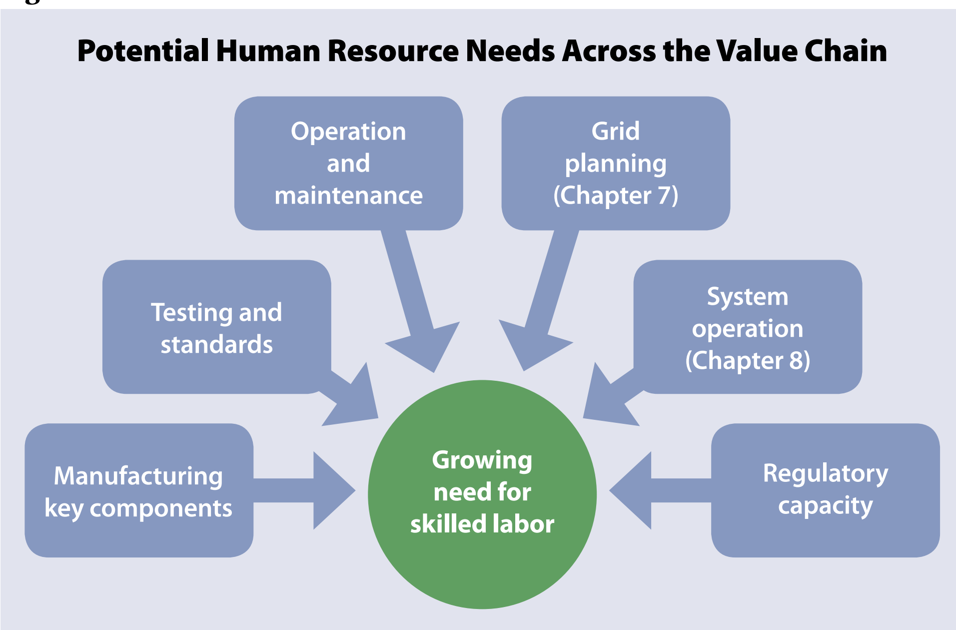
18 MNRE/CII, 2010.

predict growing needs for labor and skills, and the extent to which programmes will be needed to augment the current workforce (Figure 9). In this respect, stakeholders pointed out a need to survey the existing capacity of universities to produce candidates with the right skills.

Additional resources will be needed not only on the RE industry side, but also to enable the integration and management of the RE produced by installed capacity. During the road-mapping process, this need was cited to be particularly important in grid planning, system operation, and regulation.

For example, although the CEA, the central grid planning body within the MoP, has deep experience of the needs of conventional power plants, its experience of renewable energy, and in particular variable renewable energy from wind and solar PV, is limited. Stakeholders suggested that the CEA should have a dedicated RE integration team. Whether or not this is so, it is likely that its human resource in this area needs to be increased.

Figure 9



Similarly, state LDCs, responsible for system operation, tend to be under-resourced. Increased electricity variability and uncertainty from wind and solar power plants increase the complexity of the system operation task. This can be assisted not only by new technology and operating procedures, but also by team members with dedicated training in new operation techniques (see Chapter 8).

SERCs are already stretched. Typically, the commission may consist of two or three members, with a modest staff. New practises and needs arising from growing numbers of independent RE producers represent a heavy burden to such small teams. The commissions themselves may need to be expanded, as well as their staffs, and both may need dedicated training to prepare them for new responsibilities.

3.5. RE Technology Needs Specific to India

It is not intended for this section to provide an exhaustive exploration of the research and development needs of renewable energy in India, but rather to touch upon the highlights, which have been raised in exchanges with stakeholders. Indeed there have been calls for increased collaboration across the sector in order to better understand the extent and nature of the research and development priorities within the wind and solar markets in India.

For the wind market development and the technology needs required to support it, the following issues have been highlighted by stakeholders:

- A need for wind mapping studies to determine wind resources within lower level (10- to 20-meter height range), particularly in urban areas. This work could support the development of a long-term strategy to support indigenous production of wind turbines suited to these particular conditions.
- For the off-shore wind market to grow, research and development is needed to assess the resource and the way it could be technically exploited; such work might include studies of offshore meteorology, marine geology, bathymetry, and offshore transmission. To support this work, international approaches might be usefully looked at, an example being the approach of the Crown Estate, which has supported the expansion of offshore wind in the United Kingdom.
- A training centre for wind energy at the Centre for Wind Energy Technology could conduct specialised/customised training courses to cater to client needs with a model laboratory containing all wind-related equipment and software to provide hands-on practical training to all levels of participants, also incorporating research and development priorities.
- A wind turbine simulator facility could train and

assess operators in general plant operation, including training in plant start-up and shut-down, supervision, and monitoring and control during normal and emergency situations and in safety procedures. In addition, the simulator can be used as a powerful tool for engineers and plant managers to verify operation and control strategies as well as investigation and testing of operational challenges.

The IEA's Implementing Agreement on Wind Energy and the IEA Photovoltaic Power Systems Programme deal profoundly with the research and development needs of wind and solar PV technologies, respectively. A number of stakeholders suggested closer interaction with these bodies to further define research tasks in the Indian context.[19]

3.6. Summary

As well as its value simply in terms of electricity, renewable energy deployment represents opportunities to support economic growth, with potential benefits in terms of expanded manufacturing, diversification, innovative research and development, and job creation.

A simple list, however, disguises the complex feedback among these potential benefits. For example, economic growth will be benefitted by the cheapest possible electricity, but it will also benefit from domestic manufacturing, bearing in mind the long-term goal to increase the manufacturing share of GDP to 25 percent, and the possibility of exports and increased opportunities for skilled employment.

Meanwhile, policy designed to shelter domestic manufacturing from the international market in the short term may inadvertently protect more expensive or less reliable electricity production for the longer term, which will have an increasingly adverse impact on industry as it grows to represent a larger share of overall production.

Human resources need to be planned for. Targeted financial support for manufacturing will be most effective if there is a skilled workforce in place to benefit from it. But the human resource need is not only in manufacturing. At almost every stage in the value chain there is a need for skilled labor: from design and manufacture of components, including key components not yet produced in India, through construction, to O&M of built capacity. It continues through new skills needed in grid planning and deployment, in system operation to manage variability, and in regulation to develop the power market in such a way that it is amenable to changing output patterns of power plants.

19 Further information on these two initiatives for wind and solar PV technology can be found at http://www.ieawind.org/about_co-operative_agree.html# and http://www.iea-pvps.org, respectively.

4. Achieving and Sustaining Investment Volume

To reach targets for renewable energy deployment such as those detailed in Chapter 1, commensurate investment is needed in manufacturing, renewable power plants, and sufficient grid infrastructure to move the electricity they generate to market, as well as a range of accompanying investments in the power system more generally.

The often-asked question, "How much investment in RE capacity is needed?" can be answered simply enough by taking the scale and timing of RE ambitions and the hardware required, and factoring in an estimation of the reduction of capital cost over time, although this in itself is uncertain. Costing wider infrastructure needs is more complex, although this too can be estimated roughly, once detailed studies of transmission needs have been carried out.

The key question, however, is "Where will the money come from?" Past power sector investment in India has usually come from the public sector. But there are fundamental questions about what the future role of public sector spending should be, relating particularly to where public spending brings the greatest added value.

Renewable energy deployment in India, alongside that of conventional energy, has to some extent coincided with a shift away from the publicly funded model to a private one. Indeed, given likely volume and time constraints on the amount of public funds available for investment in energy infrastructure, it seems increasingly likely that the major role – particularly as regards new power plants – will be taken by the private sector.

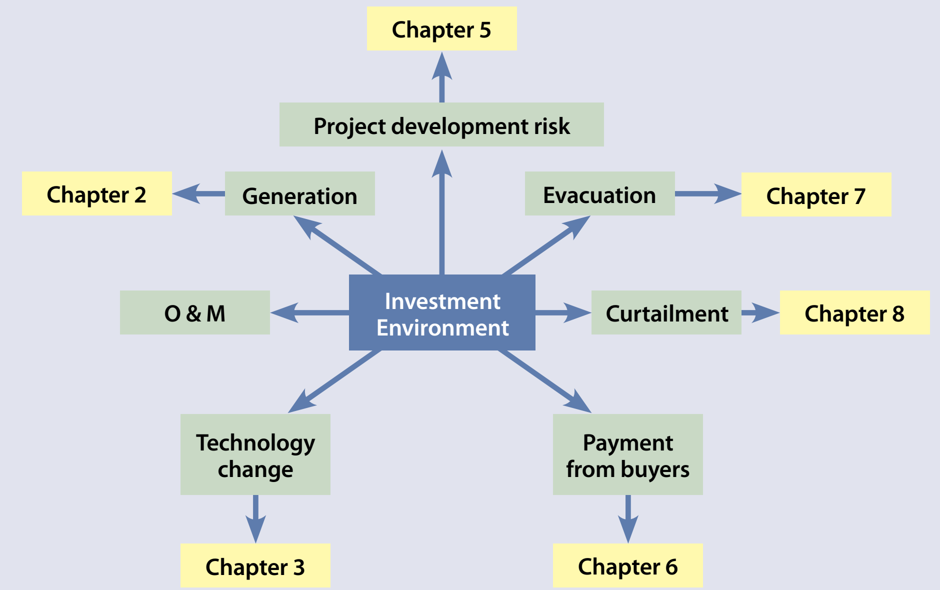
It is essential, consequently, that private investors both domestic and foreign find India an attractive place to do business. The level of risk, but also uncertainty as to what that level actually is, are of the greatest concern to investors. If risks are well understood, manageable, and acceptable, then funds are more likely to flow.

These risks may relate to the technology to be deployed in a project, project performance in terms of energy output, the reliability of the buyer, and a host of other factors operating in the context of current policy, regulation and legislation. The sources of many of the key risks are highlighted in subsequent chapters in this report, as illustrated in Figure 10.

The role of public institutions, at both central and state level, may be to address those risks over which they have the greatest control, thus providing greater certainty for investors – in a sense, the collateral. The public sector can also make use of products and services provided by the private sector in their approaches to risk mitigation, for instance in wind resource assessment or turbine warranty, where companies such as 3Tier and GE offer packaged services.

Figure 10

Sources of Risk and Their Discussion in This Report



4.1. The Investment Market

India has established itself as the fifth largest renewable energy market in the world and has ambitions for further growth. For the short-term at least, the general consensus of stakeholders is that some technologies are more expensive than conventional power, and require support from government to make investment in them more attractive. The nature, consistency, and extent of that support directly influence the volume of investment flowing into the sector.

The investment market has evolved in response to initiatives at central and state levels. Historically, wind power led the market, driven by central support in the form of AD – tax benefits offered from 1995 – coupled with state-level incentives such as preferential FIT and/or liberal open access policies. From 2007, investment was further encouraged with the introduction of the (central) GBI, which in 2013 saw wind capacity reach 20 GW nationwide.

Then the solar market began to pick up, driven by the launch of the JNNSM in 2010, which saw capacity reach 427 MW by 2011. 2011 also saw the peak of investment in and across the renewable energy sector.

Uncertainty hampers the development of a sustainable market for renewables in India. Part of the problem appears to be that as energy is a "concurrent" policy issue (i.e., within the purview of both central and state governments) investors often do not regard India as a single market, but rather as many separate markets, each with its own particularities, risks, and opportunities. Combined with the tendency of policymakers to tinker with support mechanisms and financial incentives, this drives the investment market toward volatile, short-term, and opportunistic behaviour.

Debate as to the most efficient approach to securing sustainable long-term investment has centred on the need to strike a balance between state and central support, and the effectiveness of generation versus capacity-based incentives, particularly how they interact with the tax environment and business models. More recently, attention has also focussed on whether lower cost, long-term, debt-related approaches are more cost effective than present approaches or whether insurance products combined with financial products need to be considered more seriously..

This report does not attempt to resolve this debate, although given limited government resources, determining how best to support investment is vitally important. A comprehensive GOI review of options for long-term support for the RE market would be a good step toward more sustainable growth in investment.

4.1.1. Volume Trends

For India to meet its targets for RE deployment, as detailed in Chapter 1, annual investment must rise dramatically and be sustained through 2027 and beyond.

Investment in RE was USD 5.7 billion in 2013, a 20-percent decline from the USD 7.1 billion invested in 2012, and less than half of the USD 12.7 billion in 2011 (Figure 11). Forecasts for 2014 suggest investment of between USD 5.5 and 7 billion, split between wind and solar (USD 2 to 2.5 billion and 2 to 3 billion, respectively, in the lower estimate) with biomass and others accounting for the remainder.[20]

Volume fluctuates as a result of wider economic factors also, but recent changes appear strongly to reflect changes to the various support regimes and delayed auction of solar PV Power Purchase Agreements (PPAs) at both state and national levels.

Recent reductions in investment were most marked in the solar sector where slippage occurred in the implementation of programmes due for 2013. Six states conducted state-level solar auctions, but many of the winning projects had not signed PPAs by mid-January 2014. Indeed, of a targeted solar capacity of 2660 MW across the six states, only 725 MW had reached the point of signing a letter of intent, a tentative commitment, or a PPA proper.

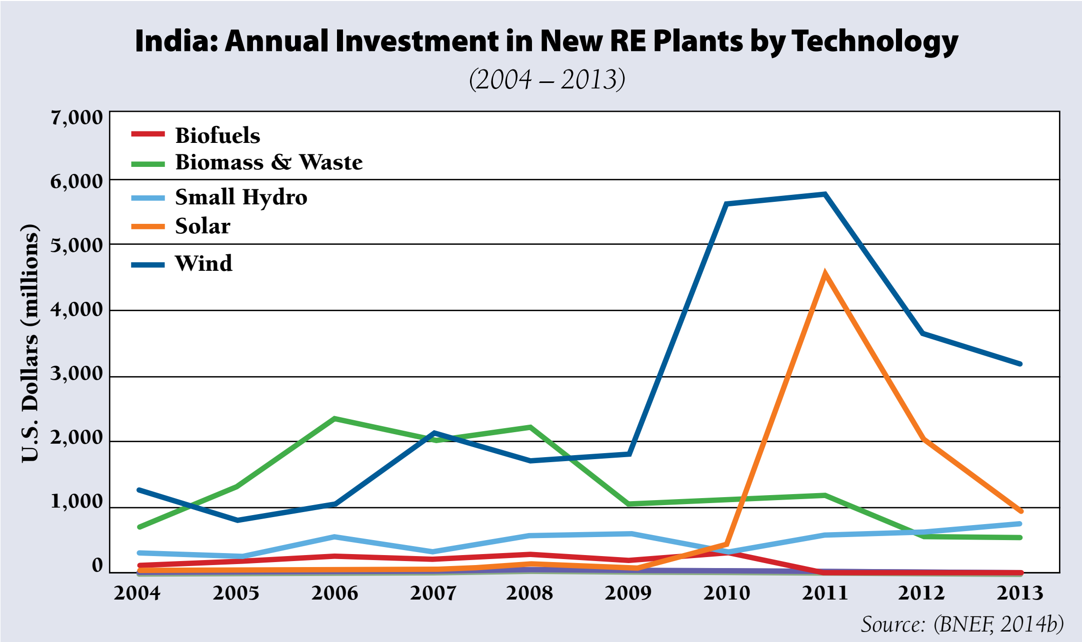
At the national level, the Solar Energy Corporation of India launched a 750-MW tender for Batch One of the Second Phase of the National Solar Mission in early October 2013; this too has suffered delays, with resulting commissioning deadlines pushing back into May 2015. Wind sector build rates also declined in 2013, falling to pre-2010 levels as a result of the withdrawal of AD and delays in the reintroduction of the GBI.

Beyond the organised auctioning of projects, solar deployment is taking the form of new captive power plant and behind-the-meter assets. Determining the scale of these assets is difficult, as data is poor. The distributed solar market is driven by recent decreases in PV prices, offering a cheaper source of electricity than the alternatives: unreliable grid-based supply and/or (back-up) diesel generator sets.

As the cost of battery storage in particular falls, and owing to their modularity, distributed PV deployment is likely to accelerate. The consequences of this are uncertain, but lessons from markets in Europe, particularly Germany,

20 BNEF, 2014b.

Figure 11



and the western United States suggest that this may erode the incumbent utility business model, with knock-on effects on the conventional electricity market.

Although most investment to date has gone into wind deployment, solar investment is set to increase, and will continue to gain on wind volumes, provided that the issues above are addressed.

4.2. Investor Types

Broadly speaking, project investment falls into two categories: (1) equity in a given project or business in return for a corresponding proportion of ownership and revenue, and (2) debt in return for a flow of interest and repayments. Different categories of investors will generally prefer one or the other investment route. For example, banks typically lend, whereas private equity firms will buy in.

Investor types include public institutions, banks, and private companies (e.g., large consumers, RE technology providers) operating from a foreign or domestic base. They may be public or privately owned. An investor's expectation of return on a project varies according to the type of investor, the length of its commitment, and their appetite for risk, which will in turn define the type of projects in which they will invest.

Investors active in India are diverse, including government institutions, banks, and companies operating from both foreign and domestic bases, either held publicly or in private ownership. Table 3 lists the investor types active in India at present.

It is also important to highlight the role of foreign governments that provide financing to component manufacturers exporting abroad, notably the Chinese and US administrations. This provision of low interest rates assists with financing of RE equipment for import into India, which is significant, as hardware represents a large part of total project costs. It thus provides an indirect subsidy to the Indian RE market.

Development banks play an important role in India. Typically they use an investment strategy, which, while commercial, also assumes a socioeconomic policy role by prioritising one investment class over another, and by providing investment at below-market rates. Globally,

Table 3

Types of Investor in RE Projects

Type of Investor	Category	Total Registered in India	Active in Renewable Sector
Commercial Banks	Public Sector Banks	26	9
	Private Sector Banks	30	6
	Foreign Banks	37	–
Equity Investors	Private Equity	51	16
	Venture Capital	180	21
Institutional Investors	e.g., Insurance Funds, State-owned, and bi-lateral and multilateral institutions	24	11
Development Banks	Development financial institutions*	3	3

**DFIs include national level institutions IREDA, IFCI, SIDBI* *Source: CPI, 2012* development bank investment in RE was more than USD 58 billion in 2011.[21]

Newer forms of renewable energy investment, such as crowd-funding, seen in North America and western Europe, whereby large numbers of small, private investors club together to reach the scale necessary to take equity in larger undertakings, are only starting to emerge in India, with the recent entry of companies such as Sunfunder. The potential to attract retail investors has been proven in these more developed markets, although investment volumes are small relative to the total. International examples of such companies include Mosaic, active in the US solar market, and Abundance, active in the UK wind and solar markets.

4.3. Finding Finance

It is important to remember that unless motivated less than entirely financially, investors will choose among investment options purely on the basis of their risk and return profiles. If one investment option is more attractive in these terms than another, it will be chosen. In other words, investment in RE is not viewed in isolation but as one option among many (mainly other infrastructure) investment options that may be less or more attractive.

As matters stand, Indian renewable energy projects are more difficult to finance than comparable infrastructure investments outside the power sector, or in other electricity markets. In common with the broader power sector, the reason for this is uncertainty of payment by the key buyer group, the Discoms. Such is the state of the latter's finances, coupled with the fact that they are likely to prioritise payment to their larger (i.e., conventional) suppliers, and a common resistance to change, that investor confidence is very low. The financial health of the Discom's is covered in Chapter 6 in more detail.

In the preparation of this report, stakeholders raised a range of issues that may act to inflate financing costs. First, underlying Indian interest rates are high, relative to other more developed markets, as a result of India's GDP growth rate, high rate of inflation, competing investment needs, and geopolitical risk. This has an impact across the entire investment market, where there is stiff competition for debt and a wide variety of infrastructure needs. However, it should also be noted that electricity regulators account for the high interest rates while establishing the tariffs to ensure a reasonable return on equity (ROE).

Secondly, compounding the first factor, in the mind of many investors solar and wind technologies still represent a relatively new and unfamiliar investment class as compared with conventional power or other infrastructure projects. RE projects are perceived as riskier with more uncertain returns.

Thirdly, as a greater proportion of the overall cost occurs upfront in an RE project (CAPEX and no fuel costs) relative to a conventional power plant, the higher cost of financing has a disproportionately large impact. This difference is compounded by the fact that the fuel costs of coal power plants are subsidised.

4.3.1. Cost of Debt

The high cost of debt compared to other RE markets is a dominant feature of RE project investment. It has been found to raise the levelized cost of energy (LCOE) of an Indian project by as much as 24 to 32 percent[22], compared to the United States or European Union, for example. The dominant reasons for this disparity are high interest rates, a shortage of appropriate debt tenors, and a lack of non-recourse debt.

Stakeholders indicated that the tenor (the duration of lending) tends to be insufficient in India, typically up to eight years. As an infrastructure investment, RE projects need longer-term debt, of ten years or more, which many stakeholders told us is difficult to secure.[23] This mismatch means there is a shortage of appropriate debt as investors seek out alternative assets that fit better with their investment horizons.

The lack of non-recourse debt – lending purely against a project's future cash flows – may reduce the breadth of financing approaches available to developers, who prefer non-recourse financing as it limits their risk and allows them to seek borrowing for future projects more freely than if they were themselves liable for the debt. In addition there is in India some debate as to whether non-recourse financing on paper really adds up to the same thing in practise.

4.3.2. Broader Market Challenges

It would be a mistake to overstate the importance of cost-of-debt issues in the investment market, as other factors raised by stakeholders play important contributory roles, as set out below.

Stakeholders gave somewhat conflicting messages on

21 BNEF, 2013.

22 CPI, 2012.

23 Although experts have indicated that several lenders offer 13 – 14 year door-to-door tenor, stakeholders indicated these loans are not readily available.

the supply of debt, although overall it appears constrained to some extent. One reason may be a sectoral limit set by internal investment committees (or other bodies responsible for oversight of an investor's activities). Once such sectoral limits are met, it may be that no further investment can be allocated in that lending period unless the risk profiles are favorable to investment.

This may be compounded by the inclusion of RE within a broader "power" sector limit or even "infrastructure" category, with the result that RE is crowded out. This may be an issue worth investigating further.

In general, a project developer may prefer a fixed interest rate on debt secured to finance a project. A variable rate of interest may be problematic, if a subsequent increase cannot be "passed through" to the customer. Stakeholders clarified that variable rates are more common in India than in more developed renewable energy markets, wherein rates are frequently fixed.

For example, an RE project promoter who has borrowed at a variable rate cannot pass on an increase in that rate to the buyer of his electricity if his tariff is fixed, as is usually the case in India. In contrast, it appears that conventional power plants are increasingly able to pass on variable costs to the buyer with whom they are contracted in a PPA, such as variable fuel costs, and may therefore also be able to pass on variable financing costs.

In passing, it is also worth noting that the bulk of debt raised for RE projects is to cover CAPEX incurred upfront (there are no fuel costs except for biomass projects). This may make such projects more sensitive to changes in the interest rate than fossil-fuel plants, which incur proportionally lower costs at the outset, and are thus better able to hedge interest rate volatility over the lifetime of the project.

Regulatory restrictions on flow of foreign capital can, and as investment grows, will, hamper access to the Indian market for foreign investors, making it less attractive than more open markets. Policies such as capital controls, limits on foreign debt, and interest rate ceilings are examples of such restrictions.

Various foreign exchange issues have impact on project finance. Currency volatility has created uncertainties for investors. For example, in 2013, the Indian Rupee ranged from Rs 53 to 68 to the USD. Possible knock-on effects are various.

Firstly, in order to protect against currency volatility, an investor can take out a form of protection against risk. This hedging transfers some or all of the risk onto a third party in return for a fee. However, as likely volatility increases, so does the cost of hedging and therefore the cost of financing projects.

Secondly, and related to the previous point, if debt is of overseas origin, perhaps in USD so that repayments need therefore to be in USD, then a weak Rupee buys fewer dollars, and the investor receives a diminished return on income from an Indian project than was expected at the time the investment was made.

Finally, given weaknesses in the Indian supply chain for RE technology, an RE project may require certain components to be sourced from overseas. A weak Rupee, relative to the currency of the country of origin of the component in question, will have reduced buying power, serving to increase the cost of that component.

4.4. Impact of Policy Mechanisms

Chapter 2 touches on the range of financial support mechanisms that have been used in India, and may be used in future. An important fact often overlooked is that the type of mechanism used may have considerable impact on investment patterns.

Investment, whether debt or equity, is injected into a developer company or a specific project to be developed. The Indian market features essentially four different types of project developer, each of which tends to structure and deliver projects in a different way, and to prefer a different form of financial arrangement.

1. **Manufacturers.** A project is developed by the manufacturer of the technology being deployed in that project. To date, this approach has been particularly common in the wind market, although more recently it has emerged in the solar market. The balance sheet of the manufacturer may be sufficiently strong to finance the project to a large extent. This may reduce the cost of the remaining capital to be borrowed. For example, the leading Indian wind manufacturer, Suzlon, has developed projects in this way, as has First Solar in the solar PV market.
2. **Discom.** Historically, the majority of (conventional and hydro) power plants have been built, owned, and operated by State Electricity Boards, which also owned the Discoms. Following the functional unbundling of Discoms from Gencos, it is worth noting that the build-own-operate approach has recently been considered in Maharashtra with regard to large-scale solar projects.
3. **Large consumers.** Commonly known as Captive Power Plants, investments are made by large consumers, mainly

for their own consumption, which retain a controlling interest in the power plant. The plant itself may be at some distance from the consumer, or alternatively co-located, such as IT parks with PV plants located within their landholding.

4. **Independent Power Producer (IPP).** The developer of an IPP project operates independently of the manufacturer of the technology, Discom, or large consumers. Many IPPs specialise in a single technology. Typically, the IPP is funded initially by an equity investment; it then raises debt on a project-by-project basis. The proportion of renewable power development in India developed under the IPP model is increasing. Current IPP plans for wind projects in India run to more than 24 GW.

To date, the type and nature of support mechanisms provided by government has influenced the type of investor attracted to renewable projects. It appears that in some cases one mechanism will appeal more to one than another, and particular investor types will seek to exploit a particular support mechanism to the full. Discussions with stakeholders suggest that this has influence on the lobby messages projected to government: such messages may suggest that one mechanism is inherently better than another, whereas in fact it may simply suit one type of investor more than another.

The clearest example of this has been the vigorous discussion of the relative merits of the AD and GBI mechanisms that have in the past been offered concurrently (but exclusively) by central government. AD allows an investor to offset a higher proportion of project capital costs (i.e., at the beginning of the project) against their overall tax liabilities in the first year. AD was until recently higher (80 percent) for solar projects than for comparable infrastructure projects. Previously the incentive was also offered to wind projects, but it was withdrawn in April 2012 and reintroduced in 2014.

AD support proved particularly attractive to wealthy private individuals, high net worths (HNW) and businesses that could benefit from tax deductions and were also seeking investment opportunities. Manufacturers with a site already identified and their own hardware ready to deploy can approach the HNW and offer a relatively risk-free opportunity to reduce his/her tax bill, while providing "green credentials" at the same time.

In other words, the principal benefit to the HNW investor is the immediate and considerable reduction in tax payable that year. In contrast, the GBI is a policy designed to incentivise higher production by being directly linked to the actual generation resulting from the power plant. As a result this structure is likely to be of more interest to an investor whose priority is a long-term return or who does not have a large tax liability.

Developers are known to exploit perceived "siloes" in government, opportunistically lobbying public bodies with the power to provide particular support regimes according to what is on offer from each – for example, simultaneously lobbying MNRE to reinstate AD while arguing at SERC hearings only for higher FITs.

Stakeholders have provided evidence of a backlash within certain Discoms, which may refuse to sign new PPAs with developers, as a consequence of what they perceive to be unreasonable profits or windfalls to IPPs. This is exacerbated by insufficient transparency around project and financing costs. Indeed, stakeholders suggested that in Maharashtra it is this perception that is driving the Discom to develop projects itself.

Determining the combination of financial support mechanisms that will encourage the greatest investment volume, and the highest and most economically efficient provision of RE (as opposed to capacity) is a fundamental step in the development of a stable, sustainable Indian renewable energy market.

4.5. Building Volume

Present investment flows into Indian renewable energy, like those of conventional power and transmission investment, are insufficient to meet India's deployment targets. A step change is therefore required to put investment flows on a trajectory that can meet policy aspirations.

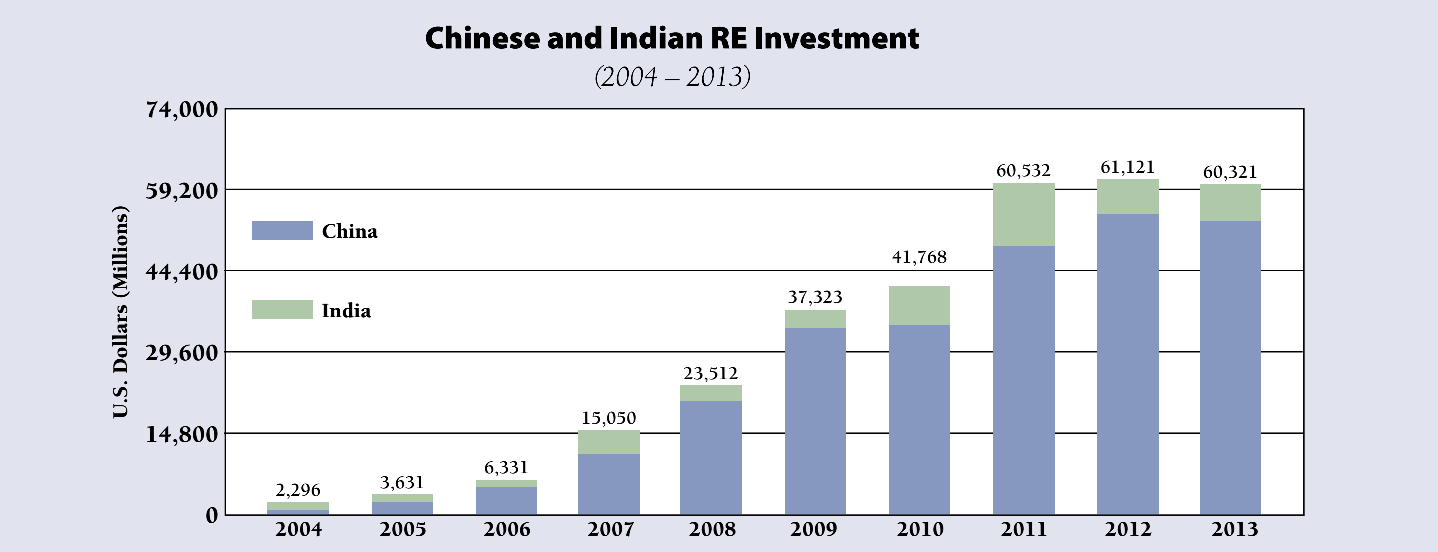
Achieving sufficient volume to achieve RE targets will require a more strategic approach to encouraging renewable investment, and progression from the short-term, and somewhat piecemeal policy approach, which stimulated investment flows of up to USD 12.7 billion in 2011, but has not sustained them.

International examples of rapid scale-up of investment reveal what is possible. South African renewable energy investment was 200 times greater in 2012 than 2011 levels. Chinese investment in RE was comparable with that of India in 2004, and yet by 2013 had vastly outstripped investment in India (Figure 12).

Unpacking what lies beneath these increases in investment will never be absolutely conclusive; however, the introduction of fundamental changes to regulatory systems and market reforms is key.

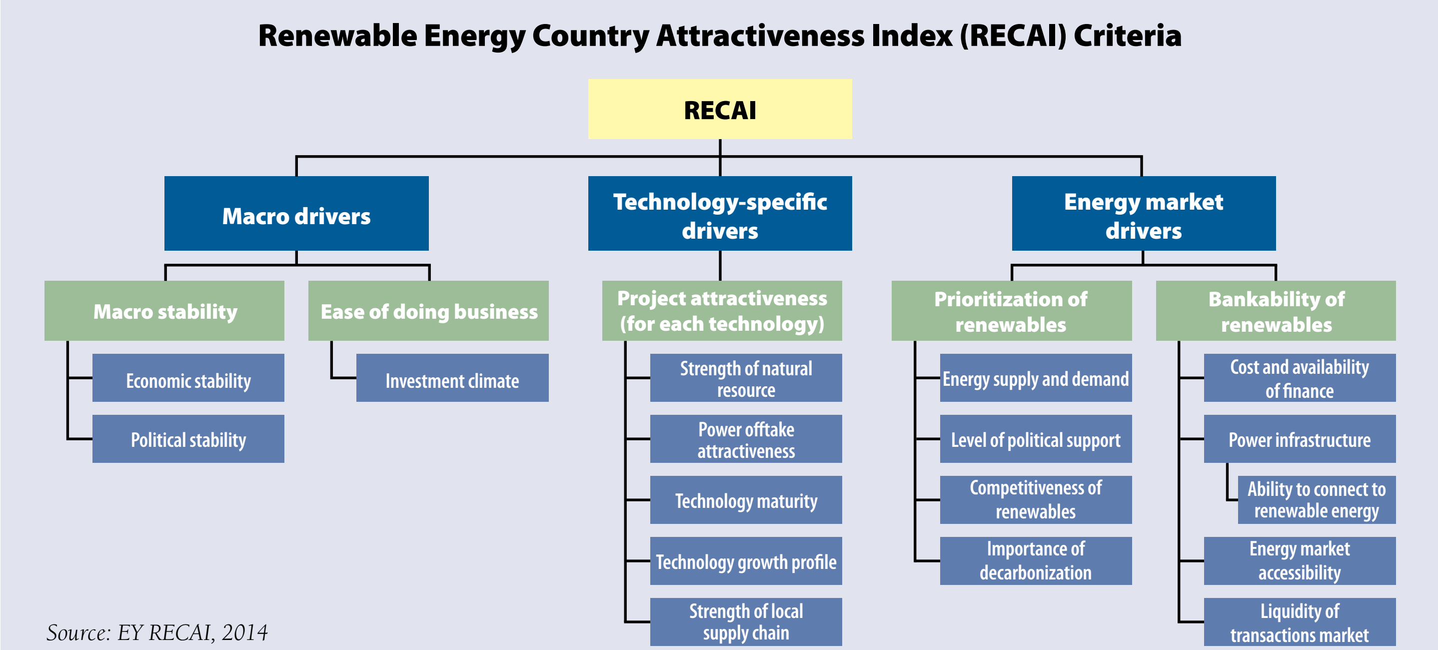
In considering the attractiveness of India as a destination for foreign investment in renewable energy, a

Figure 12



Source: (Bloomberg New Energy Finance)

Figure 13



Source: EY RECAI, 2014

useful comparative tool might be the Renewable Energy Country Attractiveness Index (RECAI) guide published by EY.[24] RECAI is based on assessment of three drivers – Macro, Energy Market, and Technology – each of which summarises a set of scored indicators (Figure 13).

The most recent 2014 RECAI sees India in sixth place, having been judged as showing signs of growth.[25] China takes first place with strong support to solar companies and directives that state-owned grid operators must buy all available solar power.

4.6. Public Sector Roles in Financing

A more explicit division of roles between the public and private sectors may help to deliver the dramatic increase in investment needed. The exact level of investment required

24 http://www.ey.com/UK/en/Industries/Cleantech/Renewable-Energy-Country-Attractiveness-Index

25 EY RECAI, 2014.

new footnotes!

is difficult to quantify. In 2013 a Lawrence Berkeley National Laboratory (LBNL) study modeled the need for additional annual investment between 2013 and 2030 of between USD 583 million under a modest scenario (RE as 40 percent of total energy needs) and as much as USD 744 million for the most aggressive (60 percent RE). Greenpeace in Energy Revolution (2012) concluded that for RE to reach 97 percent of production would require annual investment of USD 117 billion through to 2050.

Discussions suggest that the private sector will remain the principal channel for financing. In contrast, stakeholders heavily emphasised that the main role of the public sector, rather than direct finance, should be in smoothing that channel, that is, providing a de-risked and more conducive framework in which investors can operate, for example, by shaping and regulating the electricity market to reduce revenue uncertainties.

The historical role of the state in power sector infrastructure investment, as in many countries around the world, may be changing, although this is unlikely to happen quickly. The Indian state has played a key role in funding and operating power plants, both at the national and state level, through direct funding or indirect subsidies such as low-cost financing or fuel.

Stakeholders suggest that in the future, the public role should increasingly be to help the marketplace for renewables to mature, so that larger and risk-averse investors are attracted to it, such as the pension and insurance funds that have become active in some markets in recent years.

If the role of the public sector does become to reduce risk for private investors, then its main task would be to address certain present "showstoppers." Importantly, these risks may result from the actions or inaction of government itself. For example, sudden changes to policy are major deterrents. Retroactive changes to tariffs or subsidies, as seen for example in recent years in Spain, where tariffs for RE were cut retroactively, can kill a market.

In addressing risk, the public sector will need the flexibility and resources to react to new risks and constraints (such as grid integration), which will emerge as renewable energy markets evolve. The renewable energy market is not static: technology costs fall; deployment will accelerate; the cost of finance will fluctuate; and the public sector role will need to respond accordingly (see Chapter 2).

4.6.1. Direct Financing of RE

There may be certain areas in which direct public financing may be of real value. It can help in the promotion of demonstration/lighthouse projects that are deemed too risky or expensive for the private sector. Examples may include early stage concentrating solar power projects or offshore wind development.

It may also be appropriate for the public sector on occasion to serve as a "cornerstone" investor on projects in which this will reduce the cost of capital and risk. This type of involvement demands careful consideration and a clear assessment of a market failure and need to act, or else public sector involvement will amount to a special subsidy to the private sector.

The current role of the Solar Energy Corporation of India is an example of how the public sector may intervene. It does this in the following ways:

1. Through provision of grant funding to marginal projects as with the first phase of the third round of the JNNSM;
2. By providing cheaper borrowing (relative to that available on the commercial market) to solar projects using GOI borrowing powers;[26] and
3. Taking on responsibility for honoring PPAs where Discoms are unable to make timely payments.

A useful international example is that of Brazil, where the Brazilian National Development Bank plays a role in offering long-term loans at below-market rates (concessionary rates) to high priority industries, including renewable energy. The bank does this by using the national government's borrowing powers and is financed through a payroll tax.

However, private sector stakeholders may be wary of public sector involvement unless it is seen as fulfilling an interim function early in the investment growth trajectory. They may deem it as a threat to their own role in the market, as the public sector is able to borrow at advantageous interest rates below their own, and this was made apparent in discussions with investors.

They may also feel that government involvement per se is undesirable, given apparent perceptions that support for RE is subject to political fashion. Instead, public sector involvement can be phased out of the market as projects are seen to establish themselves and no longer require support,

26 Some experts suggested that the government could take mezzanine financing debt, allowing other debt tranches to have lower interest rates. Other experts felt mezzanine finance would be too complicated and expensive for government to take when scaling up investment, although it might be appropriate for relatively small investments in new, higher-risk technologies.

new footnote!

as in the same way private investment moves from equity investment and is refinanced by pension or other long-term funds as risks reduce and projects mature.

4.6.2. New Roles for the Indian Public Sector

Although stakeholder pressure to act on a number of fronts is considerable, domestic public sector institutions have had to date only a limited role in stimulating RE investment. Stakeholders suggested a number of additional possible roles:

1. Provide full or partial loan guarantees, underwriting the repayment of loans taken out to develop a project. As yet, examples of this approach exist only in the energy efficiency sector, wherein both USAID and the International Finance Corporation (IFC) have initiatives in India. The IFC in conjunction with the Department for International Development (UK government) are planning to launch an initiative to support the REC market.
2. Socialise the costs of new transmission and take the risk of deploying new transmission lines before the power plants they are to serve have been built, passing on the costs to the consumer through bills). There may be some reluctance to proceed with this approach as utility bill increases are a politically charged issue, although experiences in the United States suggest that cost/benefit studies of line additions can help prioritise and screen proposals, often resulting – additionally – in lower bills owing to access to cheaper power.
3. Assisting foreign investors in entering the Indian market by assuming the currency risks associated with investing in India. The GOI role might be twofold, first in reducing or removing fees for sovereign guarantees, typically in the range of 0.25 percent to 2 percent, secondly in absorbing hedging costs, which currently run three to seven percent. These roles would have clear value to overseas investors, who regard India as a risky investment destination, but further work needs to be carried out to determine whether it is the most efficient form of public support and whether it damages domestic lending.
4. Help channel disparate finance streams in a more targeted way. For example, IREDA might expand its role in funneling all overseas aid and development assistance into RE and transmission infrastructure projects. In this respect it might also expand its efforts in reducing interest rates to projects through the use of funds from the National Clean Energy Fund, while ensuring that these reductions are reflected in the bid.
5. Support the development of government-backed special purpose vehicles, which take on some of the development risks, both financial and non-financial, from the RE developers. This might resemble the Solar Park project at the state level in Gujarat, for example.

4.6.3. International Lending

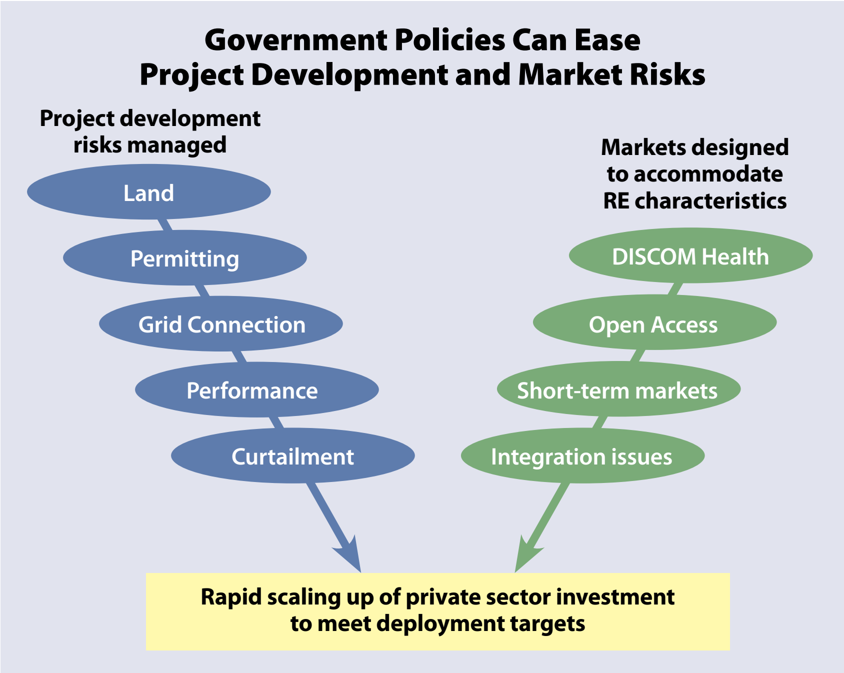
International public sector investors are present in the Indian renewable energy and infrastructure market. These lenders are policy driven, with investment flowing in response to the strategic priorities determined by the national government. Lending is sometimes defined as "soft" or "patient," in that loans may be provided on more favorable terms than those available commercially, being at lower rates and over longer tenures. Involvement may come in one of the following two ways:

1. Equity investments in developers, and subsequent debt investments into their projects, designed to catalyse market development. For example, the IFC backing of NSL Renewable Power and Azure Power Renewables.
2. Investment in essential transmission infrastructure to address the key risk of adequate evacuation infrastructure provision (see Chapter 7). Examples include the Asian Development Bank's USD 500 million investment in evacuation (connection) infrastructure in western Rajasthan for the Bhadla solar project, and the KfW Bankengruppe EUR 1 billion loan for "Green Energy Corridors" transmission infrastructure.

In the future, there are several ways in which development banks such as the World Bank could extend their services to encourage further investment in renewables. The crucial questions here are in what way can public funds be used to attract the most investment, and what is necessary to bring in commercial lenders. In considering these issues stakeholders have suggested that:

- GOI could request a pooling of development bank loans, so that a more significant and concerted financing effort can be made to reach India's RE goals.
- Banks should innovate and offer blended finance, whereby public and private loans are mixed for investment in renewable energy projects. This blending allows the tenor of loans to be extended and the interest rates reduced, while providing security to the private investor through the subordination of the

Figure 14



public loans (i.e., the private funds are repaid first). In this way there can be a multiplier effect in which the public funds could attract from three to ten times the volume of commercial finance.

4.6.4. Reducing Risks for Private Investors

The key role for the public sector, according to stakeholders, is in reducing the risk that RE projects represent to private investors. Reduced risk is the route to lower financing costs, which will attract more investment.

As highlighted in Figure 14, and developed further in Chapters 5 and 6, respectively, the two principal areas of risk that could be addressed by government at all levels are:

1. Those encountered when developing a project; and
2. Those relating to selling the electricity generated by a built asset, at a price that covers the cost of developing the project, servicing debt, and providing adequate return.

4.7. Data Transparency

Before turning to those issues, however, it is worth highlighting a common problem. The estimation of risk and return is based on data. The more numerous and reliable those data, the easier is this task. The level of risk does not necessarily deter investors – if the return is commensurate – but uncertainty relating to those risks is a showstopper. In other words, if the data are available, the necessary pre-investment analysis can be performed, and a decision made either way. But no decision can be made without data.

Data transparency in particular is required in:

1. **CAPEX.** Requirements (the cost per MW of a wind turbine, for example) have risen in recent months. On its own, this will be a deterrent. However, in many cases the increased production of electricity from the larger turbines causing this CAPEX increase may compensate for it. In any case, it is the production cost that will have bearing on what is reasonable to demand in terms of production tariff. If these data are not clear to investors, the uncertainty will be a showstopper.
2. **Capacity building.** Improving the awareness, knowledge, and understanding of investors about RE to improve their due diligence on the project proposals. To support this technical assistance from central government would help open the market to smaller-scale banks without a dedicated in-house capability.
3. **Sale price.** Sale prices are negotiated bilaterally in most cases on a project-by-project basis. This means that the price will not be guaranteed with any degree of certainty until the PPA is signed. Consequently the investors will not wish to dedicate funds to that project until that certainty is present. If price discovery were easier, as is the case where electricity is traded multilaterally in power exchanges, for example, investors might be readier to commit earlier.

4.8. Summary

In order to achieve and sustain the necessary investment flows for India to reach its RE potential, a change of approach is needed, with careful consideration given to the future role of the public sector. At the same time, private investment needs to find RE opportunities more attractive for the long term in order to support future growth.

Project risk underpins the public/private relationship. Investment risks are unlikely ever to be totally understood and quantified. However, they may be transferred between stakeholders, better understood, and more reasonably priced, which will reduce financing costs and enable more projects to be commissioned.

Policymakers at both central and state levels have acted to support RE market growth since the 1990s. Although there have been successes, growth has not been smooth, steady, or consistent. Notable are a tendency to short-termism and a somewhat fuzzy division of responsibility between state and national government. An appropriate mix of support mechanisms to encourage investment growth is needed, key issues being the level of support provided, with specific longevity and certainty.

The Indian RE investment market is diverse, with domestic and international participants, including state and private banks, private equity firms, corporations, and development banks. RE investment has been reported to be more difficult and expensive than in the wider infrastructure sector. Reasons for this include the financial health of Discoms, India's underlying interest rates, perceptions of technology risk, and the specific investment profile of RE projects.

Stakeholders consistently emphasised that private sector investment is essential, and that the role of the public sector should be to create a conducive environment for private investment to flow and in funding essential infrastructure. Balancing public and private sector roles will be a central challenge for policymakers in the coming years.

5. Project Development and Operational Risks

Investment flows to where, for a given return, the risk is least. Capital is blind: it will avoid RE if it is less attractive than alternative investments. This chapter highlights risks often encountered in the development and operational phases of renewable power projects, which deter capital.

Effective management of project development risk will encourage the market to pull toward deployment targets as listed in Chapter 1; to develop the RE industry outlined in Chapter 3; and to build investment volumes as discussed in Chapter 4.

Policymakers should understand the full extent to which their actions can support (or undermine) the business case for a specific project. Perhaps the greatest policy impact will be the existence (or not) of a regulated premium tariff, or some other financial mechanism; but an enabling project development environment is also of the utmost importance.

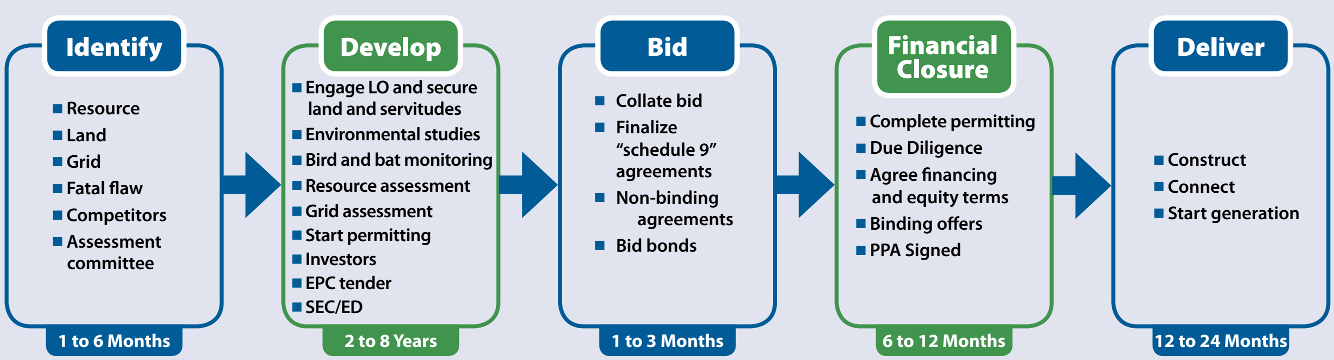
The business case for a renewable power plant depends on a financial appraisal. During this, investors seek to determine the risk profile represented by the project, considering issues such as resource assessment, technology selection, construction process and timetable, and O&M plans. The investor needs to be sure that the project developer is able to secure rights and access to land, that a grid connection will be completed in time, that permits will be secured on schedule, and that local stakeholders with influence over the project are on board. Until such issues and others are addressed, it is unlikely that any financial commitment on the part of an investor will be forthcoming.

Figure 15 illustrates a generalised wind energy development process in South Africa. It sets out the timeline for the development process, divided into five key stages: site identification, project development, bidding, financial closure, and delivery. Although this is merely an illustration from one country, it highlights a point common in all geographies: that although investors are identified early on in the process (Step 2), they will only be amenable to financial close (Step 4) once the issues discussed in this chapter have been addressed. This is particularly the case with regard to the acquisition of land to site the power plant.

Stakeholders representing a wide range of developers, both manufacturers and independent, domestic and international, and investors, highlighted their key concerns, although there may be others that did not arise in discussions. Table 4 provides a list of potential barriers encountered in the international experience of wind power, along with a number of solution options.

Figure 15

Wind Energy Project Development From the Developer's Perspective in South Africa



Source: (IEA, 2014b)

Table 4

International Experiences of Barriers to the Development of Wind Power Projects

Barrier	Details	Solution Options
Inaccurate or inaccessible meso-scale data on the strength and distribution of wind resources	• Absence of public data on energy content of wind resource • Absence of data on resource quality (e.g., climatic conditions, local conditions)	• Develop or procure national wind atlas and make it publicly available • Establish national platform for anonymous data sharing, to improve access to and accuracy of wind data
Obstacles to wind plant siting	• Data on land/seabed topography and geology are inaccurate or unavailable • Desirable sites are inaccessible to construction and maintenance teams	• Undertake geological and topographical survey in priority areas • Support extension of grid into targeted wind development areas • Ensure interface with local government on infrastructure planning • Encourage sharing of weather data
Connection to grid is constrained	• Transmission/distribution grid owner may not wish to facilitate connection • Connection fee may be excessive • Point of connection may be disputed between developer and transmission owner • Long distance between potential site and grid node a barrier owing to cost or existing rights of way	• Regulate monopoly control to allow access for Independent Power Producers • Regulate system operators to ensure rates are cost-based • Distinguish connection costs from grid reinforcement costs and assign appropriately

5.1. Siting and Access

After the energy resource itself, which for solar and wind resources is geographically constrained, respectively, to a lesser and greater area in India, the land on which the power plant will be built is perhaps the most fundamental aspect of project development. Adequate space is a critical requirement of wind and solar projects, which require a greater surface area per MW than conventional power plants burning fuels with high energy density. For example, five acres per MW of land is usual for solar PV modules.

Meeting wind deployment targets will mean approximately 10,000 additional turbines will be installed under the 12th Five Year Plan. Most of the installed wind power in India is concentrated in two areas: Tamil Nadu, Karnataka, and Andhra Pradesh in the south and the western states of Maharashtra, Rajasthan, and Gujarat. The most heavily developed area is a corridor of high wind speed land running west to east from Tamil Nadu into Karnataka.

There are many outstanding issues relating to land acquisition, and it is a foregone conclusion of many developers that the new "Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act" will make land acquisition more difficult and/or costly for the industry. This is not only the case in the building of plants but in the pre-development phase also: prior to the building of a wind power plant, anemometry masts are set up two to three years ahead, to measure the wind resource.

Stakeholders have stated often that the best sites have already been developed. However, discussions suggest that suitable sites both for wind and solar deployment are not in short supply per se, although they may be hard to secure.

Indeed, many of the best sites in Tamil Nadu, for example, have been developed or "banked" for development at a later date. The Centre for Science and Environment (CSE) therefore sees this factor among others leading to the deployment of wind in hitherto undeveloped areas of some states. In Gujarat, in contrast, which contains a high proportion of arid or barren land, land availability is not generally considered to be tight.

Land may be publicly owned ("revenue" land) or it may be privately held, which includes much of the 142 million hectares of agricultural land in the country. Forestry land, which may be publicly or privately held and covers 67 million hectares, may not be sold but can be leased for sufficiently long periods.

Public and private ownership present different challenges to the developer. Some developer stakeholders suggested that privately owned land is more attractive than revenue land, although land prices, for example, vary widely.

Others have pointed out that historical allocations of land ownership mean that ridge land tends to be publicly owned, whereas valley land tends to be in private ownership. This can lead to problems of accessing the ridge land where the wind resource may be strongest, through multiple private ownerships in the valley.

5.1.1. Land Classification Effects

Aside from the energy resource – biomass, wind speed, insolation, and so forth – renewable power plants have specific needs. Access is essential in all cases, of course. The underlying geology will be important for larger plant, and orientation will be important for solar PV plants. Aside from these fundamentals, land may be deemed unusable for RE owing to competing, sometimes historical, uses.

Following Independence, all land in India was classified under one of the following rubrics, and this classification persists to the present day[26]:

1. Forests;
2. Area under non-agricultural uses;
3. Barren and uncultivable land;
4. Permanent pastures and other grazing land;
5. Land under miscellaneous tree crops;
6. Cultivable waste land;
7. Fallow land other than currently fallow land;
8. Currently fallow land; and
9. Net area sown.

At first glance, some of these rubrics appear unsuitable for RE development. However, in many cases renewable power plants can coexist with other land uses, such as cropping and livestock.

In addition, stakeholders reported that land may not actually resemble its classification. Most commonly, forested land, which accounts for 23 percent of classified land may not always be forested, but instead low scrub, for example, or even barren. Although classification is needed in order to protect valuable ecology, for example, it may be necessary to update the classification of land in some areas to facilitate deployment of renewables.

Aside from forestry, possible land-use clashes between intended RE use and existing usages include national parks, agriculture, and mineral extraction. Conflicts may be exacerbated by an absence of due process governing permitting, acquisitions, and environmental impact, for example, whereas local populations and developers come into conflict over different issues in different locations.

Examples of such conflicts are evident in the northern part of the Western Ghats in Maharashtra, where the development of a wind project is reported to have had negative impacts on the ecology of the area. This has resulted from the construction of access roads and the consequent heavy erosion and landslides during and after the monsoon. In this example, no EIA was undertaken and the developer is reported to have ignored forest classification and made no effort to reinstate hillsides.[27]

5.1.2. Land Acquisition

Setting aside the issue of cost for the moment, simply the ability to acquire land is critical to the success of a project. Non-availability of land is a major cause of delays to infrastructure projects, and these delays can add significantly to the project cost to be ultimately borne by electricity consumers.

Stakeholders involved in the road-mapping process showed a marked preference for the straightforward purchase of private land. Although this is relatively straightforward, relative to securing development rights in publicly owned land, it is not without its difficulties.

One of these has been limited regulation and oversight, resulting in potentially unfair treatment of the selling landowner(s). Like the power sector, land in India – with the important exception of agricultural land – is a concurrent issue. Forested land, for example, is subject to both central and state oversight, and it appears that some important issues relating to the availability of land, and fair compensation for it, are falling between these two stools. For example, there is evidence that local and tribal populations in forests are being insufficiently compensated for the loss of their land, which may be privately owned or subject to public regulation.

Wind and solar power projects are subject to local laws and must get approval from the rural local bodies. Panchayati Raj Institutions (PRI) – rural local governance bodies – are empowered to make decisions on rural clearances for development of projects. Under the Panchayati Act, the PRIs (or Gram Sabha at the village level) must be consulted by the project developer prior to

26 According to the Data Book 2011 of the Indian Agricultural Statistics Research Institute, classified land makes up 93 percent of India's total land area.

27 CSE, 2013.

establishing a project in their jurisdiction. This is intended to give villagers/locals the right to raise their concerns.

The CSE reports, for example, that the rights of tribal communities living in protected land are being overlooked, including in forested areas. The rights of tribal communities living in forest areas are protected under the Recognition of Forest Rights Act of 2006, which recognises the rights of tribal populations over forests for their livelihood. This covers some 1.8 million hectares of land, much of which lies in key development states, including Andhra Pradesh, Madhya Pradesh, and Maharashtra.

However, in 2013, a circular excluded linear projects such as the roads and transmission lines needed for any power project passing through such lands from the need for approval.[28] For example, a national platform of tribal and forest dwellers' organisations in ten states has stated that the Recognition of Forest Rights Act of 2006 has been routinely ignored by the Forest Advisory Committee when recommending forest clearances.

There have been allegations against specific developers that they have acquired and otherwise encroached upon tribal land in Kerala to lay substantial roads to transport blades and other components to the project site, without compensation to tribal communities living in the vicinity and paying taxes for that privilege, despite that the Kerala Restriction on Transfer by and Restoration of Lands to Scheduled Tribes Act, 1999, prohibits this.

Stakeholders highlighted the need for state governments, which take precedence over central government in land-use issues, to shore up the rights of local populations, while also clarifying what land is available for development, and the circumstances under which this is possible.

5.1.3. Land Costs

The cost of land may range from 2 percent to more than 50 percent of total project costs for infrastructure projects generally. However, the CERC requires that for power projects, the land component should comprise no more than three percent of CAPEX, which is thought to be a way of ensuring prices remain competitive and that land cost does not dominate CAPEX. But this can be restrictive in states where land prices are high. For example, the cost of barren land – the only land deemed suitable in Haryana for solar PV projects – is reportedly five times the cost of equivalent land in Rajasthan.

The Land Acquisition Act (LAA) that came into force at the beginning of 2014 (replacing the previous LAA of 1894) aims to reinforce the rights of (smaller) landowners and local populations, whose land may be brought into public use for purposes of industrialisation, development of essential infrastructural facilities, and urbanisation. The LAA has significant repercussions for RE power plant developers, particularly in terms of the cost of land.

The law requires a social impact study to be made prior to land transactions in order to ensure minimised disturbance to the owners of the land and other affected families; and it includes a focus on the adequacy of compensation to land owners, as well as rehabilitation and resettlement benefits.

Stakeholders pointed out that the LAA has tried to solve the problem of fair valuation of land that is to be purchased for infrastructure projects. It requires that compensation for land in rural and urban areas should amount to four times and two times the market rate, respectively. Stakeholders felt that the reasons for these multiples are unclear, but this may reflect the difficulty of valuing non-economic value associated with land that may have pertained to a family or community for many generations.

Stakeholders also pointed out that the LAA requires that 80 percent of landowners impacted by a given development give their approval before a sale can be made. Such issues may slow development and add to costs.

A fair price for land is of course essential, as is the availability of land in the timeframe of present RE deployment targets. It may be that a national land register maintained by an empowered regulator, in close collaboration with states' governments, could help resolve such complications.

Even if private lands are available, and at an acceptable price, regulation requires that if it is classified as agricultural land, an application must be made to convert it to non-agricultural status, which stakeholders reported to be a time-consuming process. In Karnataka, for example, not only may agricultural land not be bought by a person/entity with revenue in excess of INR 200,000 pa, but the process of conversion to non-agricultural use takes two years.

5.1.4. Revenue Lands

Different states have different practises. For example, in Bihar, developers of solar PV are unable to access public lands, and have no assurance that it will be available in future. In consequence, land must be procured from private parties. Given the relatively high population density in Bihar, this has significant cost implications.

28 CSE, 2013.

Madhya Pradesh has a large barren land area. The state government acquires land and provides user-rights to developers for a 25-year period (i.e., aligned with RE project lifetimes). If there are competing parties, the land is allocated to projects with the greater electricity production potential.

Madhya Pradesh also has a high potential for development on tribal lands. The state government has developed a policy, expected to be approved soon, that will give user-rights to wind developers on a mutual consent basis, under which the developer pays for the use of the land and provides 20 days of Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA) wages per month to the owner, who will also be allowed to use adjacent, vacant land.

Public land can potentially be "allotted" to developers, which is not possible with private land, of course. This offers an opportunity to embrace a "zoning" approach to development of wind power, with the potential benefits highlighted in Chapter 7. Zoning may be an efficient way of ensuring that RE plants are built where the resource is best, as well as of ensuring that sufficient land is made available. Zoning can also factor in the location of grid assets, the third fundamental planning factor for siting a power plant.

So far a zoned approach has been used only for the Gujarat Solar Park programme, with some success. Zoning was strongly supported by many stakeholders. Moreover, these highlighted that a competitive bidding process can be used. This would aid (electricity) price discovery, as well as serving to level the playing field between developers with and without "banked" land assets.

Stakeholders also highlighted that allocation processes should have three key characteristics:

1. Fairness to all stakeholders;
2. Reasonable duration, sufficient for a 25-year RE project lifespan, and taking into account cost efficiencies of repowering projects in due course; and
3. Processes that are sufficiently progressive to allow for the specificities of RE development.

5.1.5. Land-banking

During the course of stakeholder discussions, it was heard many times that certain developers, including those who have been active for longer and involved in manufacturing of turbines also, have acquired the ownership of, or user-rights to, many high-resource sites. Although this in and of itself may just show forward-thinking, it is also the case that often these sites are held undeveloped for long periods, delaying deployment of RE.

Land banking puts developers without land at a disadvantage to those who have already bought private land, who can bid in competitive tenders at a lower price than those for whom the land cost will represent upfront CAPEX. Alternatively, it may drive off competition, thus providing an opportunity for inflated bids.

In Karnataka, for example, much of the revenue land has been banked, and may be held without development for as long as seven or eight years. Furthermore, the developers may have acquired the user-rights for only a few MW, whereas the allotted area could support very much more than that. One senior stakeholder suggested that this might be 100 times the amount.

Policy changes in 2012 have eased this problem, but apply only to new allotments. As a result, much land remains locked up. It was suggested that these developers should build on these sites by a specified date or have their user-rights revoked. This would be similar to an approach recently announced in the United Kingdom with regard to housing development.

The new policy allows for a facilitation letter of 12 months' duration, with the opportunity to extend for six months. Referred to as "buying a footprint," it was stated – importantly – that banks would finance on this basis.

5.2. Environmental Aspects

Potential development sites may be in remote and environmentally sensitive areas, where few data exist as to sensitive ecosystems, and the likely impact on them of development. Wind power projects are not covered under the 2006 Environmental Impact Assessment (EIA) notification and are therefore exempt from that requirement to perform an EIA; yet 45 percent of installed wind development is in environmentally sensitive forest areas.

State Pollution Control Boards are the relevant authority in the granting of Consent to Establish and Consent to Operate permits to industrial units, including renewable power plants. The Consent to Operate permit is usually provided for a period of five years and routinely extended if there are no complaints lodged.

Ministry of Environment and Forests guidelines exist, however, for example, under the Forestry Act. These provide guidelines for the award of clearances for wind power projects, but the CSE reports that these are routinely bypassed with only superficial attendance to their requirements.

On the other hand, there is the position of the developer, who is faced with regulations that vary from state to state, and the knowledge that if regulations can be bypassed there is every likelihood that the competition will do so and thus be able to complete a project faster and at less cost than if it had complied.

The obligation to perform an EIA is likely to arise as deployment of RE accelerates. The impact of several hundred GW of new capacity needs to be minimised. Stakeholders also pointed out that soon companies in this sector will have to comply with Corporate Social Responsibility regulations under the recent Companies Act enacted in August 2013.

The zoning approach highlighted above for efficient allocation of land would also be of benefit from both environmental and commercial perspectives. Stakeholders pointed out that a strategic approach to environmental assessment over entire zones could be superior to a solely project-based EIA process, whereas the subsequent local EIA would be less onerous for project developers.

5.3. Grid Connection

Connection is a critical milestone in the development schedule. Reliable knowledge of the lead-time to achieve it is essential. Developers have reported that connection to the Interstate Transmission System (ISTS) could take three years to complete, whereas intrastate lead-times are closer to one year, although processes and schedules differ from state to state. This has implications for speed of RE deployment and potentially increased finance risk leading to higher costs.

The Green Corridors Report[29] appears to corroborate this lead-time issue:

> *"…development of connectivity transmission system, establishment of RE Pooling station as well as transmission system strengthening in STU network for RE absorption, takes considerable time which is significantly more than the generation gestation period. In addition, transmission system strengthening works at ISTS level, being developed through competitive tariff based bidding, also requires about 3-4 years time. In view of the above, efforts should be made for faster implementation of the associated transmission works for RE, avoiding generation bottleneck."*

The 2010 Grid Code lays out nondiscriminatory connection arrangements that apply to power plants connecting to the ISTS. It does not specify how the cost burden of such a connection is allocated, which is reportedly the responsibility of the developer.

The Electricity Act of 2003 stipulates that, intrastate, the respective state transmission utility (STU) or the Discom is responsible and is to pay for the reinforcement of the grid infrastructure to manage the evacuation of electricity from renewable power plants. It is also responsible for extending the grid up to the wind farm pooling station. However, given the financial health of Discoms and some STUs, this may not be the case in practise, with states adopting a number of ad hoc arrangements for grid connection).[30]

Experiences in Gujarat have revealed an alternative approach to increasing certainty as to connection lead-time. A large number of solar PV power plants simultaneously under development represented too great a burden on the resources of the STU, which, although willing to provide the connections required, would have needed several years to complete them all. The solution arrived at was for the STU to provide all the necessary equipment for connection, while the developers provided the manpower, as well as the finances (which would in any case have been theirs to cover). The STU and developers alike felt that this was an effective and mutually beneficial arrangement.

The Gujarat Solar Park, in contrast, did not need to resort to this fallback arrangement. A zoning approach can help to provide connection lead-time certainty, if grid owners (STU/Discoms) receive a clear signal as to the number and location of lines, well in advance of the construction of the power plants.

The CERC has regulated that renewable power plants greater than 50 MW may connect to the ISTS, but no plant has yet taken advantage of the benefits this may afford in terms of reduced congestion at the higher-voltage grid.

This may be because development and sale frameworks are local. It may also be because, under the Point of Connection transmission charging system (on a MW basis), charges to wind projects may be too onerous, as their capacity factors are lower than conventional plants. Unlike present day solar, wind has no free or special dispensation on transmission charges. Furthermore, PGCIL substations are often far from wind farms, resulting in high connection costs to the developer. Although CERC regulations require PGCIL to plan and build such interconnections, this is opposed by PGCIL.

29 PGCIL 2012.

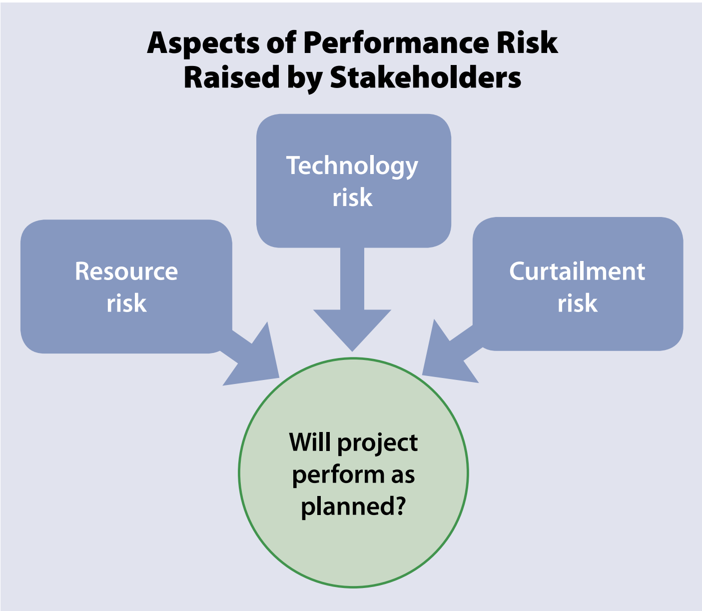
30 GWEC, 2012.

5.4. Performance Risk

Risk to the investor does not cease with the successful commissioning of the power plant. There are a number of performance risks, which will need to be managed ahead, during the project-planning phase. Performance is simple to measure: Does the power plant sell the projected amount of electricity?

This will be a function of a number of parameters, including (1) that the energy resource will be in reality as indicated in the resource assessment, (2) that the technology will perform as expected, and (3) that the electricity produced will not be curtailed. The first two aspects, at least in theory, are under the complete control of the power plant developer. The third risk element, curtailment, is much harder to predict or monetise.

Figure 16



Investors require guarantees that output targets will be met with a certain probability. In the planning and financing stage of a wind farm project, a risk assessment is required, quantifying all risks related to the wind farm financing. This technical due diligence results in a prediction of average annual energy production.

This prediction is known as the P50, meaning that probability of reaching a higher or lower annual energy production is 50:50. P75 and P90 represent a probability of meeting annual energy production of 75 percent and 90 percent, respectively. Both the latter values are widely used by banks and investors as a base in their financing decisions, the latter representing more stringent requirements.

5.4.1. Resource Risk

The longer the period over which resource data are gathered, the more likely it is that it will cover and account for periods of unusual weather, and the more likely it will be therefore to provide an accurate picture of average annual output, as well as seasonal and potentially diurnal variations in that output.

Aside from the value this represents in terms of integrating that electricity, and therefore of reducing the likelihood of curtailment, a deep knowledge of the resource represents certainty of revenue to the investor.

Investment grade resource data represent a major stepping-stone to streamlined and accelerated RE deployment. Meso-scale resource data, using cells of two to ten kilometers squared, if of sufficient quality, provide a valuable indication of where the best sites are located.

Publicly available meso-scale wind maps of India are not yet available, but even these would not provide sufficiently precise data on the wind resource. They may, however, be useful in establishing where to site wind measurement masts bearing anemometers to physically measure wind speed and direction, among other factors. Two or three years of data are usually considered necessary to give a clear idea of the resource.

Resource risk is common to all development markets for wind power. In every country there will be areas of complex terrain that are more difficult to model, even with real data, than others. Stakeholders did not raise India-specific concerns.

Stakeholders did, however, highlight the following potential roles for the GOI and/or state governments, possibly in collaboration with industry groupings:

- In making resource data publicly available, as it is collected;
- In carrying out meso-scale wind resource mapping of areas with a high wind resource revealed through macro-scale mapping (approximately 50- to 200-km cells);
- In financing the erection of anemometry masts for wind measurements in probable deployment areas; and
- In leading the assessment of offshore wind resources.

These roles would fit well with the overall picture emerging in the roadmap process of the key government role as provider of investor security for private investment in renewable power plants, rather than leading financing itself. For example, greater and more accurate data sets made available to the industry as a whole would facilitate the planning of larger groups of power plants, representing a more attractive proposition to major investors.

5.4.2. Technology Risk

Technology risk represents the probability that the technology deployed – for example, the solar PV module, the wind turbine, the biogas digester – will not perform as desired. It can be quantified in terms of expected availability to operate. Availability represents the amount of time a wind turbine, for example, is expected to be available for operation (i.e., not presently stopped for maintenance or fault).

The international experience shows the availability of modern wind turbines to be approximately 98 percent, whereas that of solar PV plants approaches 100 percent. Most thermal power plants have availabilities of 70 to 90 percent, the lower range being associated with older plants with longer downtime for maintenance.

Some stakeholders in the finance sector revealed considerable mistrust of RE technology, which they perceive to be less mature and less reliable than conventional technologies. Examples include wind turbine rotors and solar PV module durability in extreme heat.

Condition monitoring and preventive action-based approaches have addressed many of these issues elsewhere, and are now being tried in India. For example, there have been press reports of collaboration between IBM and Bharat Light and Power in such initiatives.[31]

Serious failures do occur. The international experience reveals common weak spots in wind power technology to be gearbox failure and blade loss. Stakeholders suggested that a database containing anonymous data of failure rates and causes of failure would be of value to the industry as a whole in the mitigation of technology risk and the reassurance of investors.

5.4.3. Curtailment Risk

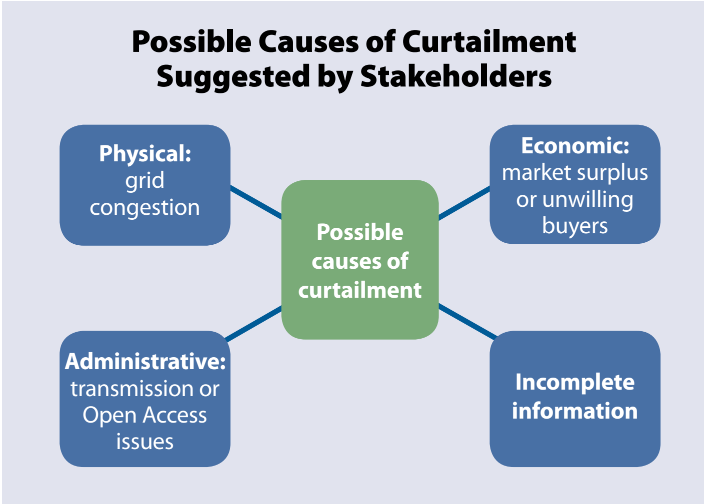
The risk of curtailment is the risk that electricity, which could otherwise be generated, will not be. This will be for one of two reasons: (1) that the grid into which it would feed is congested, and cannot carry any more electricity, or (2) that there is no buyer for the electricity.

Curtailment per se is not an evil. A small percentage of curtailment, occurring during the windiest hours of the year, may be cheaper than the cost of a line that can carry every last unit of output into the grid. But this calculation will be worked into the calculation of project cash flows. However, above a certain level, curtailment can seriously affect project revenues. For example, plant operators in Tamil Nadu, with the highest share of wind energy in the country, report significant curtailment, which has resulted in a drop-off in investment in new plants in the state.

Different sets of stakeholders asserted that congestion is occurring at different levels, some locally to the power plant pooling station, others that congestion was a problem in the ISTS (Figure 17).

Interestingly, stakeholders were often confused or unclear as to the reason for curtailment: whether physical, relating to the physical congestion of a line to carry electricity; administrative, relating to rights to use a line; or economic, relating to a surplus in the market. Although India has a peak electricity deficit, there are times – for example, at night, when wind output is up and demand down – when there is a local surplus. Although RE in theory has priority access to the grid in such situations, in reality it may not be possible or economic to back down conventional power plants to the extent that all the wind energy can be accepted, so it is the wind plant that is curtailed.

Figure 17



This poses the question why the electricity could not be sold further afield, where there may be demand. This again may be because the ISTS is congested, or it may be that there are market reasons why these power plants may not sell their electricity further afield. For example, they may not be able to achieve an OA contract with buyers outside the state owing to administrative complications or cost (see Chapter 6).

31 See, for example: http://www.bloomberg.com/news/2013-11-19/bharat-light-partners-ibm-to-boost-india-wind-farm-output.html.

There is a total absence of transparency as to curtailment volumes in India. Utilities buying the electricity do not wish to reveal their data, nor do those selling it. However, until data are available, the extent of the problem will remain unclear, and the causes of it likewise. There is an urgent need for analysis of the issue to identify where congestion is occurring.

It is commonly said, for example, that the ISTS is seriously congested, but actual data are not available, and at least one set of stakeholders pointed out that this may not be the case. If so, this will have major implications for the validity of such studies as the Green Corridor Report, which is predicated on an existing and urgent need for enhancing interstate transmission.

5.5. Summary

The development and operational phases of a project both carry considerable risk. Reducing these risks, and making the level of risk more certain, will increase investor appetite.

Overall, there is a need to streamline, accelerate, and standardise the acquisition of permits, clearances, and other administrative hurdles that the developer must cross. These relate particularly to land acquisition and environmental permitting. Although it is vital that social and environmental values are upheld, excessively long processes will jeopardise the country's ability to accelerate the deployment of renewable power plants and exit its peak power deficit situation.

Development in afforested areas is a concurrent issue; agricultural land is a state issue. Both are seen as key development areas, alongside barren and other land classifications. Faster, more sensitive development in both land types could be made possible with a standardised procedure for acquiring sites and the necessary clearances for projects of a given size. Such an approach might be taken to both private and public land.

Renewable power plants compete with a number of other land-uses. An integrated mapping approach might be the right approach to managing trade-offs among such vital activities as agriculture, forestry, ecology protection, mineral extraction, power production, and areas or urbanisation.

A layered approach to mapping could also factor in the location of the power grid and renewable energy resources. This could then be made available publicly, and provisions made to ensure that within identified areas, every priority would be given to enabling a conducive investment environment and strategic environmental assessment.

Such an approach would help to manage resource risk, as well as the risk for curtailment of power plants resulting from inadequate grid infrastructure. This ties in closely with the zoning approach discussed in more detail in Chapter 7.

It is essential, however, that data be acquired and understanding built up of exactly where and why congestion in the grid is occurring and what may be done to alleviate it.

6. Buying Renewable Electricity

The installation of new renewable power plants is only part of a successful strategy. Willing buyers of the electricity they generate must be in place when they are ready to begin operation. And investors will not invest in such assets if electricity off-take is not satisfactorily secure.

The design of an electricity market greatly influences the degree of risk to investors in both power plants and transmission systems. The greater the certainty that the electricity generated by a new asset will find a buyer, the more certain are project cash-flows, and the more attractive such projects are to investors. This is discussed in more detail in Chapter 4.

Four routes to market exist for Indian electricity, although as this chapter will explore, not all are yet navigable for renewables.

Electricity may be:

1. Sold to a Discom through a regulated, long-term PPA;
2. Sold directly to a consumer through an unregulated OA contract on various timescales;
3. Sold in the short-term market, either "over-the-counter" (directly between two parties) or via one of the two national power exchanges; or
4. Both generated and consumed by the same party, known as "captive power."[32]

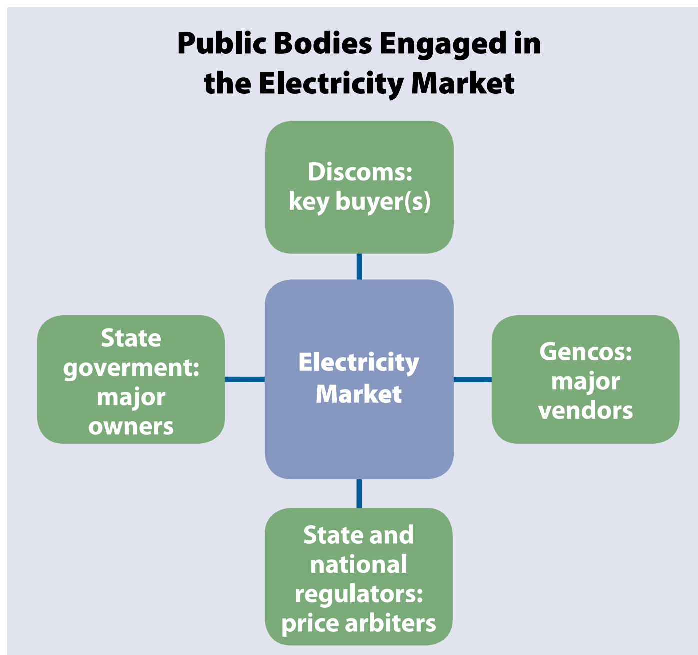
Discoms are by far the largest purchaser of electricity, including that from renewable energy sources (RES). However, as many stakeholders pointed out, Discoms are often hard-pressed, both in terms of financial liquidity and resources generally, and may not be able to fulfill this role reliably.

RES are not evenly spread about the country. The consequent importance of interstate trade of electricity arose often therefore in discussions with stakeholders. Electricity buyers in RES-poor states may be relatively less willing to purchase Renewable Electricity Certificates (RECs) than actual (renewable) electricity. RECs are perceived often to be a secondary priority.

Meanwhile, Discoms in RES-rich states indicated that they would support additional RE deployment (including for interstate sale) only if they are assured of sufficient willing buyers, and if the impact on their grid of additional RE capacity, particularly in terms of system balancing, is addressed.

The role of institutions (Figure 18) at the centre and in the states, both executive and regulatory, will be critical in enabling the interstate trade of electricity. This includes the Discoms, publicly owned Gencos, the state government, and the SERC.

Figure 18



6.1. Power Sector Asset Ownership

Until the unbundling of vertically integrated utilities into distinct transmission, generation, and distribution arms (within a common, state-owned, holding company), and the establishment of independent regulators in the late 1990s and

32 Captive power plant owners may be able to sell a proportion of the electricity they generate.

early 2000s, the power sector was publicly owned and largely operated by the states through State Electricity Boards.

These State Electricity Boards owned the majority of power plants, whereas the remainder was owned by the central government. However, over the last 20 years, private ownership has grown and now accounts for almost a third of installed capacity. Nevertheless, the central government continues to own the fuel that feeds – at least partially – those power plants, as well as the means to move it about the country by rail, from the mine to the power station.

State governments continue to own and operate the Discoms, the intrastate transmission companies (Transco), and state LDCs, whereas the central government owns and operates the interstate Transcos and national/regional LDCs.

Almost all RE power plants have been built and are owned privately. It is generally expected that private ownership of the power sector will continue.

The private sector is increasingly involved in the import of coal and natural gas, but centrally owned Coal India is the main importer. Typically imports are more expensive than the domestic coal with which it is pooled to temper the final coal price to generators.

Captive power plants are owned by large consumers with sufficiently large electricity requirements to make it economical to produce their own. There are two types: where the consumer has the power plant installed on its premises (behind-the-meter), and where the consumer is located separately from the power plant.

6.2. Trading

Power procurement is mainly done through long-term PPAs between electricity buyers and sellers, whereas a small proportion of wholesale electricity is traded short-term.

PPAs may be signed over various time frames: long-term (years to decades), mid-term (months to years), and short-term (days to months). Most commonly, the seller is a publicly owned Genco (either centrally or at state level), or an IPP. In addition, wholesale market brokers sell a small amount of electricity.

The buy-side of the PPA is usually a Discom, but also large commercial and industrial consumers buying through OA arrangements. The price of a PPA is regulated by the SERC, except under the OA model. Payments are made directly (between buyers and sellers) with no intermediary. In case of breach of contract, the only recourse is to initiate a judicial proceeding, which may be a long, drawn-out process. This is significant given the poor financial health of many Discoms.

Electricity can also be bought and sold on the day-ahead through independent brokers, and through the two recently established power exchanges. In the latter case, the exchange serves as the financial intermediary, and, in sharp contrast with bilateral transactions, the associated payment risk is insignificant.

6.3. Unit Commitment Aspects

Which power plants will generate and when is decided through a process known as unit commitment (UC), which is updated on a timescale of one to two weeks ahead. The process varies from state to state, and it is likely that changes in the resulting "dispatch stack" reflect the availability of power plants rather than the cost of procurement, as these are fixed in the PPA. In other words, UC takes economic aspects into account only to a certain extent and is not in any sense dynamic.

The fine-tuning of UC, according to short-run marginal costs of production (Economic Dispatch), does not appear to be done anywhere in the country. Rather, Discoms will ask LDCs to dispatch generation up to the price-level that the Discom can afford, financially and politically.

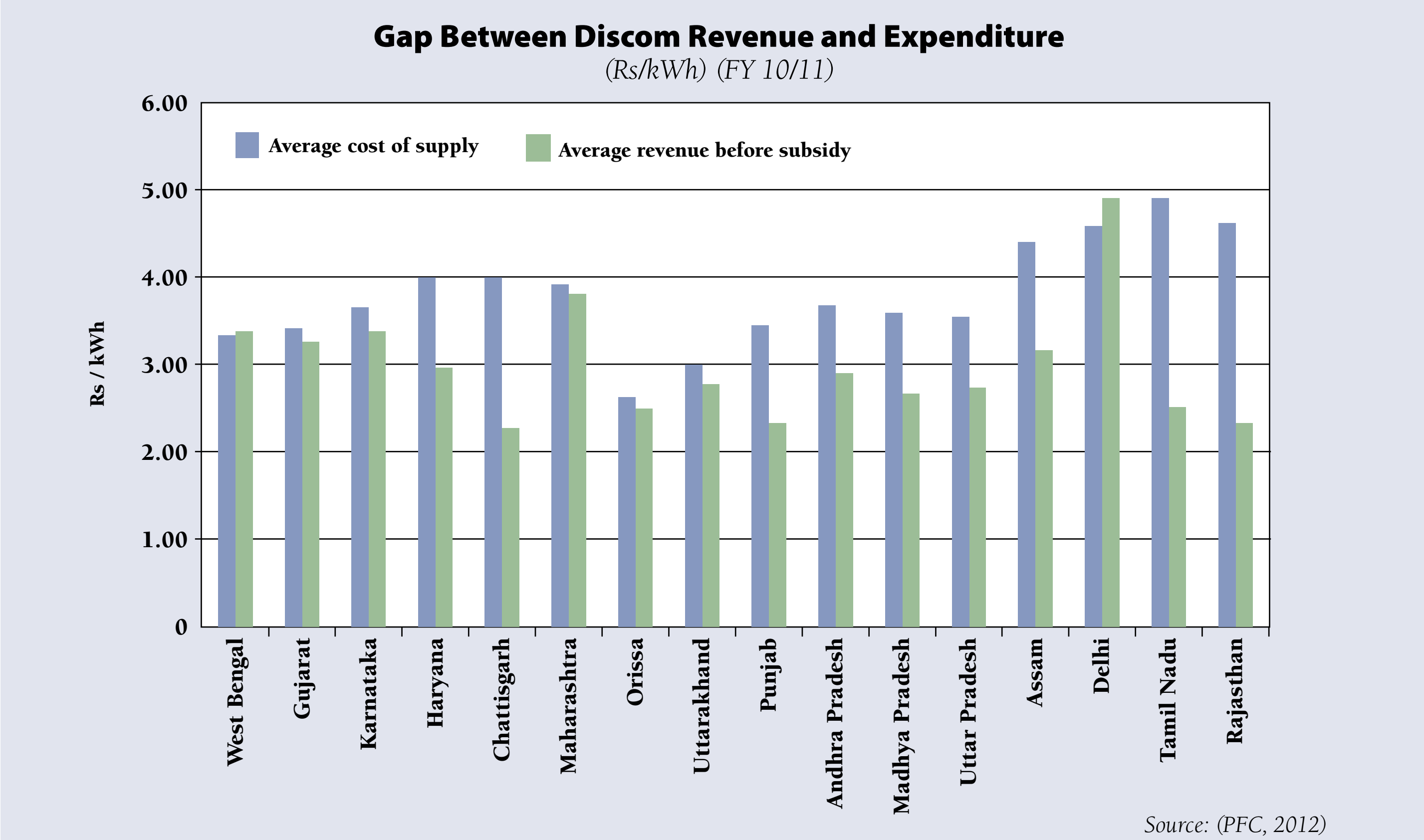
6.4. Discoms: the Key Buyers

Stakeholders revealed that power sector investments are seen often to have junk status. The primary reason for this is the financial ill health of Discoms. As the latter are the main buyers – sometimes the sole buyers – of electricity, this represents a major disincentive to potential investors. In other words, if accelerated growth of RE and conventional generation is required, one of the priorities is to rehabilitate the Discoms.

Until Discoms are financially stable, their ability to provide the "collateral" – the risk control needed by private investors – will be at best gravely limited. This problem, amounting to insolvency in some cases, results from a gap between the costs incurred by Discoms, mainly in the purchase of electricity, and their revenues from the sale of that electricity and state government subsidy. This gap is illustrated for selected states in Figure 19.

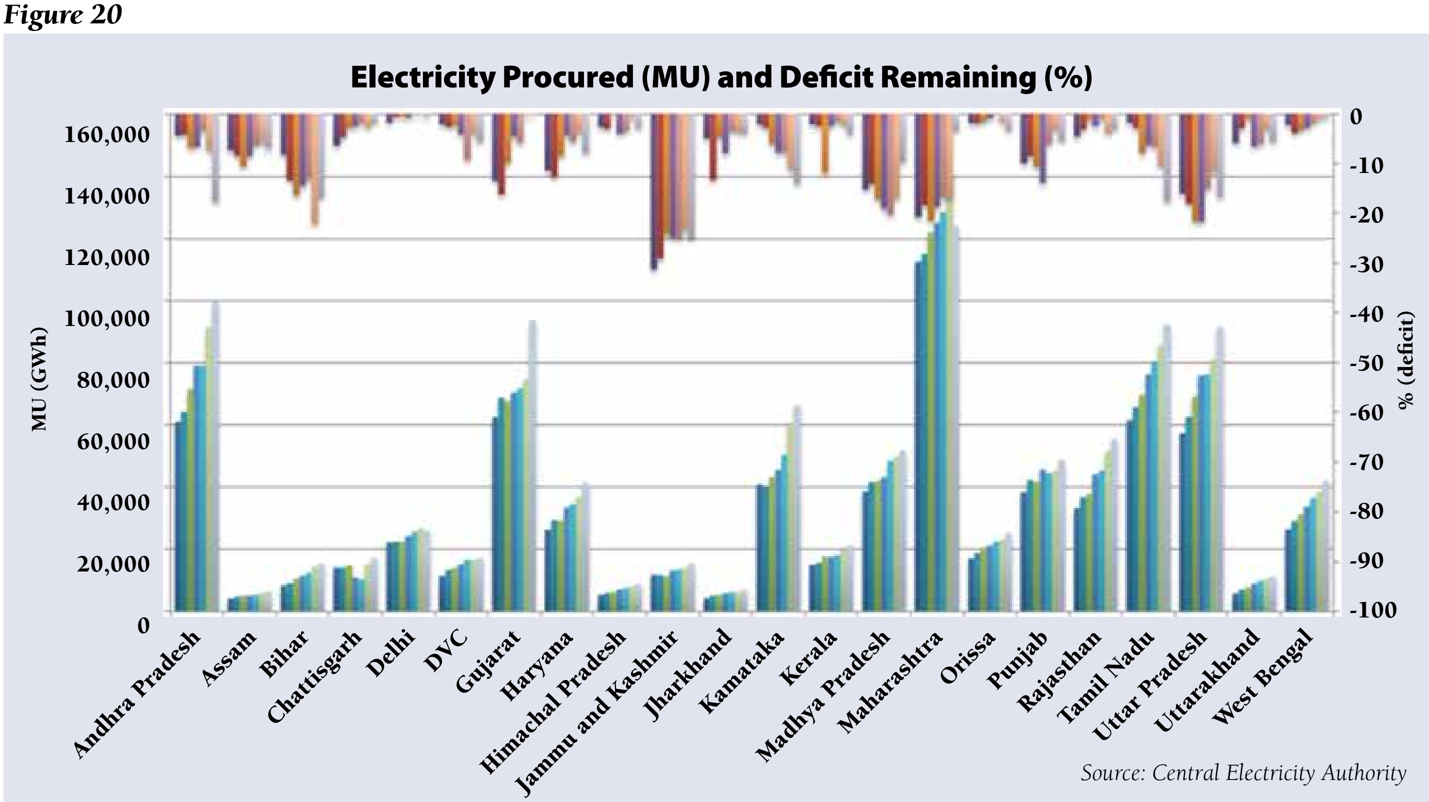
Discoms differ dramatically from state to state in many ways, including size, the relative proportions of consumer segments, and tariffs charged. There may be only one, or several. Figure 20 illustrates their relative size in the lower part of the figure, in millions of units procured (GWh), and

Figure 19



Source: (PFC, 2012)

Figure 20

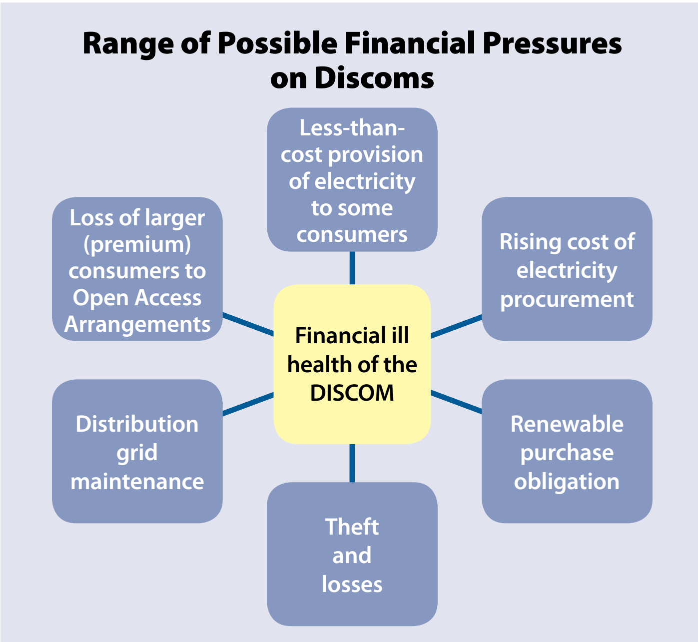


Source: Central Electricity Authority

the fact that all are growing steeply.

In theory, Discoms are required by the Universal Service Obligation to provide electricity to all their consumers. But until such a time as they are able to afford to do so, and when the Universal Service Obligation is enforced, they will instead continue to shed demand (load-shedding) at the level at which procuring additional electricity becomes financially uncomfortable.

Figure 21



While load-shedding remains an option, the alternative of purchasing more expensive electricity from existing renewable or gas-fired plants, for example, will remain on the shelf. The same problem undermines deployment of new capacity, renewable or otherwise.

The upper part of Figure 20 shows the deficit remaining between electricity procured and demand, as a percentage, for the financial years 2006–2007 to 2012–2013.

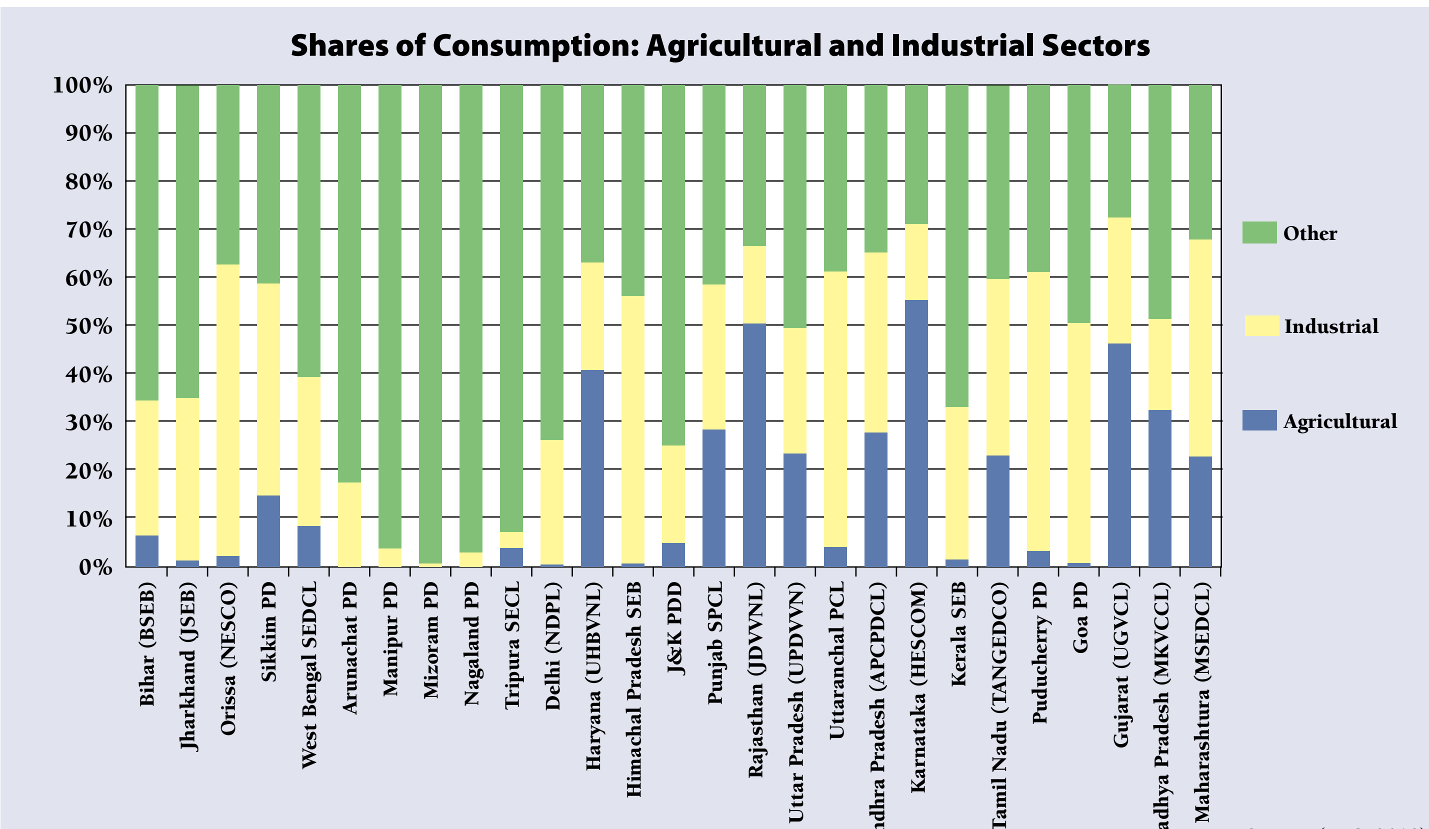
A number of interconnected and conflicting pressures on the Discom cause this revenue gap, as highlighted in Figure 21. Chief among these is the requirement on them to provide electricity at very low cost (usually less than the cost of procuring it) to agricultural consumers.

6.4.1. Subsidised Agricultural Consumption

Historically, the electricity price charged to agricultural consumers has been very low, or zero. This is intended to support socioeconomic objectives of government, such as food security and affordability, and rural economic development (e.g., income growth and job creation).

But, insofar as Discoms are often concerned, and from

Figure 22



Source: (PFC, 2012)

a purely financial perspective, this requirement represents an enormous burden. In the large agricultural states, agricultural load amounts to a major portion of a Discom's consumer base, more than half of BESCOM's load in Karnataka, for example, as shown in Figure 22.

As stakeholders pointed out repeatedly, many agricultural consumers are not metered. Electricity theft routinely occurs. Attempts to increase the metering of this consumer segment have been highly problematic, with reports of metering equipment being sabotaged, possibly as consumers may infer that attempts to meter consumption, even if a zero-tariff applies, may lead eventually to the imposition of a tariff.

The supply of electricity to these consumers is sporadic, being when the cost is lowest. Thus, in a somewhat chicken-or-egg situation, farmers are not inclined to pay for what they may perceive to be a poor quality of service. Meanwhile the Discom is less inclined to provide a reliable service to consumers who pay so little for it.

Until the advent of SERCs, the provision of electricity was not regulated, and was simply provided by the state government-owned vertically integrated electric utility. Providing support for agriculture through no-/low-cost electricity was simply part of the state government's budget, a policy agenda not unlike public health, for example.

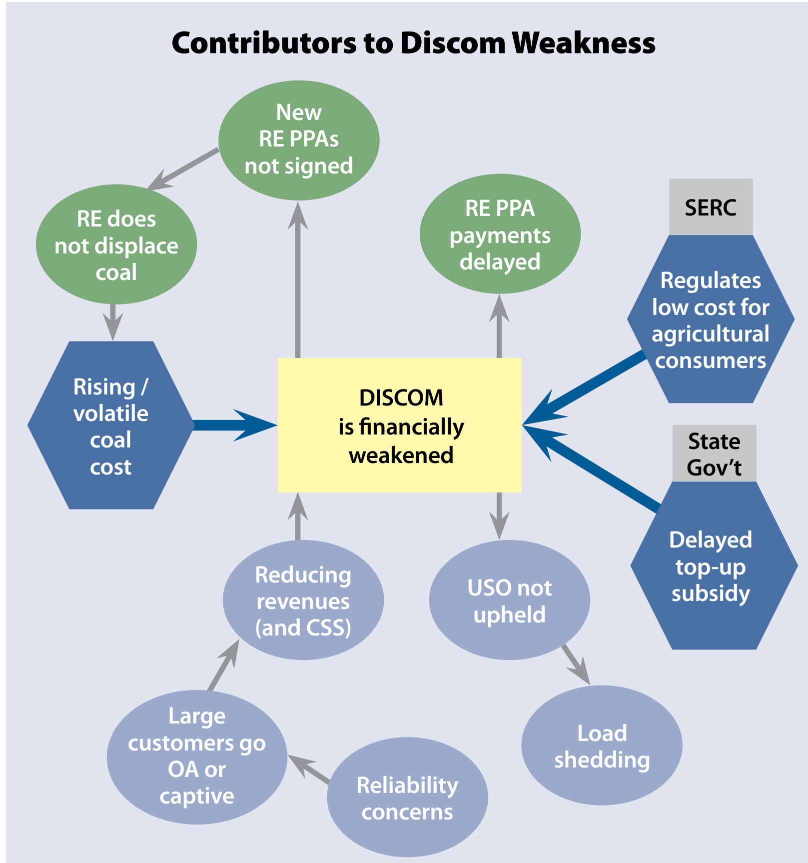
With the advent of independent regulators, and unbundling from direct state control, Discoms began to be run as independent companies with separate financial control, throwing the disparity between their expenditure and revenues into stark relief.

State governments are expected to cover the cost of this disparity. For example, the authors were informed that in Maharashtra, 12 to 13 GW of agricultural load is charged at Rs 0.8/kWh, whereas the cost of procuring that electricity to the Discom is Rs 2.4/kWh. This amounts to a difference of approximately Rs 1000 crores per annum.

In reality, however, this subsidy may be delayed substantially, and payment in any case is subject to the state government's own financial health. If the subsidy does not arrive, the deficit will simply remain on the Discom's balance sheet.

Thus there is a fundamental policy conundrum to be solved. It hinges on the mechanism through which the support for agriculture is to be provided. Should it be provided indirectly, through the Discom – as done today – or through alternative mechanisms, such as, for example, a direct financial transfer to the consumer.

Figure 23



Unless a long-term solution is established, the status quo of provision of electricity at less-than-cost will continue to be a major burden on Discoms. The most serious consequence of this, purely in terms of meeting the demand for electricity, is that insufficient investment is made in new generating capacity, including renewable capacity. Stakeholders consistently pointed out that this problem still has not been addressed successfully and conclusively in most parts of the country. This chain of cause and effect is highlighted in Figure 23.

Although not a focus of this paper, the price of coal is also a major factor. The price of imports, mainly from Indonesia, has increased considerably in recent years, while volatility is also an issue. This burden may fall on the shoulders of Discoms, following a recent CERC decision to allow the owners of power plants in Mundra, Gujarat, to pass on their rising coal costs to state buyers.

6.4.2. Political Pressures

Discoms are to provide electricity to different consumer categories at prices approved by the SERC. SERCs are quasi-judicial bodies that typically do not regulate prices on their own, but rather react to "rate cases" filed by Discoms, comments filed by other parties, and through regulatory proceedings.

Stakeholders have indicated that in some cases a SERC may also be subject to political pressures, from state government, to reduce tariffs for certain sets of consumers. At present the state government can intervene in pricing, citing "extraordinary circumstances." Thus a Discom may be required to price electricity in a manner that is politically expedient but economically unsustainable.

Similarly, stakeholders have drawn attention to the fact that reduced load-shedding of politically sensitive areas, or at politically sensitive times, may be required by political forces. Political interference of this kind in unbundled utility companies, which are expected to operate on commercial principles, remains a problem.

6.4.3. Erosion of Customer Base

Discoms, facing as basic a problem as ensuring short-term cash flow, are obliged to raise tariffs on larger/wealthier consumers (typically industrial and commercial, and including OA consumers), in effect cross-subsiding poorer consumers (Figure 24). This is known as the Cross Subsidy Surcharge (CSS), and the authors were informed that in Maharashtra alone, for example, this amounts to Rs 9000 crores.

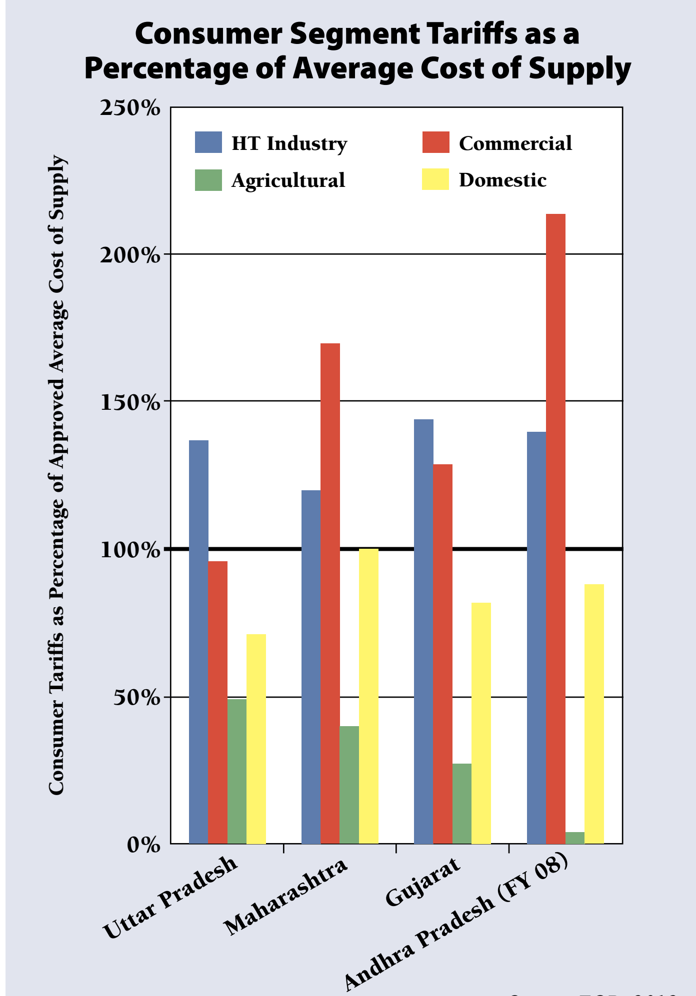
But rising tariffs may encourage those who can afford it to look for their electricity elsewhere than from the traditional Discoms. This includes mainly larger commercial and industrial consumers, who may choose to invest in their own captive power plants,[33] including distributed renewable options, or to take advantage of the OA mechanism to enter into PPAs directly with power plants, rather than pay rising tariffs to the Discom.

These large consumers make up the most valuable segment of demand to the Discom, in financial terms. Their departure reduces revenue further still, while reducing the options available to the Discom to halt what may become a cost spiral.

This is a key reason a Discom may be reluctant to allow large consumers to take advantage of the OA mechanism, even though it is the latter's right to do so, and even though they can oblige OA consumers to pay a cross-subsidy surcharge.

But Discoms have no recourse if large consumers choose to simply generate their own electricity behind the meter, an occurrence that is likely to increase with deployment of new renewables, which typically have smaller units sizes than conventional power plants.

Figure 24



Source: FOR, 2013

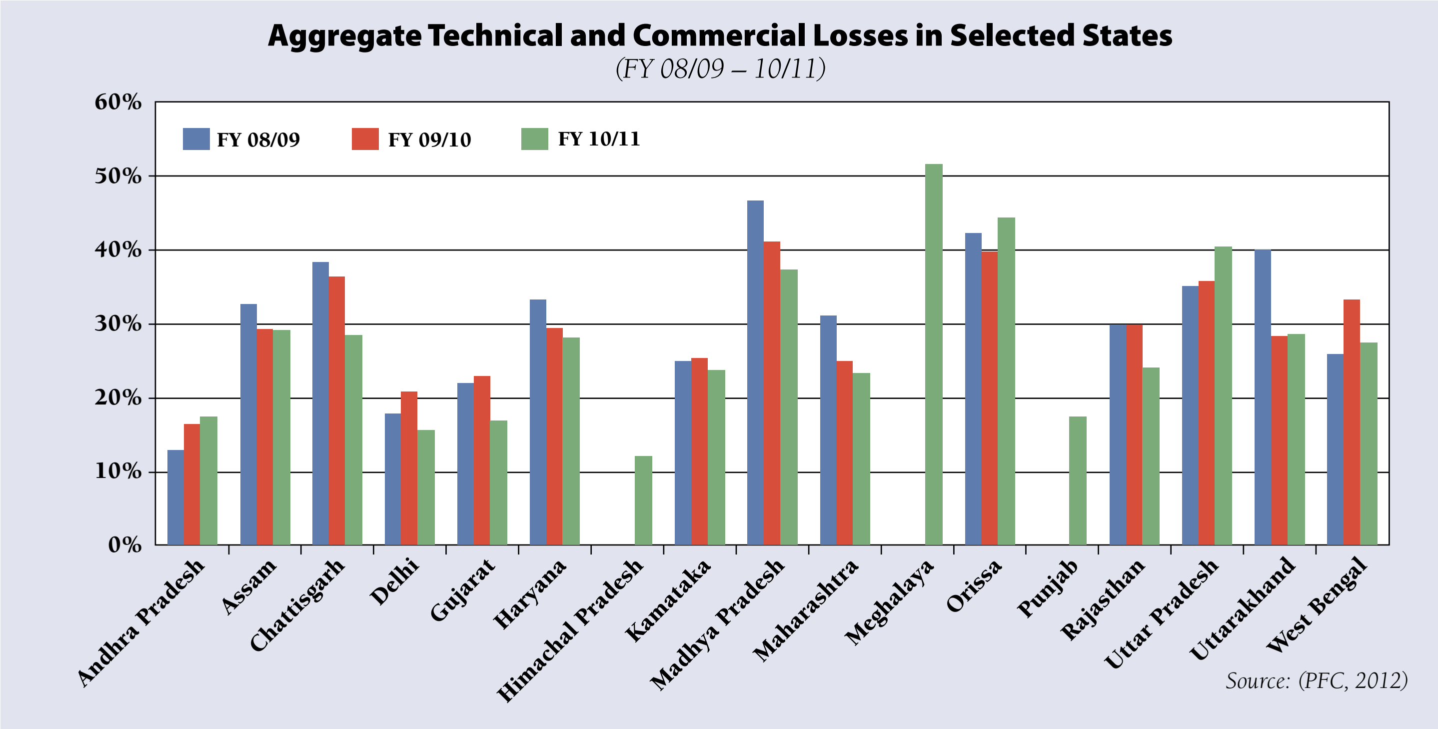
Finally, it is harder for Discoms to justify rising tariffs when Aggregate Technical and Commercial (AT&C) losses are commonly in the range of 20 to 40 percent (Figure 25, next page).

6.4.4. Easing the Burden

In the intervention by central government of 2001 to 2003, Discoms were assisted financially on the expectation that they would improve their performance. Fundamental problems as highlighted above were not fully addressed,

33 Owners of captive plants in Maharashtra, for example, need only to consume 51 percent of output of the plant. The remainder can be sold to other (often smaller) consumers also seeking an alternative to the Discom. This power sale attracts the CSS.

Figure 25

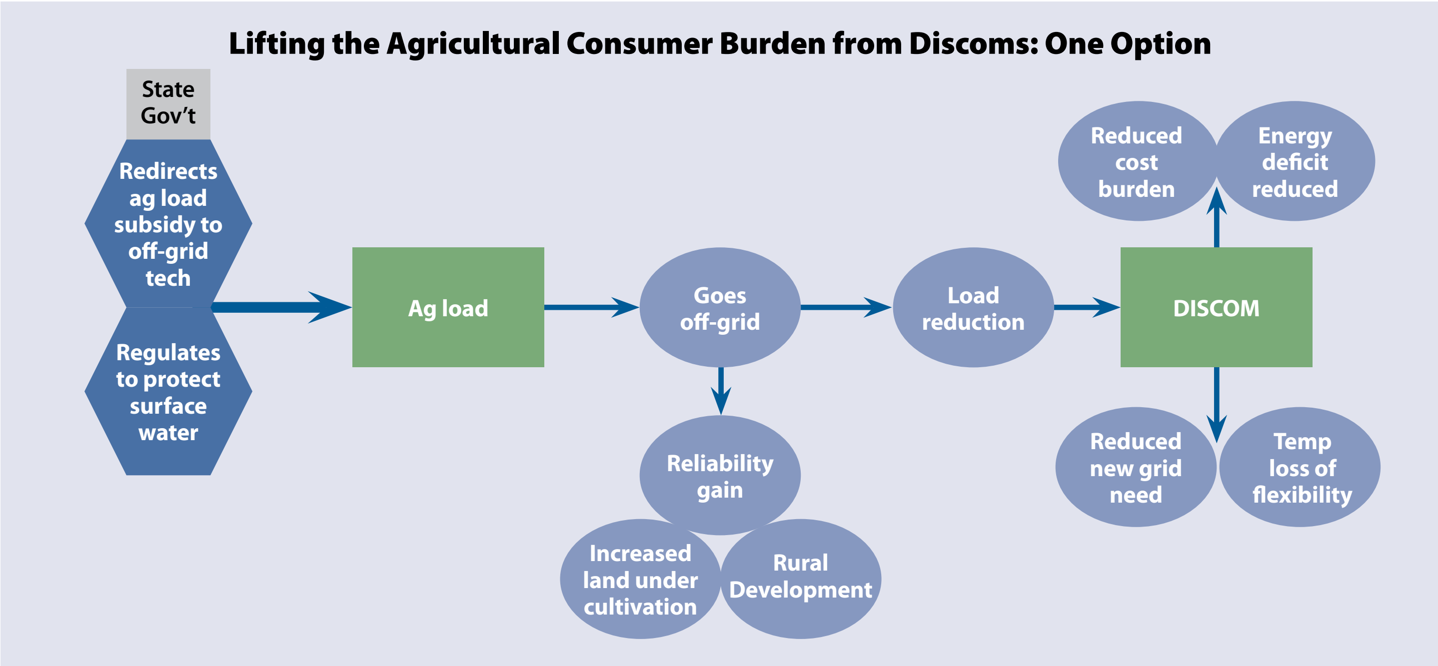


however. Indeed, a new round of measures to improve the financial standing of Discoms is now underway, following the recommendations of the Shunglu Committee in December 2011.

As discussed in Section 6.4.2, political pressure may be applied to Discoms to keep electricity prices at a level at which profitable commerce is impossible. Ensuring that the Discom is able to set tariffs at least to recover their costs, regardless of political and social considerations, may be an essential step toward stopping the rot.

This in turn raises the critical question of how the electricity needs of poorer consumers would be met under such a tariff regime. A number of stakeholders highlighted the benefit of off-grid energy solutions in this regard, suggest-

Figure 26



ing that, given the accessibility and relatively ubiquitous nature of RE resources compared to fossil resources, renewable energy may play a major role here.

The primary constituent of agricultural load in India is for water pumping. This is typically done using pumps of a few horsepower each, connected to the distribution feeder (low-voltage power line). An alternative might be to take this load off the grid and install solar-powered pumps, the technology for which is now mature after more than a decade of field-testing. Indeed, Karnataka is launching a solar pump scheme in March 2014, wherein 1000 to 2000 pumps will be provided to farmers in the first year. Similar agricultural solar pump programmes have also been initiated in many states (e.g., Gujarat, Maharashtra, Bihar, and Punjab).

The installation of these pumps could be financed with a direct subsidy from the state government, rather than using the funds to offset the Discom's financial losses in supplying that load, as illustrated in Figure 26.

This is just one option. It is included here as an illustration only. Such a fundamental shift would need to be gradual, carefully monitored, and modified when unintended consequences arise, as they inevitably do when such complex systems of inter-related services and needs are altered.

For example, stakeholders highlighted that water pumping is at present constrained by electricity supply reliability. Already stressed water resources could be impacted negatively if the pumping window were significantly widened. Others mentioned that there is a measure of convenience for the Discom, and protection of coal power plant revenues, in being able to return supply to the agricultural load at off-peak times, without backing down (inflexible) coal plants. This measure of flexibility would be lost if this load went off-grid.

6.5. Open Access

6.5.1. How Does OA Work?

OA is provided for in the Electricity Act of 2003, which requires "non-discriminatory provision for the use of transmission lines or distribution system or associated facilities with such lines or system by any licensee or consumer or a person engaged in generation in accordance with the regulations specified by the Appropriate Commission."

At the distribution level, the intention is to allow generators other than those contracted by the local Discom to inject electricity into the grid, provided that a PPA has been signed with a buyer for that electricity.

The objectives of the drive for OA are as follows:

1. To encourage greater competition in the wholesale market segment;
2. To provide consumers with the option to buy electricity at less cost, if cheaper alternatives to the Discom exist; and
3. To ease supply shortages by allowing private investment in new power plants.

OA consumers are generally large consumers, such as textile, cement, and steel units, with demand of 1 MW or more. OA allows them to source their needs from a range of alternative producers, rather than solely from the Discom in whose catchment their plant is located.

A power producer, public or private – it might even be a Discom from a neighbouring state – can enter into a PPA with whomever it wishes, including a power exchange. Prices in OA PPAs are agreed to by the contracting parties, and are not regulated.

Access to the ISTS is regulated by the CERC. Access to the ISTS for buyers and sellers can be granted for three different durations, as follows:

1. Long-Term OA: for a duration of 12 to 25 years;
2. Medium-Term OA: for a duration of 3 months to 3 years; and
3. Short-Term OA: for a duration of less than 1 month.

Regulation of OA to the grid at the intrastate level (Transco/Discom ownership) is done by the SERC, and durations vary from state to state.

6.5.2. Distribution Level Issues

Putting aside for the moment the question of whether or not sufficient grid capacity actually exists to handle new flows of electricity, the key issue is whether or not (independent) renewable power plants are able to secure long-term access to it.

As mentioned above, a consequent revenue reduction may discourage a Discom from allowing larger customers to leave its catchment for alternative providers. Discoms levy charges on consumers moving to alternative providers, known as wheeling and banking charges.[34] Stakeholders highlighted that the process of setting these charges is opaque and fraught with complications, and that Discoms have no incentive to facilitate OA.

The charges are often bundled together with the CSS,

34 The wheeling charge is intended to cover the costs of wear and tear on the network.

along with other charges as they arise, and combined they may be prohibitively high. It should also be noted that the administration relating to the setting up of an OA agreement, at the distribution level, is in the hands of the Discom also. Stakeholders have suggested that in certain cases, the Discom may deliberately erect administrative hurdles to the completion of such an agreement.

In the Indian market of today, buyers and sellers of electricity have a strong preference for long-term contracts. However, long-term access to the grid is likely to be seriously restricted. Stakeholders have suggested that the grandfathering of access is an issue (i.e., that existing power plants, regardless of economic or efficiency aspects, retain priority access).

In this respect it should be highlighted that the same (public) company owns both the distribution grid to which access is being sought by the RE IPP, as well as conventional power plants of longstanding connection to the grid. Private electricity producers may therefore find their access limited to the medium- or short-term options. Aside from adding to transaction costs, such durations are likely to be unattractive to investors in such projects.

Finally, in an OA agreement, the producer is required to signal a daily production schedule, deviations from which are subject to penalties. As discussed in Chapter 8, day-ahead output forecasting, particularly for wind power plants, is subject to considerable uncertainties, and such penalties would be financially onerous.

In short, stakeholders felt that OA is a work in progress, even for conventional generation, in most states. In the development of this roadmap, no instances were identified wherein a privately owned renewable power plant had entered into an OA agreement, although stakeholder interaction was not exhaustive, and instances may exist in Karnataka and Gujarat, for example. This appears to be because such arrangements at the distribution level are prohibitively costly, and because the scheduling requirements are too onerous.

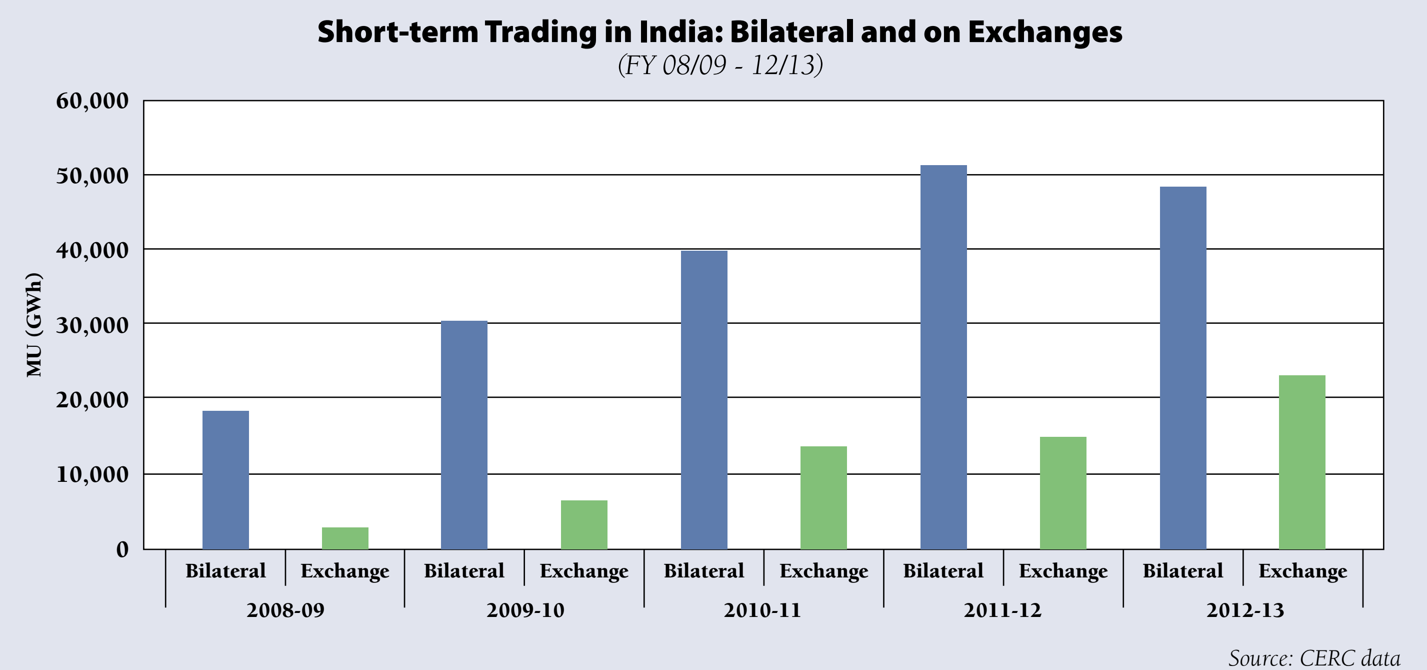
In contrast to OA at the distribution level, OA to the transmission level and particularly to the ISTS appears to be significantly more successful, with OA agreements between some very large consumers and producers. However, no RE plants are connected to the ISTS at present, although there is some discussion of RE UMPPs as an option.

6.6. Short-Term Trading

In the short-term market, buyers and sellers trade electricity mainly on the day-ahead to dispose of surpluses and make up shortfalls. Buyers are mainly Discoms and large consumers, the sellers mainly large power plants and Discoms.

The volume traded short-term is small compared to overall Indian consumption. In FY 2012/13, the energy

Figure 27



Source: CERC data

available for consumption amounted to 911,432 MU (911 TWh), of which 71,280 MU (71 TWh), or approximately 7.8 percent, was traded in short-term markets. But short-term trade is growing, as illustrated in Figure 27, up 240 percent in the last five years.

There are two power exchanges, the Indian Energy Exchange, and Power Exchange India Limited. In both, almost all trading is on the day ahead (Day Ahead Market). The Day Ahead Market is a double-sided blind, uniform-price (marginal price) auction that closes at noon on the day prior to delivery.

The power exchanges are simply financial entities, allowing buyers and sellers to trade transparently at a common price. Like, for example, the power exchanges in the United Kingdom and Spain, they are not managed by the operators of the system, as in the eastern United States (PJM) market, for example (run by the Regional Transmission Operator), or Nord Pool in Scandinavia (run by a collaboration of the Scandinavian Transmission System Operators).

From three days ahead of delivery, the exchanges communicate their needs to the National Load Dispatch Centre (NLDC), at which point congestion among regions is taken into account to generate zonal day-ahead prices for electricity. Grid congestion is the major constraint on volumes traded on the exchange, according to the Indian Energy Exchange, with volume constrained down from five percent of total consumption, to only approximately 1.8 percent.

6.6.1. Potential Benefits for Variable Renewable Energy

Short-term markets can benefit all power producers, as it enables them to update their positions closer to the time of delivery to account for unexpected variations in output. This is particularly the case with variable renewable energy (VRE) such as wind and solar PV, in which cases the actual output will be known with much greater accuracy closer to real-time (see forecasting aspects discussed in Chapter 8). Such markets may also provide the opportunity to flexible power producers/consumers to modify their output/consumption if the price incentive exists for them to do so.

To be of most benefit to VRE, trading should be possible right up to the time of delivery, inside the preceding hour (the hour-ahead). Trading that closes on the day-ahead will mean that the actual wind and solar electricity production seen 24 to 36 hours after trading has stopped will be subject to large uncertainty. If penalties for deviating from the schedule exist, as in India, this route will not be financially viable.

Power exchanges can provide a platform to trade closer to the time of delivery. And if the pool of electricity being traded is deep enough, buyers and sellers can rely on it to provide for their needs in the short-term, while wind and solar producers can fine-tune their schedule to minimise deviations from it.

It is possible to trade intra-day on the Indian power exchanges, but present volumes are negligible. Stakeholders were of the opinion that Discoms will have little interest in trading intra-day while load shedding remains so open an option. If the Universal Service Obligation were to be enforced, however, then the picture might be different: the short-term needs of Discoms arising from uncertainties in demand and supply could stimulate flexible producers to sell in such markets.

In contrast, trading over-the-counter (i.e., an arrangement that is not transparent to other players) does not offer this benefit. Such trades provide limited forward visibility of price, and they do not provide sufficient certainty that the opportunity to trade will be present when needed.

It is unclear what the value of power exchanges might be in terms of deploying RE. It is certain that trading in the short-term through liquid exchanges greatly facilitates a dynamic approach to buying and selling electricity (i.e., trade is able to respond to fluctuating output as the weather changes). But the extent to which India should embrace short-term trading at the expense of long-term bilateral PPAs is less clear.

It seems likely, however, that power exchanges will continue to become more attractive for the purchase of electricity at short notice, to manage deficit and surplus generally. This in turn would suggest a growing potential usefulness in managing the variable output of wind and solar power.

For example, if a Discom has a surplus of wind electricity generated when load is low at night, but is able to trade it over the exchanges to cover growing nighttime load in another state (e.g., industrial, air-conditioning), then this represents an opportunity to make better use of VRE. Of course, this would be subject to sufficient transmission network capacity being available, and this is discussed in the next chapter.

6.7. Summary

The greater the certainty that the electricity generated by a new asset will find a buyer, the more certain are project cash flows, and the more attractive such projects are to investors.

At present, power sector investments are seen to have near "junk" status. Of the four routes to market for RE, by far the most important is sale to Discoms. But these institutions are often hard-pressed financially, and their ability to provide the "collateral" – the risk control needed by private investors – is gravely limited.

A number of burdens weigh upon the Discoms and prevent them from acting with their commercial best interests in mind. Chief among these is a requirement to provide electricity at less than cost to agricultural consumers, while corresponding subsidy from the state government is often late, or not commensurate.

Many stakeholders recommended that investigation of methods to alleviate pressures on the Discoms be given the highest priority. One such method may be to lift away the agricultural demand from the Discoms by providing off-grid alternatives directly subsidised by the state. An on-grid method might be to remove the requirement on Discoms to provide electricity at less than cost, redirecting the subsidy received presently to the consumer.

While other aspects such as scheduling requirements deter OA contracts for VRE producers, it appears that Discoms, in part owing to their financial precariousness, may be reluctant to facilitate OA to their distribution network assets. Wishing to avoid the loss of their higher revenue customer base, they also prevent renewable energy power plants from accessing alternative buyers.

Power procurement is at present mainly done through long-term PPAs between electricity buyers and sellers within the same state. Short-term markets are still small, as is trade interstate. If the Universal Service Obligation were enforced, the short-term needs of Discoms arising from uncertainties in demand and supply, including that of renewable energy production, might stimulate activity.

At fair prices, and subject to greater knowledge of interstate transmission capacity, this could also facilitate relatively RE resource-poor states to meet their RPO, and contribute to a more nationwide approach to meeting renewable energy targets.

7. Planning the Grid

Power plants and consumers are linked in "real-time" through transmission and distribution networks – the grid. Because electricity cannot yet be stored at scale, it must be consumed as it is generated.

Broadly speaking, the grid in India is subdivided into three main categories: the ISTS, which consists of very high-voltage lines connecting states, intrastate transmission at a lower voltage, and a distribution grid in each state at a lower voltage again.[35]

Power plants are connected to the grid at different levels. Some of them, including the very largest coal-fired plants (UMPPs) feed into the ISTS, whereas other large power plants feed into the intrastate transmission system.

A distinction should be drawn between the addition of a new line to evacuate electricity from a new power plant, and the construction of new lines to better manage the flow of electricity around the network as a whole and to consumers. It is not enough to simply connect a power plant to the grid: the electricity produced must not overload the existing grid.

Unlike conventional, fossil fuel-fired power stations, renewable power plants only generate under appropriate weather conditions. This variability of output has caused concern to system operators throughout the world, and there is a range of tools with which it can be managed. While Chapter 8 discusses operational tools to manage this variability, this chapter discusses tools that can be used to plan the grid to better manage variability.

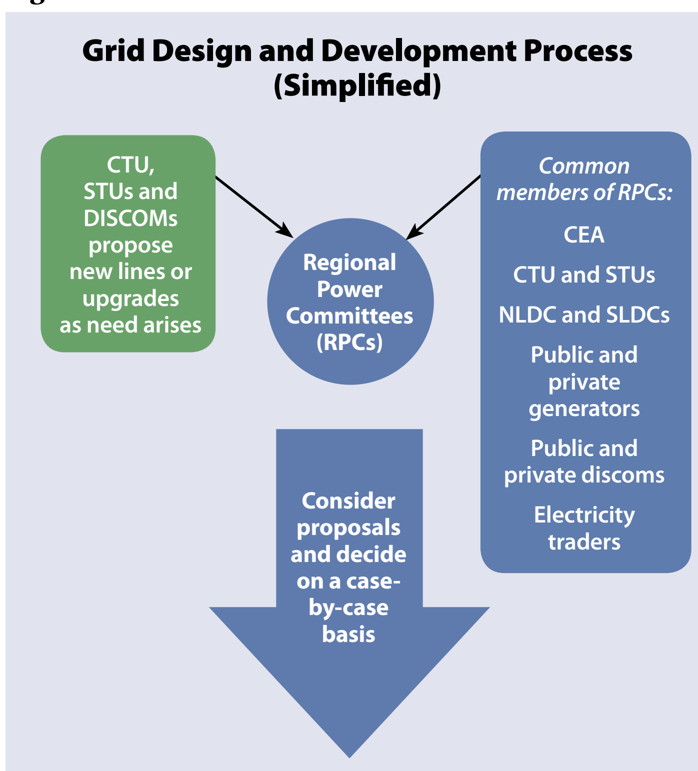
The voltage level at which a power plant is connected has bearing on the ease with which its output can be managed. The authors were informed that most wind power plants in Tamil Nadu are connected at the 33-kV level, at which level their output is not visible to the state LDC. Consequently, planning of system operation cannot take such plants into account. In Gujarat, in contrast, most wind plants are connected at 66 kV or above, with the result that their output can be "seen" by the state LDC.

The Indian grid is already extensive. Rolling upgrades and replacements will increasingly be needed as equipment reaches the end of its lifespan, and as the demands placed upon it increase. Meanwhile some 600,000 villages remain without electricity. Unless an off-grid solution to the electrification of the latter is taken, then taken together these two tasks represent a significant opportunity: both upgrades and new lines can be designed to better manage large shares of variable RE.

7.1. Grid Planning Today

The work of "finishing" the grid is never done. New consumers and power producers are connected continuously. Nowhere is this more the case than in India. A number of

Figure 28



35 This is a general characterisation. Some states own very high-voltage lines (e.g., 400 kV), whereas centrally owned lines may be as low as 220 kV and 132 kV.

central, regional, and state-level institutions are involved in developing and maintaining the grid to meet these new demands, interacting, among other ways, through Regional Power Committees (RPCs), as illustrated in Figure 28.

The need for new lines, commonly resulting from the signature of a new PPA between a conventional power plant and a Discom, for example, may be considered by a number of bodies, including the CEA, Discoms, the STU, the Central Transmission Utility (CTU), also known as PGCIL, and national and state-level generators.

The authors were informed that the process for a new renewable power plant in Karnataka is as follows: the state nodal agency for RE development will sanction plans for a new power plant, present them to the state LDC, which reports to the STU with recommendations for additional lines or reinforcements needed to accommodate that plant. The STU then coordinates with the CEA and the CTU.

Given the need to massively increase Indian electricity generation capacity, to meet the needs both of unelectrified populations and future demand growth, recent initiatives have endeavoured to plan the grid for deployment of renewable power plants. Proactive, long-term planning is included, for example, in the Green Corridors Report, and Desert Power 2050. These are described briefly in Box 1.

Green Corridors and Desert Power

The Transmission Plan for Envisaged Renewable Capacity, the so-called "Green Corridors" Report, was released by PGCIL in July 2012. Its objectives were threefold: to identify additional transmission infrastructure needs of likely wind, solar, and hydro capacity in RE-rich states such as Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Maharashtra, Rajasthan, Himachal Pradesh, and Jammu and Kashmir during the period of the 12th Five Year Plan; to estimate the CAPEX of such additions; and to propose approaches to funding.

Desert Power India – 2050 – Integrated Plan for Desert Power Development was released by PGCIL in December 2013. It focuses on opportunities to harvest solar power in the north and northwest of the country, specifically in the deserts and wastelands of the Thar in Rajasthan, the Rann of Kutch in Gujarat, Ladakh in Jammu and Kashmir, and the Lahul and Sipti valley in Himachal Pradesh. The study suggests that five to ten percent of the unproductive wastelands in these areas (7400–14,800 km2) could produce 220 to 450 GW of solar and wind power. Similar to the Green Corridors Report, the study assesses the cost and extent of transmission infrastructure to evacuate electricity thus generated to demand centres.

7.2. Additional Needs of RE

It has become something of a truism that renewable energy resources are far from load. This is far from true in the Indian case, particular as regards the solar resource, which is impressive throughout the country (Figure 29). In contrast, the harvesting of the best wind resources may indeed require new transmission lines.

Figure 29

Global Horizontal Irradiance Map of India

Prepared by NREL

Source: http://mnre.gov.in/sec/solar-assmnt.htm

International experiences suggest that the most important task is to manage the trade-offs among:

1. The cost of the transmission line;
2. The amount of electricity it will carry to the load; and
3. The benefits represented by new lines in terms of reducing the need for balancing power (by smoothing aggregated output), and increasing capacity value.

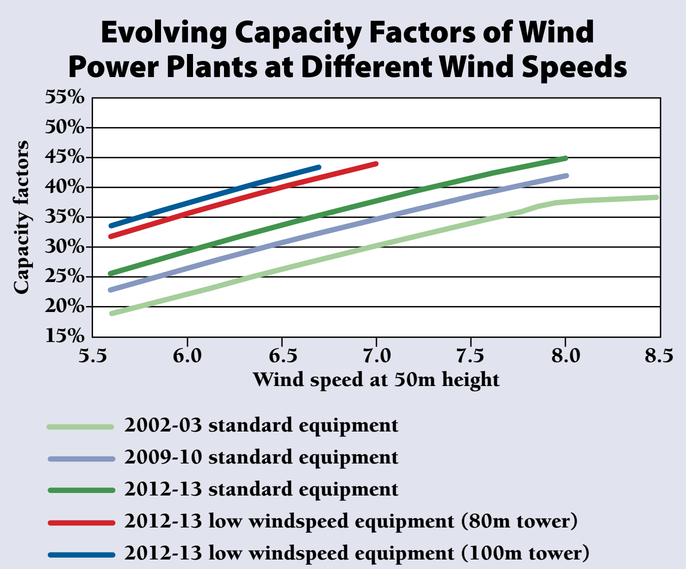
In a truly system-wide planning exercise, these factors must be weighed together, but let us start with the most obvious factor: how much electricity will the line bring to market?

The capacity utilisation factor (CUF) of a transmission line expresses how much of its capacity is in use on average. The CUF of a power plant is relevant when dimensioning the capacity of the line through which electricity is evacuated to the wider network, and the extent to which the grid will need to be reinforced in the locale of that connection.

In theory at least, a coal-fired power plant can generate around the clock, maximising the usage of the lines connecting it to consumers. This means that the owner of the transmission line can charge on the basis of MW, for the full capacity of its line, and the power plant can afford to pay.

In practise, coal CUFs in India may be significantly lower than the 80 percent or so hoped for (approximately 60 to 65 percent), whether because of low efficacy of older plants and maintenance requirements, or fuel supply shortages. Nevertheless, solar and wind power capacity factors are considerably less than this.

Figure 30



Source: IEA 2013, based on analysis by Ryan Wiser et al of LBNL

Figure 30 illustrates that the CUF of wind plants is lower, but also that it has risen considerably over the last decade, as turbine technology and siting techniques improve, and as turbines grow taller to take advantage of the higher wind speeds higher up. At an average speed of 6.5 m/s, CUFs in 2002 were approximately 25 percent, versus approximately 40 percent today.

Many stakeholders cited local grid congestion as a primary cause of curtailment. Given inadequate data on power flows in distribution networks, however, it is unclear if congestion is actually occurring, or if curtailment is caused by other factors, such as low demand (e.g., at nighttime); an inability to wheel power out of the state owing to congestion further afield (e.g., on the ISTS); or an inability to find a buyer further afield for one reason or another.

Assuming that, as stated by many stakeholders, it is a matter of local congestion, then the priority is to assess the extent of that congestion and the causes of it. This issue is explored further in Chapter 8, in the context of Renewable Energy Management Centres. The process of securing grid connection is explored in Chapter 5.

7.2.1. Smoothing Output Through Dispersal of Power Plants

Output from wind- and solar PV-powered plants depends on the weather, which fluctuates continually as part of a number of complex geophysical processes that mean that output varies also. Figure 31 illustrates this variability.

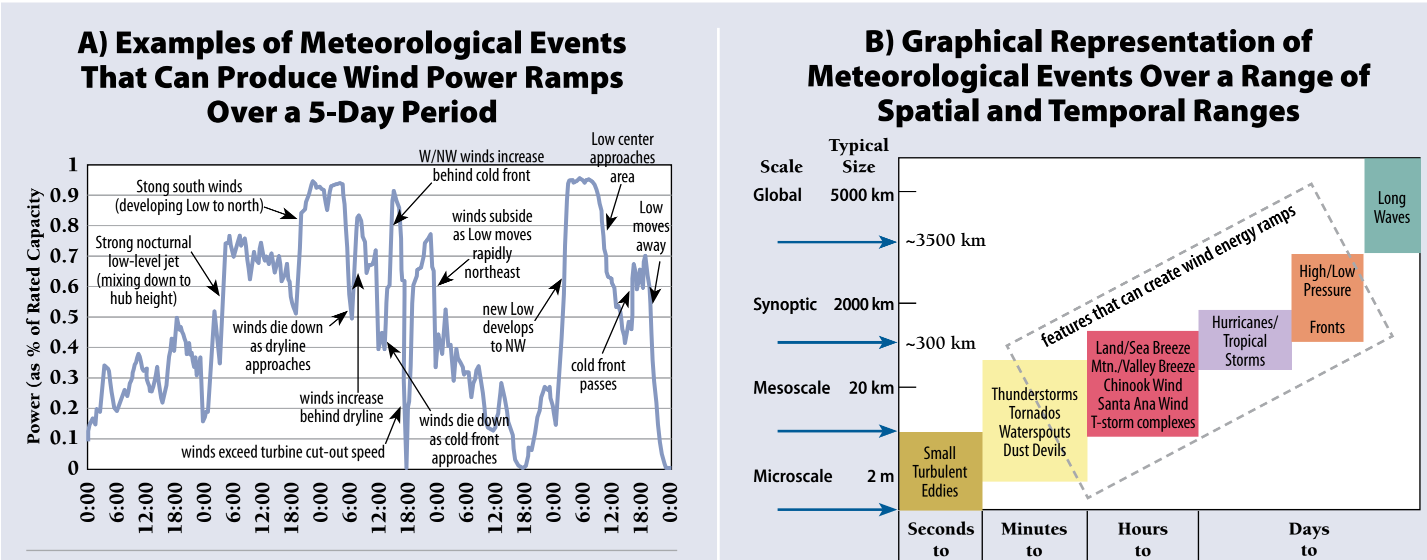
Solar PV output is also subject to shifting daylight patterns over the year. The timing of output is also uncertain, which is discussed in Chapter 8. In contrast, fossil-fired power plants rely on fuels that can be stored (although they may equally be subject to supply shortages).

The output of one wind or solar power plant is far more variable than the output of 1000 such plants taken together. Their dispersal over a wide area has an additional effect: ramp rates, the rate at which output increases or decreases, are markedly reduced. Moreover, the extent of ramps, taken as a percentage of installed capacity, is smaller.

In other words, wind and solar output will reduce/increase more slowly, and to a lesser extent, when taken as an aggregated whole. The consequence of this may be a significant reduction in the amount of flexibility – and the speed at which it is needed in the system – to balance the variability of the aggregate RE generation.

This in turn would mean that other power plants needed to step in when the wind falls, such as coal plants, would need to increase their output at a correspondingly slower

Figure 31

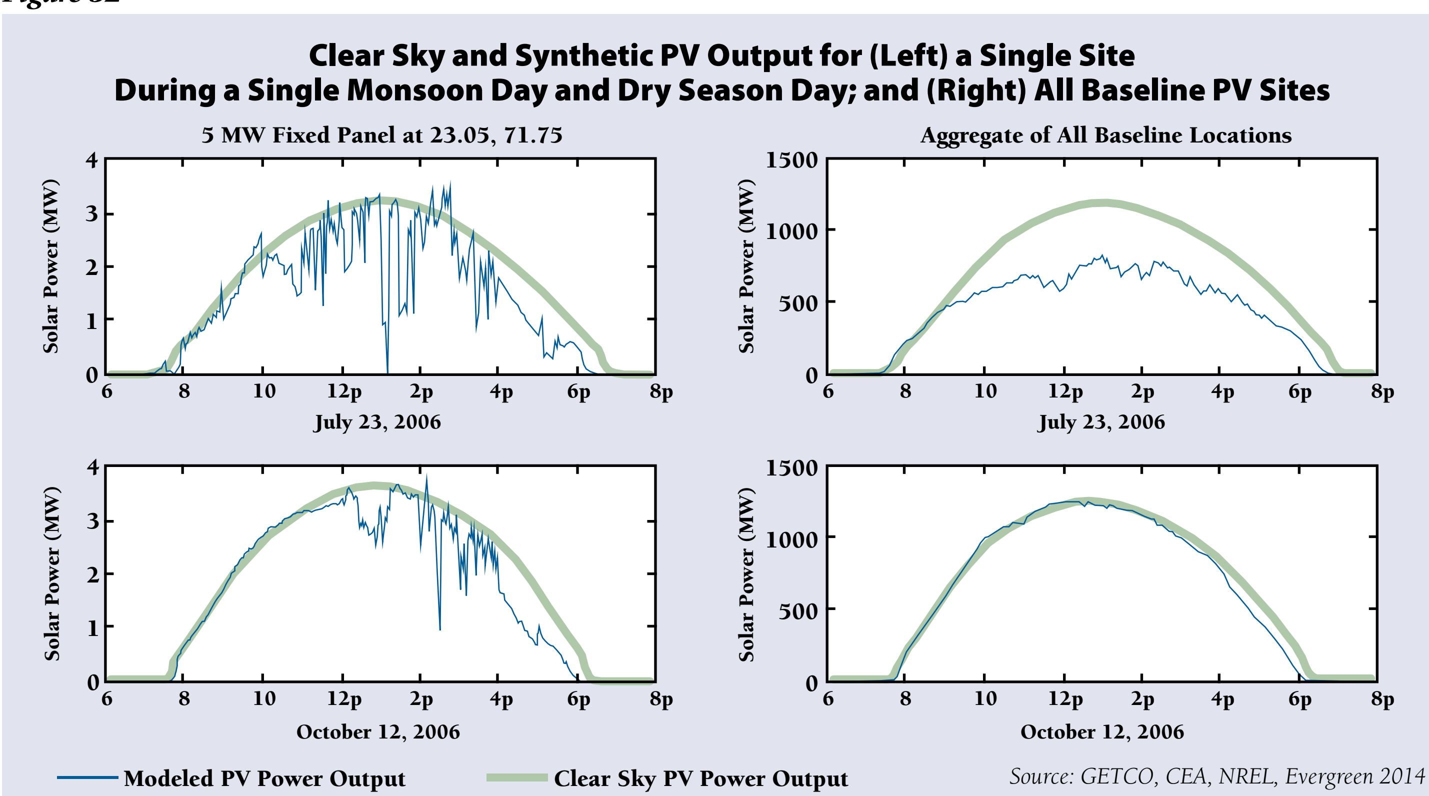


Source: Marquis et al., 2011[36]

rate. Furthermore, if coal plants are also aggregated over a larger footprint, the ramping (up or down) of each coal plant may also be substantially smaller and slower than what would be required from just one coal plant. Consequently, the ability of the system as a whole to both absorb and respond to the variability of RE generation may be significantly improved when the geographic size of the balancing area and the size of the system is large.

Understanding of the value of dispersal of VRE power plants over a wide area has recently benefitted from research carried out by Gujarat Energy Transmission Corporation Limited (GETCO), the CEA, National Renewable

Figure 32



Source: GETCO, CEA, NREL, Evergreen 2014

36 Images in the publication of Marquis et al were originally courtesy of C. Finley of WindLogics.

Energy Laboratory (NREL), and Evergreen Renewable Consulting.

This joint study highlights the important impact on variability of aggregating solar power output in Gujarat over a wide area. Its "baseline scenario" comprises 1.9 GW of solar PV capacity, being all existing and expected capacity in the state, according to GETCO. Figure 32 illustrates the output of a single 5-MW plant on a single day during monsoon and dry seasons, and compares its output variability with the output of the complete baseline capacity, using historical solar resource data with one-minute resolution.

The very large smoothing effect of the portfolio approach, as seen in Figure 32, highlights very strongly the weakness of approaches to modelling the output of solar PV by simple extrapolation from one site, as this fails to take into account the smoothing effects on output of dispersal and the concomitant dramatic effect of a portfolio approach on the capacity value of the total solar PV portfolio.

The consideration of this phenomenon approach can be considered the first of three steps toward effective management of the variability characteristic of wind and solar PV power plants, as illustrated in Figure 33.

Figure 33

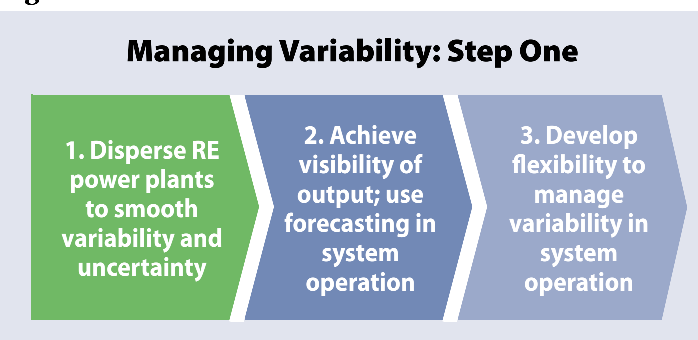
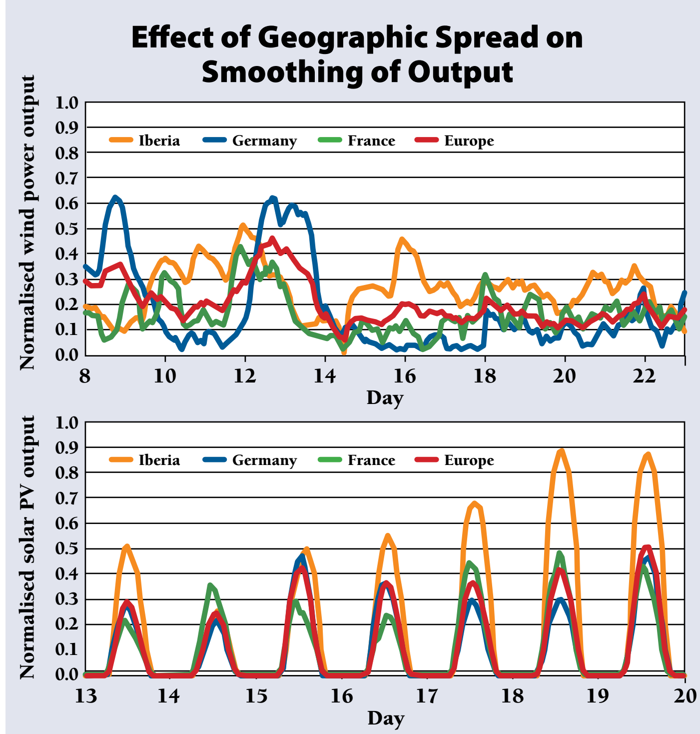


Figure 34 illustrates the effect of aggregation in Europe, for both wind and solar power plants. The orange, green, and blue lines represent the overall wind outputs in Spain/Portugal, Germany, and France, for wind in the upper figure, and for solar in the lower figure.

In both cases, the black line represents output over the European area. Particularly apparent in the wind case, but also with solar, both the extent and rate of ramps, shown as a proportion of installed capacity (i.e., not in absolute terms), are decreased.

Moreover the number of hours when output is zero becomes nominal. In other words, a part of the portfolio somewhere can, for all intents and purposes, be guaranteed to be operating at any given moment. This means that although variable renewables are primarily a source of energy that can displace production from conventional power plants and so reduce fuel costs, they also can have a capacity value, assuming that the grid is uncongested and electricity can flow unimpeded.

Figure 34



Europe = all European case study countries. Generation data for April (top) and March (bottom) 2011. Output normalized to installed capacity.

Source: IEA, 2014

Capacity value may be calculated as Expected Load Carrying Capability, although a number of other metrics are also used. Its calculation differs for thermal and variable power plants. For thermal units, the primary characteristics that influence overall system adequacy are the units' available capacity and forced outage rates. The data on long-term forced outage rates need to be available for different size and type of power plants, and can be compiled from a large data set of similar units.

With respect to wind power, the correlation of the timing of output and the timing of peak net load is the key factor with impact on the capacity value calculation,[37] along with adjustments for outage rates and forecasting errors.[38]

37 Net load is a term used to represent the MWs of load (demand) remaining to be satisfied once wind (or other variable output) has been accounted for. Peak net load therefore is the point at which this value is highest.

38 See IEA, 2014, for example, for further discussion of this topic.

Table 5

Estimation of Wind Capacity Value in India

State	Estimated Potential at 80m (MW)	Capacity Value (%)	Capacity Contribution (MW)
Andhra Pradesh	14,497	25.5	3,697
Gujarat	35,071	29.5	10,346
Karnataka	13,593	24.0	3,262
Maharashtra	5,961	23.0	1,371
Rajasthan	5,050	20.5	1,035
Tamil Nadu	14,152	23.0	3,255
Others	14,464	24.0	3,471
Total	**102,778**		26,438

Source: ICF, 2013

The correlation between power from wind and load is also site-dependent, for example, in some areas there may be a diurnal and/or seasonal wind pattern.

Table 5 lists capacity values for wind power in selected Indian states, as calculated in a recent study by ICF International, based on estimates of the wind resource at 80 meters in altitude, and assuming that the wind plants are connected to an uncongested grid.

It is important to note that geographical dispersion in wind and solar plants will not happen unless there is incentive for developers to build in this way, or unless it is explicitly planned for.

In addition, dispersal of generation assets may imply additional transmission needs. Both perspectives should be borne in mind when planning additional lines.

7.2.2. Complementary RE Technologies

While considering the dispersal of wind power plants to smooth their overall output, it may also be helpful to consider potential complementarity in the output of different renewable energy technologies. Figure 35 shows the monthly output of wind and solar power plants in Germany. In the summer months solar output is higher, whereas the winter months see higher wind output. Taken as a whole, the outputs of the two technologies are highly complementary.

India, of course, has a very different climate from Germany. Most importantly seasonal variation in solar output is likely to be smoother, while in some parts of the country wind output is highly concentrated in the monsoon months. Nevertheless, the point remains that when considering the cost of new transmission, it is not just the wind resource that should be borne in mind. Rather the planning of new transmission should take into account the portfolio mix of power plants that will give an output that make the best use of transmission.

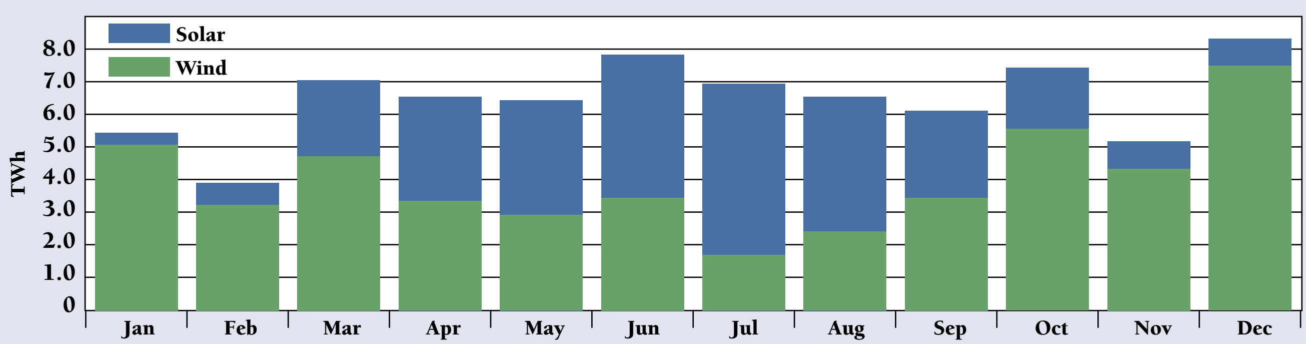
7.3. The Role of Evolved Grid Planning

This smoothing effect, through both geographical and technological complementarity, could be increased if the grid is planned to take advantage of them. As discussed above, grid planning to date tends to be somewhat piecemeal. A planned approach could see the building out of transmission to where resources are strongest and most complementary.

It is of primary importance that the planning of new transmission to cater for the needs of new renewable power plants should take into account the needs of other power plants, and upgrades to the power grid necessary even in

Figure 35

Monthly Output of Wind and Solar Power Plants in Germany (2013)



Source: http://www.ise.fraunhofer.de/en/renewable-energy-data the absence of these new needs.

At the same time, the trade-off mentioned above between connecting distant RE resources and the marginal benefit of doing so in terms of cost needs to be considered. Accessing high quality resources generally lowers the per-kWh generation cost of VRE power plants. However, connecting distant plants to the grid can be costly.

There is also a trade-off between the cost of transmission and the proportion of rated capacity that can be accommodated. A wind power plant, for example, may only generate at rated output for a small number of hours per year. This means that if transmission capacity is dimensioned according to rated output, a proportion of it may be underused for the rest of the year. The cost of this unused portion may outweigh its benefit in terms of those few hours, and it may instead be prudent to plan the curtailment of the margin of wind output instead.[39]

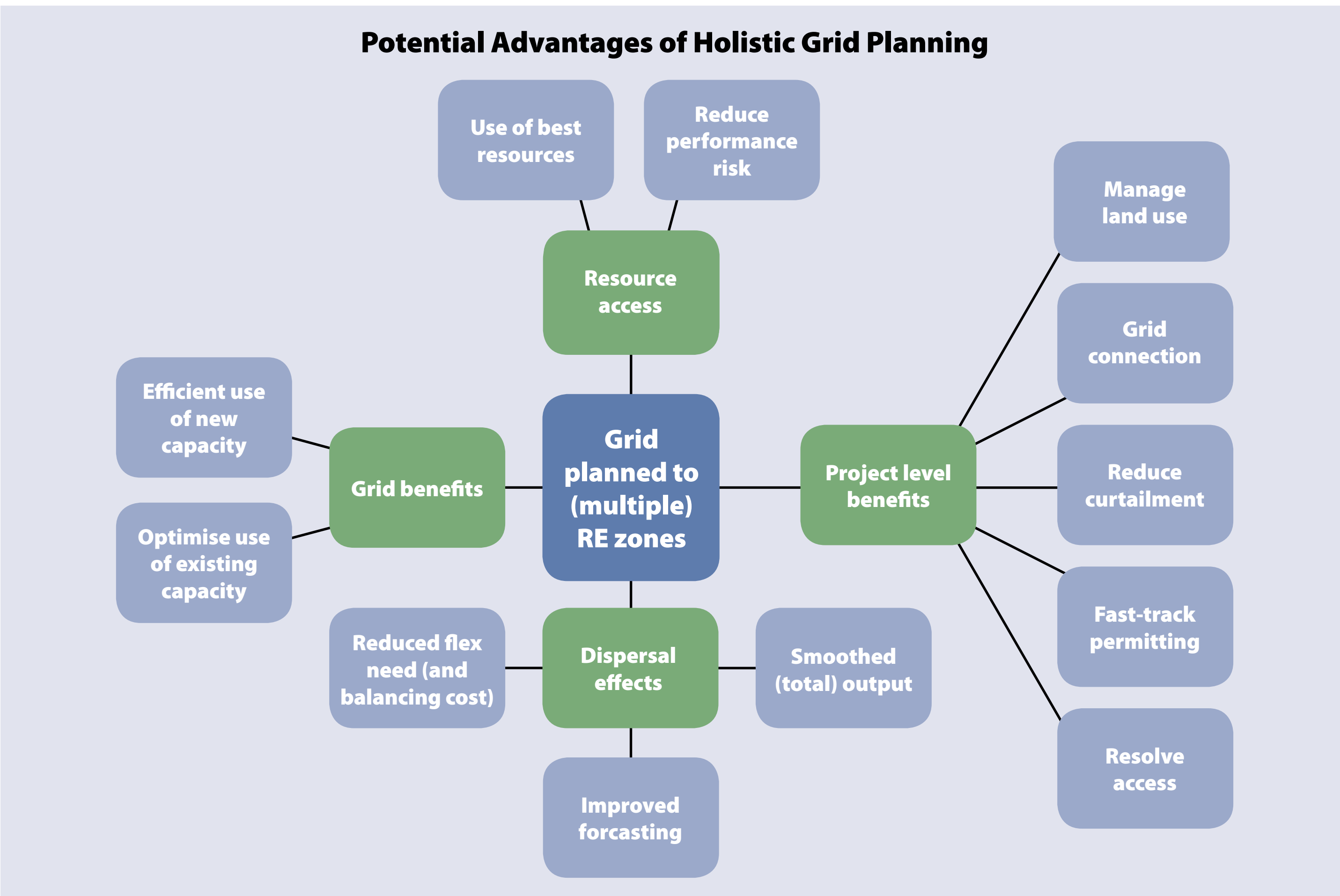
Transmission constraints can be both real, based on actual line loading, or administrative, based on rights to the line. Line-rating, the process by which lines are characterised in terms of their capacity to transmit power, tends to be very conservative, and often based on imprecise, rough calculations. Examining rating processes, and considering dynamic line ratings might be valuable. International experiences suggest that it may be worthwhile to analyse line constraints using historic RE power delivery data, when considering the needs for additional lines to scale up RE deployment.

Dynamic line rating is not practised in India, but can significantly increase line capacities and reduce the perception of congestion. For example, during high wind periods, ambient temperatures are low, increasing carrying capacity.

7.3.1. The Potential Value of Zoning

As well as the smoothing effect on output described above, the holistic planning of transmission may bring a host of other benefits in India. These are summarised in Figure 36.

Figure 36



39 IEA, 2014.

As discussed above, new lines would provide access to the highest wind speed and/or greatest insolation areas. The wind resource in such areas should be assessed in detail by a neutral party before they are selected, to effectively manage performance risk to investors (as discussed in Chapter 5). Moreover the zoning approach may make it easier for investors to select a portfolio of projects, over which the probability of one plant underperforming will be reduced.

The choosing of the best resources – subject to the trade-off with cost outlined above – and the fact that they are feeding into a single (new) framework as opposed to the multiple lines that might result from a more piecemeal approach, is likely to optimise the CUFs for new transmission assets. It also makes possible the planning of solar and wind power plants concurrently, taking advantage of complementarity in output profiles discussed above.

Leading with transmission provides time and a strong signal to stakeholders, which would enable them to manage a number of key potential obstacles (e.g., curtailment, discussed in Chapter 5) to the development and deployment of the RE projects.

It also may considerably reduce the challenges associated with identifying sufficient land for the siting of new power plants and transmission corridors. The pre-definition of development areas means that limited public resources can be used in a more focussed manner, identifying land that may be available, and streamlining/replicating permitting procedures. Similarly, environmental impacts can be assessed more strategically, reducing duplication, and in advance, reducing uncertainties in project development that can deter investment.

It may also have benefit in terms of leveling the playing field between developers that have already banked land assets for development, and those who have not.

Grid connection lead-times can be planned for and managed down. If the STU and Discoms affected know in advance where new lines will be needed, this will help them to plan their already stretched resources accordingly.

Similarly the need for new access infrastructure, such as roads and rail links that may be through problematic terrain, can be assessed holistically, minimising duplication and providing greater clarity of the value these will have, in terms of new power supply.

Curtailment risk, as discussed in Chapter 5, is a major deterrent to investment. Power flows can be modelled in advance, to assess whether modest curtailment at a few times of the year can be tolerated in order to manage overall costs of new transmission while not undermining revenues to wind power projects.

Although these benefits will need to be assessed in detail for relevance in the Indian context, it should also be noted that the private sector would need to be closely consulted in any such zone-planning efforts. Without full transparency, stakeholders suggested that the private sector might oppose what they might see as interference by the state.

7.3.2. Zoning Practises

There are similarities between such a zoning approach and current procedures that may be used to procure new conventional power plants. Traditionally, Discoms and state agencies have adopted two bidding practises for new types of power plant: "Case 1" and "Case 2" bidding. In a Case 2 bidding process, the procurer (state/central government) must identify the land required for the power production project and then acquire it. The procurer must also develop the necessary power evacuation and access infrastructure, and obtain the necessary environmental clearances. The Discom/agency also specifies in advance the type of power plant eligible to bid (i.e., it is not an open competition in which all technologies compete).

Only once this complete framework has been established is the project opened to bidders, who compete to offer the lowest MWh tariff. Thus, the state acts as facilitator, taking the lion's share of the risk while private project developers build the project with greater security than otherwise. Many state governments have used this mechanism, using Special Purpose Vehicles for making the necessary arrangements. For example, contracts for coal-fired UMPPs have been awarded after a Case 2 bidding format.[40]

Under its Solar Power Policy of 2009, the state of Gujarat has accelerated its development of utility-scale ground-mounted solar PV power plants in wasteland areas. The "solar park" that is presently being realised is made up of many power plants. Aside from price and allocating the Discoms as buyers, the policy has provisions, among others, to:

- Identify suitable locations for solar projects, and prepare a "land bank";

40 In Case 1 bids, the power procurers, which could be either the state looking to procure power or the privately owned electricity Discoms, call for price quotes for the project for the fixed amount of electricity, irrespective of the source or fuel, the location, and the technology used for power generation. The Discom issues a tender for long-term PPAs. Bidders are evaluated on criteria such as land availability and fuel sourcing, among others. The bidders are responsible for obtaining clearances and approvals.

- Create/upgrade access infrastructure such as roads;
- Manage rights-of-way issues;
- Secure a water supply;
- Secure clearances (e.g., planning and environmental) required from the state government;
- Build support for public awareness; and
- Develop appropriate manpower skills.

In these respects, the Solar Power Policy in Gujarat bears many resemblances to a zoning approach.

An example of the zoning approach may be found in Texas in the United States. In 2005, the legislature ordered the Public Utilities Commission of Texas (PUCT) to designate Competitive Renewable Energy Zones (CREZ), for which specific transmission improvements would be required to connect the wind power plants, to be built subsequently, to load centres. The PUCT designated five zones that cover much of west Texas. Distances between these zones and the major load centres in the east are as much as 650 km.

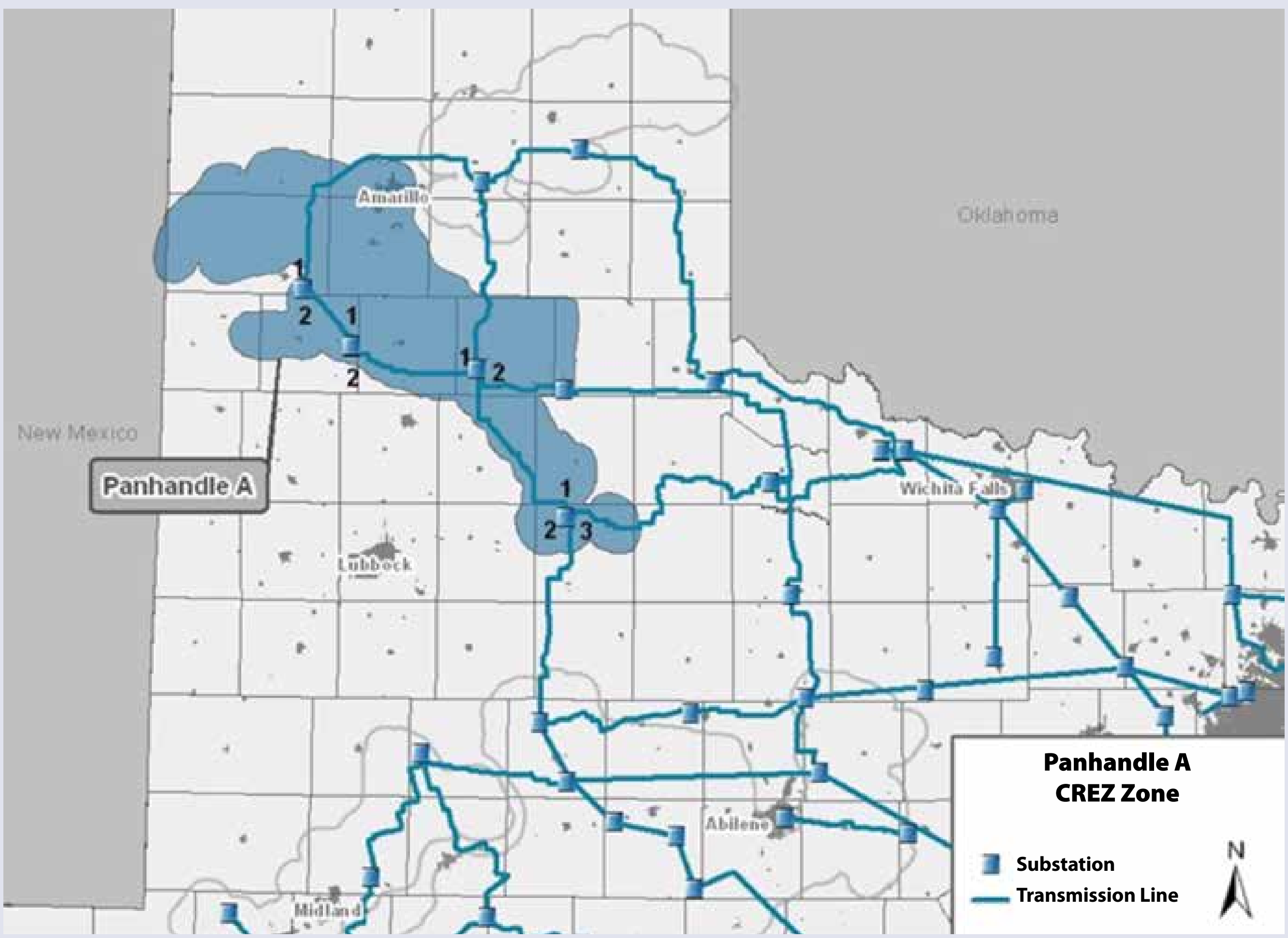
To connect these zones, the PUCT selected from among several options a plan to build new 345-kV lines to accommodate an additional 11.5 GW of wind power generation capacity. Figure 37 illustrates the new lines planned in the panhandle (northwest) of Texas to feed wind output from future power plants to load centres in the east.

CREZ was largely finished at the end of 2013. Because of CREZ, the Electric Reliability Council of Texas reports that wind-related congestion between west Texas and other zones has largely disappeared. Transmission between the west and north hubs was the most congested in 2011, and third highest in 2012, but is no longer even in the top 30.

Key to the Texas CREZ process was the provision that a CREZ line approval meant instant "used and useful" status, and immediate rate-base cost recovery even during

Figure 37

Competitive Renewable Energy Zones (CREZ): New Lines in Northwest Texas



Source: http://www.texascrezprojects.com construction. The lines were "socialised" in the sense that all customers paid for lines that contributed to meeting the legislated RE obligation (Figure 37).

A new approach was adopted recently in Brazil. This was to identify resource-rich areas and hold auctions to build new lines to these areas. This was first done in 2012 in advance of the wind auctions held in 2013, so that the lines and pooling substations would be in place when the wind power plants are scheduled to be commissioned in January 2015. It is possible, however, that transmission will be delayed by unrealistic assessment of costs by transmission developers.

The new lines cannot cover all the terrain that could potentially be developed for wind power. In February 2013, the regulator, Agência Nacional de Energia Elétrica, reportedly announced that developers wishing to build outside of areas with existing or planned lines will need to build the required transmission themselves. This would amount to an additional ten percent on average on the cost of the project, and would be a significant disincentive.

7.3.3. Holistic Thinking in Grid Development

Thinking further ahead than the next power plant is important, as is considering the needs of all power plants simultaneously. In 2005, The German Energy Agency, DENA, produced its first report on the needs for new transmission, the DENA Grid Study 1. This was an important leap forward for wind power planning in Germany, but it was not until the second study was published in 2010 that the needs for new wind power plants were considered hand in hand with those of the power system regardless of wind power development.

The Green Corridors Report and Desert Power resemble the DENA 1 study to a certain extent. They too provide important insights into approaches that may be beneficial, but without being integrated into wider power sector development needs.

The European Network of Transmission System Operators for Electricity is required by the European Commission to produce a Ten Year Network Development Plan (TYNDP). The first (pilot) was produced in 2010, and its second update is to be completed in December of this year, with further updates in the years to come.

The objectives of the TYNDP are (1) to ensure greater transparency regarding the entire European electricity transmission network and to support the decision-making process at regional and European levels, and (2) to form the sole base for the selection of Projects of Common Interest to reinforce or upgrade the grid.

Key findings of the TYNDP 2012 included:

1. **Permitting:** one in three planned investments is experiencing delays in implementation owing to long permitting processes;
2. **Congestion caused by RE:** the need to invest EUR 104 billion in the refurbishment or construction of roughly 52,300 km of extra high-voltage power lines clustered into 100 investment projects across Europe; and
3. **Grid extension:** extending the grid by only 1.3 percent a year enables the addition of three percent additional generation capacity and the reliable integration of 125 GW of renewable energy sources.

Projects of Common Interest will benefit from faster and more efficient permit granting procedures, improved regulatory treatment, and possible access to financial support from the Connecting Europe Facility, under which a EUR 5.85 billion budget has been allocated to trans-European energy infrastructure for the period 2014 to 2020. Figure 38 illustrates some of the key congested areas to be upgraded.

Such an approach in India would require close collaboration among states, and the recognition of projects of mutual benefit. Collaboration already has strong roots, in the Regional Power Committees, but would need to be deepened.

Other approaches that may provide useful learning opportunities include the Multi Value Project Portfolio approach used by the Mid-continent Independent System Operator in the United States. The California Independent System Operator, meanwhile, accepts bids for approved transmission planning projects.

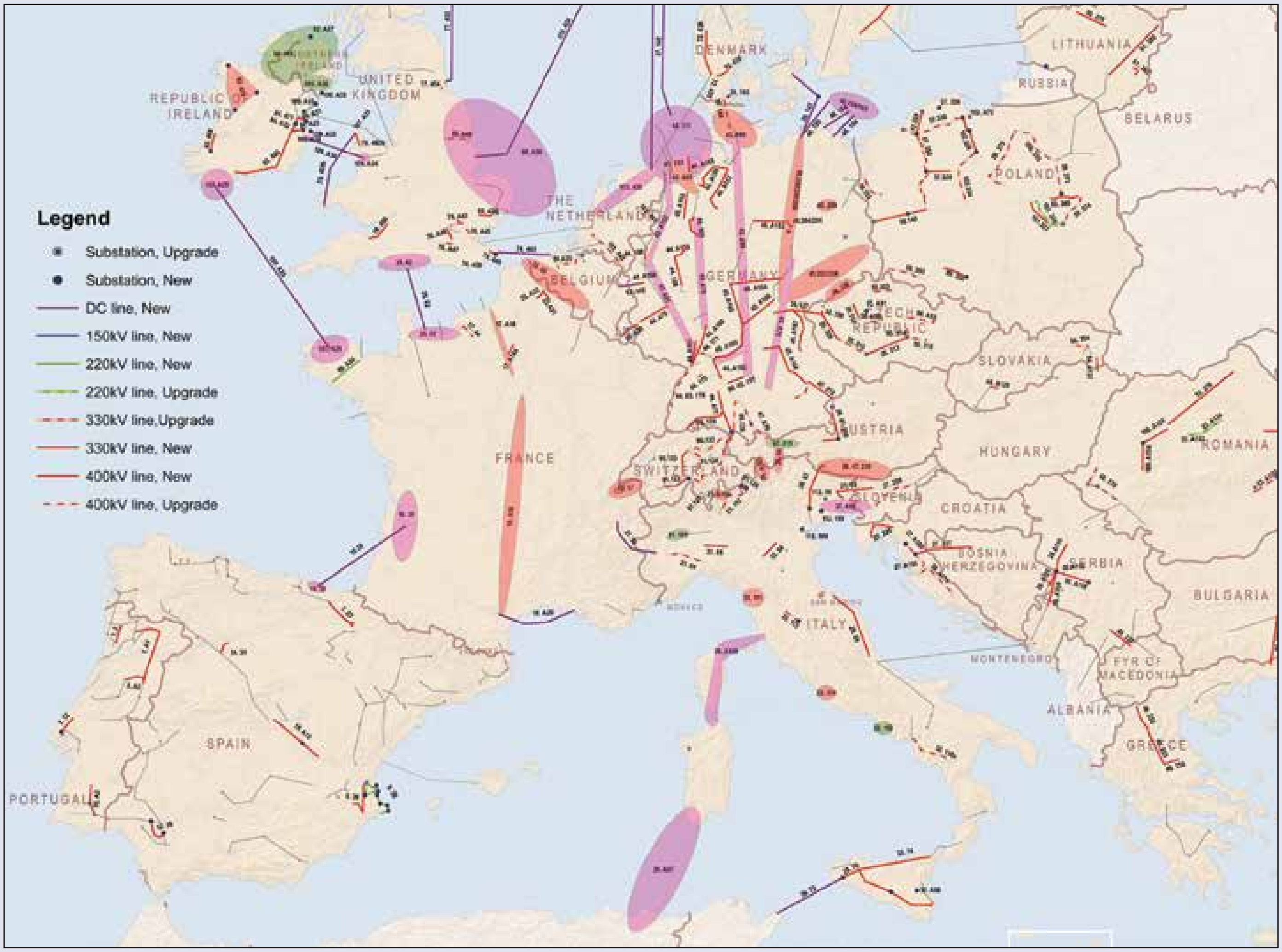
It is important to note, however, that because transmission planning and development can take a long period of time, it's all too possible for unforeseen events to emerge if a piecemeal approach is taken. For example, extensive transmission network planning to manage wind power plants did not prepare German system operators for the extraordinary explosion of solar PV capacity at the distribution level that resulted from an attractive FIT.

The unexpected can also arise from the more conventional power sector: since the success of the CREZ approach in Texas discussed above, intra-zonal congestion in west Texas has soared because of load growth from oil and gas development.

Excessive caution relating to fears of variability may delay connection of power plants unnecessarily while

Figure 38

TYNDP 2012: Projects of Pan-European Significance (2017–2022)



Source: https://www.entsoe.eu/major-projects/ten-year-network-development-plan/tyndp-2012/Pages/default.aspx

network upgrades are made. Effective February 2011, wind power plants in the United Kingdom are offered connection dates based on the time taken to complete their connection to the grid, and ahead of the completion of any wider transmission system reinforcements required under security standards.[41]

International experiences suggest that the first task when considering large-scale grid development is to acquire reliable data of the need for it. In the process of developing this roadmap, it became apparent that the true extent of congestion on the ISTS is unknown, although most stakeholders assumed that it was heavily congested, as discussed previously. This information is a critical need: without it, high-voltage grid plans will have no basis in fact.

7.4. Paying for New Transmission

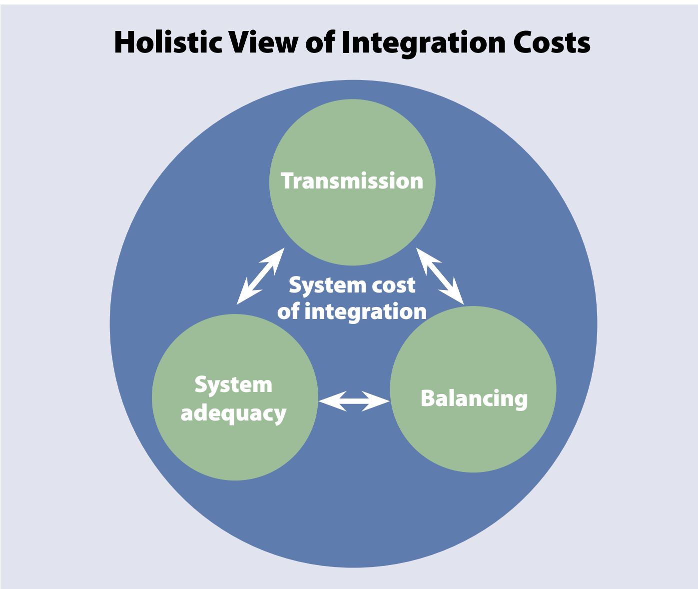
With holistic planning can also come a more holistic understanding of costs. The additionality of RE transmission needs should be properly identified so that costs can be apportioned accordingly; but RE is not the only cause of grid development needs, and co-benefits to the wider system should be taken into account. These benefits are not easy to establish; they may include aspects highlighted in

41 It is acknowledged that connecting generators ahead of the completion of these wider works may result in additional constraints on the system operation, the cost of which is socialised.

Figure 36, above, such as trade, greater ability to manage variability, and energy security. The cost burden is therefore similarly hard to allocate.

Similarly, the costing of new transmission for RE should not be considered in isolation from other renewable energy integration costs, such as balancing, and investments that may be needed in due course to maintain the adequacy of power capacity. For example, an investment in grid infrastructure may contribute to smoothing the variability of VRE at the system level, and thus reduce balancing and adequacy costs.

Figure 39



The construction of new lines may take two to five years, whereas the construction of a new solar PV power plant may only take a year or less. From this point of view it is logical in a centrally planned approach to commence grid construction some time before the PV power plant. However, the installation of new lines when certainty of their eventual use is absent raises important questions.

1. Who will pay to construct them, given a (present) absence of users?
2. What business model will offer the least risk of not recouping those costs, and the best returns to investors?
3. How should costs be recouped?

Private investment in the construction of new lines to high RE resource areas would depend simply on the revenue that owners of such lines would derive from their use. Wheeling charges – charged by the (public) owner of the grid to private generators for use of their system – are usually calculated on a MW basis, as highlighted at the beginning of the chapter. This is practicable for owners of power plants that operate around the clock, but may be too onerous for, for example, a wind power plant with a rated capacity of 100 MW, but a CUF of 35 percent.

Stakeholders highlighted that in some parts of the country there may be periods where in contiguous months, output is just five to ten percent of rated capacity. If charging were done on a MWh basis, as some stakeholders suggest, the revenue to the owners of such lines would be minimal.

Furthermore, it is, to say the least, unlikely that competing, commercial developers of RE power plant will collaborate and share the risk of constructing substantial transmission assets.

Stakeholders pointed out that, given that central government intervenes to establish links to new, conventional UMPPs, it would seem unlikely that the same approach would not be applied to RE power plants of similar scale. Thus it seems likely that the cost of new transmission assets could be socialised either to taxpayers or ratepayers.

In 2009, the United Kingdom adopted a comparable approach to relieve offshore wind farm developers of the risk that grid connection would be hindered/delayed. New transmission lines are built at the public expense, the cost of which is passed on to ratepayers. Would-be Offshore Transmission Operators submit tenders in competition for operating licenses for these lines, which is intended to ensure least cost and delay to the developers of actual wind power plants. At present nine such Offshore Transmission Operator agreements are in place.[42]

7.5. Summary

Many stakeholders cited congestion as a primary blockage to greater RE deployment. Some stakeholders claim that congestion occurs at the intrastate level, blocking the evacuation of electricity from power plants; others claim that congestion of the ISTS is blocking the wheeling of power further afield in times of local surplus.

It remains unclear where congestion is actually occurring, or if curtailment is caused by technical or market factors. In discussions, both are confused routinely. The extent of congestion both locally and intrastate is a critical area for analysis and should have high priority, as it will have bear-

42 See: https://www.ofgem.gov.uk/publications-and-updates/offshore-transmission-factsheet

ing on new grid needs that will take time to deliver.

More complete planning of transmission can also help manage the variability characteristic of some renewables. The more dispersed wind and solar power plants are, the less correlated and the smoother their aggregated output, reducing the cost of balancing and the need for additional flexibility.

In addition, the zoning approach may also: (1) enable access to the highest wind speed, (2) facilitate the identification of portfolio of projects likely to be of interest to larger investors, (3) optimise the CUFs of new transmission assets, (4) facilitate planning of solar and wind power plants concurrently, (5) manage land availability and access infrastructure needs, (6) encourage streamlining of permitting and grid connection procedures, and (7) reduce the risk of curtailment.

Although international practise suggests that the planning of renewable and conventional power plants is essential, however, it also highlights the need to remain flexible. One way to do this is to revisit plans regularly in the light of technology and other developments.

International experience suggests that the cost of large-scale transmission developments should account also for potential benefits in terms of reduced balancing needs, as well as their impact on the capacity value of the connected variable power plants. But in any case, new transmission may need to preempt generation, as it takes longer to build. This raises important questions as to the financing of such projects.

8. System Reliability with VRE at Scale

The capacity and location of the grid is a matter for careful consideration and planning. It is the vehicle through which power and load are brought into balance, and that balance is maintained.

Transmission and distribution networks are essential to move RE from where it is generated to the load. As discussed in Chapter 7, a large-scale transmission grid can also bring about considerable benefit in terms of reducing the extent of variability of output from wind and solar PV power plants and in terms of increasing access to flexibility resources in adjacent states.

This chapter looks at the other part of the integration story: the ways in which high penetrations of variable renewables affect the operation of the system and the ways in which system operation can be altered to manage it in order to bring about a reliable and cost-efficient supply of clean energy.

The physics of integrating VRE is less well understood in some quarters than financial or market aspects. Consequently, although renewable energy is advocated strongly, and financial mechanisms to support its deployment are much discussed, the perhaps less well understood system operation issues tend to be overlooked.

One senior stakeholder in system operation stated, "It scares me that land and funds are offered without addressing [these] issues. Anything that is not priced does not get the necessary focus, such as flexibility, reliability."

Indeed, stakeholders often pointed out that the design of financial support mechanisms should account for the resulting effects on system operation. One mechanism will differ from another in terms of the technologies stimulated to deploy, the range of system challenges they represent, their locations, and their capacity (as discussed in Chapter 2). For example, some stakeholders have suggested that the AD mechanism may have encouraged wind turbines that are harder to manage than those stimulated by the GBI.

Others highlighted that there are no reliability standards to express the acceptability (or not) of power interruptions to consumers. Such standards recognise the trade-off between the high marginal expense of the last power plant(s) needed to maintain absolute reliability of supply, and the value of those few hours/days when power may be lost. The situation in India is quite different. The obligation on Discoms to serve all their customers all the time is not upheld, and outages are at present a part of everyday life.

Internationally, there are two somewhat separate concepts within "reliability." Operational reliability is mainly about resource adequacy and determining reserve requirements to cover uncertainty and variability. Contingency reliability is the ability of the system to recover and maintain stability after faults and loss of large transmission or generation elements.

Grid Code-related standards could help with both issues. The Indian Electricity Grid Code[43] is the right venue for addressing such topics as low- and high-voltage ride-through provisions, voltage and reactive power (VAR) support, frequency and inertial response support, and reserves response.

Grid discipline in India is somewhat relaxed relative to international experiences, and stakeholders expressed concern during the roadmap process that in such a system, the introduction of still more variability and uncertainty on the supply side would be a considerable additional burden.

Meanwhile, although must-run status of renewable energy is provided for in statute, in practise it is very hard to know if this status is maintained. The causes and frequency of curtailment of RE plants are far from being clear (see Chapter 5 on operational risks).

A number of public bodies are involved in the operation of the power system. In an increasing number of mainly wealthier countries, system operation is independent of transmission and generator ownership. This is not the case in India, however, and system operation is itself shared considerably between the state LDCs and Discoms.

43 IEGC, 2010.

8.1. Power System Operation

A power system has to ensure that the production and consumption of electricity is almost perfectly balanced at every moment, in all parts of the system. Every conventional generator operates synchronously with every other, and all generate according to the needs of the machinery and domestic appliances (the load) that they power.

This physical link is expressed by the system frequency, which needs to be maintained. If generation rises above consumption, the frequency will rise. If it fails to keep pace with consumption, frequency will fall. As generation and consumption vary continuously in fact, the frequency is constantly oscillating above and below the target or "set point" of 50 or 60 Hertz.

The objective of the system operator is to keep frequency within this specified range, and to minimise the number of excursions from it, to prevent damage to the power system as well as load-side equipment. This is done in a timescale of minutes to hours. Of course, effective planning can make system operation easier,[44] but here we focus on the period just before electricity is produced and consumed.

When above the set point, production will need to be decreased, and vice versa. But there are alternative options to maintain balance: for example, demand can be controlled to fit with production; electricity can be stored in a hydro reservoir, battery, and in a range of other ways under development; and electricity can be imported and exported. All these options, if available, offer a measure of elasticity between production and demand, known as flexibility.

8.2. System Balancing Today

Balancing in India is overseen by a state LDC, and is done by each state as a whole. Given that some states are very large indeed – comparable to many countries in scale – this is already a very significant task.

The state LDC oversees the commitment of units to generate electricity at specified times. This UC may be done fortnightly (although this varies from state to state) on the basis of schedules communicated to the state LDC by public and private generators. The state LDC manages these schedules, updating UC accordingly; it also compiles actual production data, which is metered.

In many countries, a system operator will have a number of tools at his disposal, which can be used to maintain the balance of supply and demand as the two sides of the equation fluctuate. Chief among these is usually access at minimal notice to "operational reserve" power and energy. In other words, small quantities of additional generation are held in reserve. These can be "spinning," in which the generation is synchronised to the grid and can respond very quickly (ten minutes or less), or "non-spinning," in which generation is not grid-synchronised but can respond within a specified period of time.[45]

In India, only one of these tools is commonly available – load-shedding. There are no reserves as such maintained specifically to manage system frequency. Shedding load is done elsewhere in the world as well, when a system has a deficit of power. As India is in chronic power deficit, it is hardly surprising that load shedding is the only real option, although, as discussed in Chapter 6, there are other reasons why load-shedding is so common that relate to the financial health of Discoms supplying the electricity to consumers.

When, for example at night, supply outstrips demand, the other option available is to curtail that supply. "Backing down" conventional – particularly coal – power plants may be technically, economically, and politically constrained, with the result that in some cases, such as Tamil Nadu, wind power is seen to be the cause of unwanted surplus, and is curtailed accordingly (data on exactly how much this is happening was not available at the time of writing). This is observed in other countries also, such as China.

Although not strictly speaking a balancing tool, the Unscheduled Interchange (UI) mechanism was designed to encourage grid discipline, and thus does make the job of the state LDC easier. Generators "dispatch" themselves, according to the production schedule they submit to the state LDC, but prior to the UI there was insufficient penalty for departing from this schedule. Consequently, generators tended to dispatch themselves solely to maximise financial benefit to themselves, without taking into account the needs of the system.

UI was introduced in 2006 to provide a form of automatic balancing in that power plants were incentivised financially to reduce production as system frequency rose above the set point, and to increase as it fell below.[46] On

44 For example, moving of demand to the nighttime trough, as in Karnataka, to reduce the extent of daytime demand peaks.

45 Reserves may be positive or negative (the ability to reduce supply quickly), and may be provided by flexible demand or by storage resources also.

46 UI provides a response on the part of generators on a similar timescale to Tertiary Reserves in power systems (outside India) with dedicated operational reserves.

February 17, 2014, a new Deviation Settlement Mechanism came into force, replacing the UI regulations of 2009. The new mechanism is intended to improve grid discipline and remove opportunities for excessive injection or withdrawal of energy, including for commercial purpose.

Since January 2014, the entire Indian grid has been synchronised. The northern, western, eastern, and north-eastern grids were synchronised earlier, while the southern was synchronised with the rest last of all. Although this is a work in progress – flows between the two are still constrained – this greatly increases the scale of each system, with important potential consequences for the ability of the whole to absorb solar and wind power.

These include the smoothing effect of geographical aggregation of variable output (wind and solar) power (see Chapter 7), and other reasons discussed below. One senior system operation official expressed it as being a major part of the system's ability to "absorb" wind and solar variability.

8.3. Additional Challenges With Solar and Wind

Variability has been discussed in Chapter 7 to some extent in the context of planning the dispersal of such power plants to minimise their aggregated variability. It is further explored here in the context of managing variability in the operational timeframe. Uncertainty is introduced here, as it is inherently an operational issue.

Neither is new to the power sector, although historically variability has been an issue primarily on the demand side, whereas uncertainty is primarily a supply-side issue. System operators have for decades managed both.

8.3.1. Variability

Demand varies considerably within the day. Daily peak may be twice the demand low in smaller systems, although the difference tends to be smaller in larger systems, for example, approximately 30 percent in northwest Europe.[47]

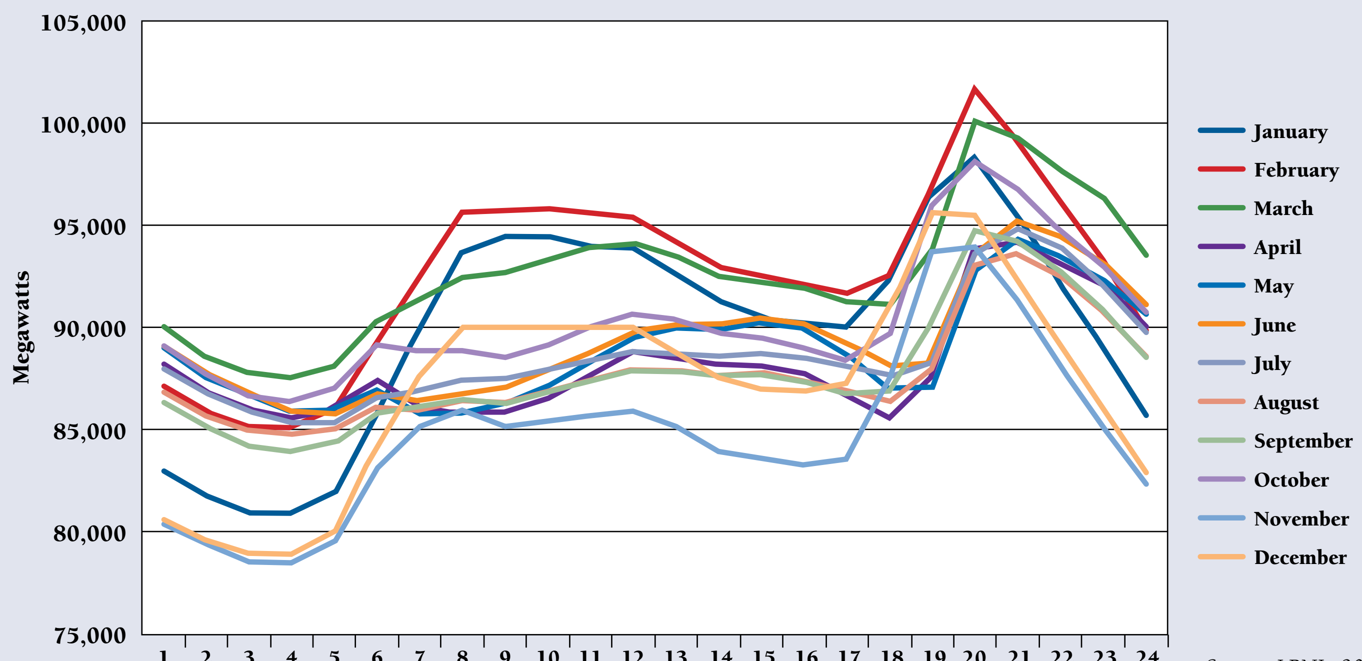
Figure 40 shows the average daily load curve of the country as a whole in 2009, for each month of the year. Load is lowest in the small hours of the morning, ranging from approximately 79,000 MW to 88,000 MW, rising to an evening peak at approximately 8 pm, ranging from 94,000 MW to 102,000 MW.

This also demonstrates the significant variations in demand over the year, which is illustrated more clearly in Figure 41. This shows the load in Maharashtra over one year, based on hourly data, fluctuating daily around the 10-GW mark in August to around the 13-GW mark in April.

47 IEA, 2014.

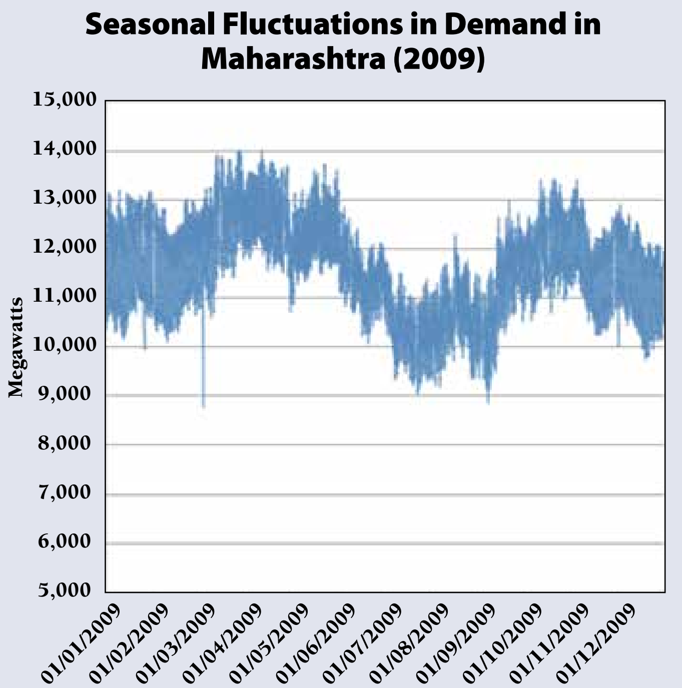
Figure 40

Average Daily Load Curves in India for Each Month of the Year (2009)



Source: LBNL, 2013

Figure 41



Source: LBNL, 2013

8.3.2. Uncertainty

Uncertainty is known in system operation also. Although the output of conventional power plants is more certain more of the time than that of variable RE plants, power systems are designed to accommodate what will be in fact very large fluctuations when such a plant does fail suddenly. These failures, not only of generator but of transmission and distribution lines also, can have major impacts on the overall system.

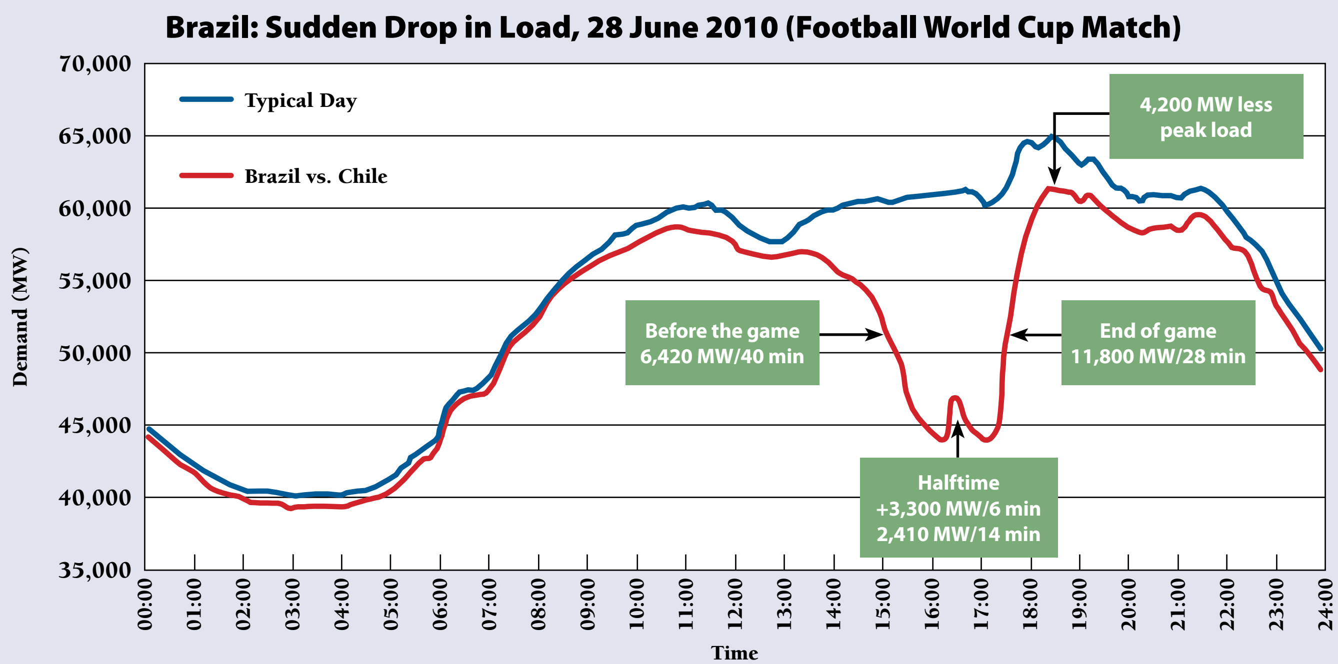
For example, on July 30 and 31, 2012, India suffered what may have been the largest blackouts in history. Both events were triggered by transmission faults during a period of extremely high demand, owing to the late arrival of the monsoon, while the late rains were also responsible for reduced hydropower capacity. A total of 32 GW of power plants were shut down across 22 states in the north and east of the country.

Unexpected events aside, both load and supply are expected to be uncertain to some extent. Power plants often deviate from their production schedule. Although precisely when they do this is not predicted, it is nevertheless anticipated that they will, with a certain probability, and this is factored into the planning of the system and of its operation.

Forecasting of demand is a mature and refined art, and mean absolute error from the day-ahead forecast in OECD countries is typically only one to two percent. But where load is particularly sensitive to weather conditions, for example, where air-conditioning represents a large proportion of demand, errors can be much greater.

On top of this, a range of events can cause demand to differ considerably from what is expected, or forecast. Figure 42 shows one such event in Brazil in 2010, during the football World Cup.

Figure 42



Source: (IEA, 2014)

8.4. Managing Variability and Uncertainty

The events of July 2012 did not relate solely to faulty hardware. The massive job of managing the Indian power system requires a commensurate level of human resources.

This will only increase as the variable output technologies such as wind and solar PV become more common. Many stakeholders signaled a major shortage of qualified personnel in state LDCs. As mentioned previously, the scale of the system they manage may be enormous, stretching personnel considerably. Finding, grooming, and retaining staff is a challenge, and particularly so with regard to RE expertise. Staff may be unfamiliar with a host of techniques that are evolving fast around the globe for the management of variable renewables, as discussed below.

A major new report from the IEA, *The Power of Transformation: Wind, Sun and the Economics of Flexible Power Systems*,[48] suggests that at a share of annual generation greater than two to three percent, wind power and/or solar PV is likely to increase supply-side variability and uncertainty. However, this will be minimal relative to the variability and uncertainty experienced already by the system as a whole. And as it is overall fluctuations that must be managed, the additional impact of the VRE plants will be nominal. This was the opinion of stakeholders involved in system operation in in Karnataka, for example, where wind penetration is at present considered to be of limited impact in these terms.

As their share in power supply increases, however, their contribution relative to other system components will be proportionally greater, and there will indeed come a time when system operation and planning needs to be changed in order to reflect this.

Assuming the power system in the state has a strong enough grid and is managed as a single entity, then it is not the variation in output from a wind turbine or solar PV module at any given time that must be balanced, but rather the overall change in the system at that moment. In other words, demand may be increasing as wind output increases; this may be beneficial in terms of the balancing challenge (and financial considerations aside). Alternatively, the sun may be obscured by clouds just as demand is rising, which is likely to increase the balancing task.

In Karnataka, for example, 38 percent of the load (the agricultural consumers) falls away at night, and stakeholders reported that it is already a challenge to manage such a drop in load, with conventional generators forced to ramp down fast to their minimum stable operating level. This minimum output level, perhaps 40 percent of rated capacity, perhaps more, represents an important constraint on a power system's ability to absorb variable electricity.

In other words, when these plants are on the "floor," short of turning them off altogether, with its own associated challenges, or exporting the surplus, there may be no load for surplus wind production to meet, and curtailment may be required at such times.

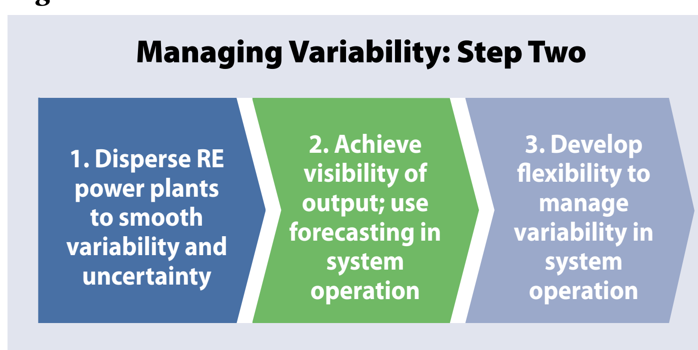
Certain system operation stakeholders felt that such non-complementarity of wind power output schedule and load was a far greater challenge than congestion of the grid, for example. In contrast, the same stakeholders found that solar PV output, coming during the day when demand is higher, was actually beneficial in terms of system operation.

8.4.1. Visibility of Output

The simplest kind of forecasting is known as "persistence" forecasting. The idea is very simply that the weather will continue to do what it is doing now. If the system operator knows how the individual turbines in a wind power plant are behaving in real time, then on that basis it can make a number of assumptions about output up to approximately two hours ahead. Similarly, solar output can be forecast based on clear-sky indices.[49]

If this appears rudimentary, the fact remains that at short timescales it is a remarkably accurate rule of thumb. It also underlines that system operation with variable power plants is something of an "art" learned over time. Thus, visibility of output is the second part of minimising the variability challenge, as illustrated below.

Figure 43



48 IEA, 2014.

49 As used in the recent Western Wind and Solar Integration Study Phase II, in the United States, for example, completed in September 2013, and available at http://www.nrel.gov/docs/fy13osti/55588.pdf.

Unit-by-unit data are important because if a wind turbine is not functioning for some reason, output will differ accordingly, and it will not be clear whether it was the forecast that was at fault or the turbine(s).

International experiences suggest that performance data already available to the operator of the wind power plant through the supervisory control and data acquisition (SCADA) system should be made available to the system operator on a minute-by-minute basis. Indeed, in the United States, connection to the grid has recently been made contingent on this commitment.

The need for real-time performance data may sound banal, but it is in fact fundamental, and a need that is very often not met in India today, where most wind/solar PV power plant operators appear to be unwilling to communicate the availability of their power plants, let alone at the unit level. This despite the fact that this is a requirement of forecasting rules introduced in 2010.

In Tamil Nadu, for example, it appears that approximately half of wind plants do not share their performance data with the state LDC. This is particularly a problem, as many wind power plants, including smaller ones deployed under the AD model before the system integration aspect was really considered thoroughly, have been connected to the low-voltage distribution grid, at 33 kV or less. At this voltage level, the grid is operated passively, which is to say pretty much left to its own devices.

As VRE is added to the grid, passive operation becomes more and more problematic. At the moment when electricity is actually delivered and consumed, the state LDC has no knowledge of what these plants are doing. They have no way of knowing for example, other than intuition, where a given group of plants is operating at maximum, or has tripped off the system. In contrast, most variable plant in Gujarat, including all of its major new solar developments, are connected at the 66-kV level or above, their output metered in real time and visible to the state LDC, which can respond and plan ahead accordingly.

This was also the case in the United States, for example, where previously there was no standard for exchanging data between wind projects and system operators. Wind companies were not familiar with the equipment needed, and the exchange was not enforced.

One of the first countries to fully integrate the real-time monitoring of wind and solar power output into its system operation was Spain. In 2006, Red Eléctrica de España, the system operator, established the Control Centre of Renewable Energies (CECRE). This is highlighted in Box 2.

The Renewable Energy Control Centre in Spain

The CECRE was established to manage a surge in deployment of wind power in Spain. Its objective is to monitor, control, and maximise RE production, while maintaining the reliability of the system as a whole. CECRE is located in the headquarters of the system operator, and is an integral part of system operation. It consists of an operational desk at which operators continuously supervise RE production. A number of renewable energy control centres around the country collect real-time information and channel to the CECRE desk, which is able to act as a single point of contact with operators of other parts of the system.

The use of automated control software, and Information and Control Technology more generally, has been a key factor in the success of the centre. The main tool used by CECRE operators, GEMAS, accesses the real-time information received in CECRE and uses it to determine whether the present generation scenario is admissible for the system according to a number of security criteria.

The Green Corridors Report published by the MoP in July 2012 proposes the establishment of Renewable Energy Management Centres (REMC) in seven RE resource-rich states: Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Maharashtra, Rajasthan, and Jammu and Kashmir. It suggests that these would work in tandem with the respective state LDC. It also proposes REMCs at the regional level, in the northern, western, and southern regions where resources are strongest, and finally an REMC at the national level.

REMCs might help inform dispatch decisions, if these are taken relatively close to real-time. For example, the REMC could signal LDCs to reduce output from coal-fired plants to fit better with the output of VRE plants if there is a risk of surplus otherwise.

Stakeholder responses to the REMC concept during the roadmap process differed considerably. It was commonly agreed that their establishment should focus on practical support to the system operator. State LDCs at present have limited technological capability in terms of monitoring and managing the grid. Automated decision-support systems, standard in the western countries, have not been made available to Indian LDCs.

The cost of doing so would be minimal in the scheme of overall system investment, but it appears to be unclear whose responsibility it would be to install such equipment. Some felt that the LDC should itself identify its needs and attempt to secure a budget from within state government funds, and felt that the REMC should be integrated with the state LDC.

Others felt that the REMC approach, although perhaps valuable, should be taken quite separately from the LDC, while remaining in close contact with it. Indeed, the Green Corridors Report in its brief allusions to the concept does appear to suggest the two entities to be separate.

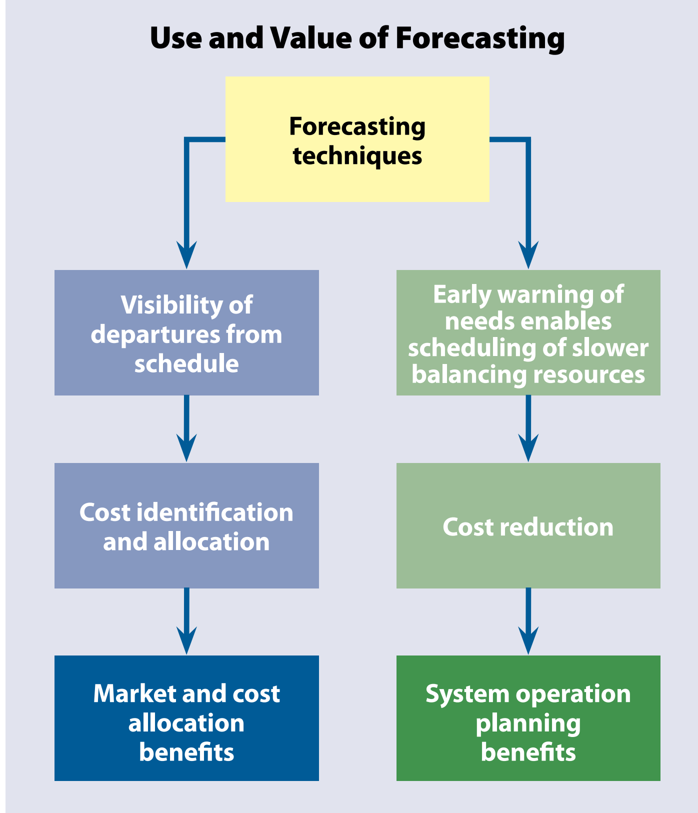
Additional information on the operation of VRE plants is certainly valuable. But it is worth considering the form in which this might be achieved. It could be argued that an entity separate from the LDC would represent another bureaucratic layer to fit in the already busy operational timeframe. An alternative approach might be to add displays with wind and solar output over time, and expected wind and solar forecasts at the relevant LDC, along with trained personnel.

8.4.2. Forecasting Changes in Output

Past performance and present output are very valuable to enhanced understanding of how variable renewable power plants are likely to behave. State-of-the-art forecasting is an important step further. Forecasting has two main functions: (1) to inform decision-making related to the trade of electricity from wind and solar plants, and (2) to facilitate scheduling of power plants and the operation of the system in the most effective and reliable manner (Figure 44). System operation is more concerned with large, infrequent errors, whereas owners will care about output errors that may even out at the system level.

Owner forecasts may be of utility scale or aggregated smaller plants, but the objective is the same: to give a clear picture of output so that owners can accurately predict volume and timing. It also provides the basis for calculating imbalances when actual production does not match the forecast.

Figure 44



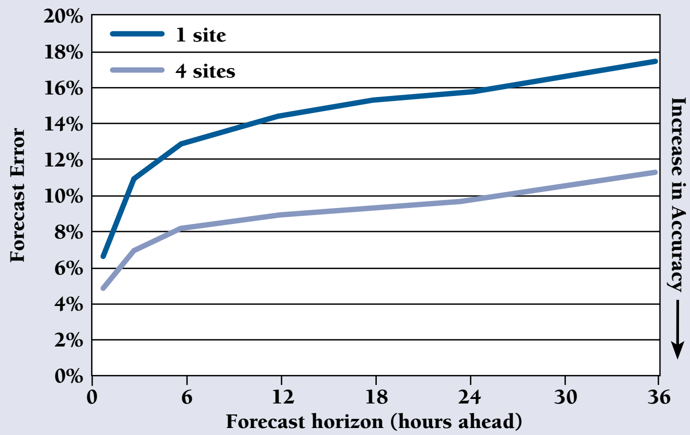
The second function is to enable the system operator to anticipate the supply-demand imbalance for any period, and plan accordingly. A few hours' notice of how wind and solar plants are likely to behave can greatly enhance the operator's ability to manage the system. Depending – crucially – on the flexibility of grid operation practises, this notice can reduce the need for very short-term flexibility (such as load-shedding or paid reserves), so reducing balancing costs; the operator can instead redispatch other, less flexible, power plants accordingly, those that are able to respond within the timeframe of the forecast (dispatchable power plants often have significant startup time requirements). In this way it can significantly increase the ability of a system to absorb variable output from these power plants.

Variations in the weather and therefore output can be predicted in terms of extent and timing, but not perfectly, and there are a number of ways in which local climatic conditions can affect the output, particularly of wind power plants. This can lead to significant under- or overproduction relative to expected. The greater the share of such power plants in the system, the greater the impact of such deviations from what is expected.

This is more pronounced in wind power output, which

Figure 45

Impact of Forecast Aggregation on Accuracy



Source: Holttinen at al., 2006 (from IEA, 2014)

does not share the underlying regularity of solar power output, although short-term variability of solar PV can be high in frequently clouded areas. If an RE power plant is expected to submit a forecast of its output as a schedule, and if deviations from this are subject to penalties, then this will also have significant impact on the profitability of the power station.

Similarly to the effect of aggregation on overall variability of output (the smoothing effect discussed in Chapter 7), the prediction of when that output will occur is also more accurate when it covers the aggregated output of many power plants rather than a single site. Figure 45 illustrates the difference in output forecast error between one and several wind power sites.

Forecasts are more accurate when the forecast horizon is short. For example, in Spain, hour-ahead forecasts are approximately three times as accurate as forecasts made of the day-ahead, as illustrated in Figure 46.

Being a younger technology, it is not surprising that solar PV power forecasts are less mature than those for wind power. Issues include being able to predict the formation of clouds day-ahead or longer in advance, and forecasting in aggregate of behind-the-meter solar systems. It can have very high accuracy indeed, however, particularly during clear weather when output can simply be determined by the position of the sun in the sky.

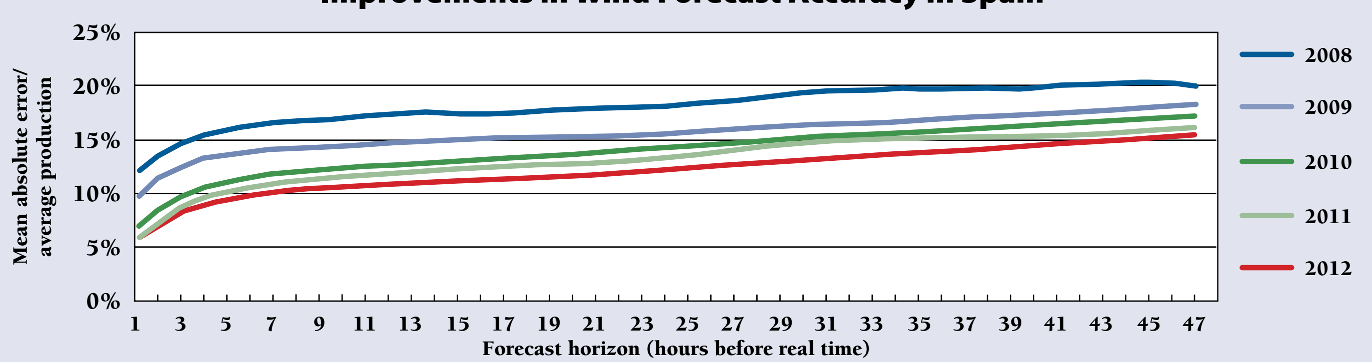
India does not have specific reserve practises or a formal market for reserves, sometimes referred to as an Ancillary Services Market. Stakeholders have suggested that such an opportunity to ensure sufficient reserves against system balancing requirements may arise as the share of solar and wind power plants continues to grow. Reserves practises worldwide are evolving rapidly to accommodate increasing amounts of VRE.[50]

Should ancillary services provision emerge, through an organised market or otherwise, the value of forecasting will again be apparent, in identifying what the requirement for reserves will be, and when. In this respect, it is worth emphasising that forecasts are only as useful as they are considered reliable by the system operator.

Forecast quality has seen major improvements in recent years. For example, in Spain, the "mean absolute forecast error," the key metric for forecast accuracy, has reduced considerably over the last five years, as illustrated in Figure 46. Forecasts looking ahead one to three hours show only half the forecast error of four years previously, while day-ahead forecast errors have reduced by a third. This is a

Figure 46

Improvements in Wind Forecast Accuracy in Spain



Source: (IEA, 2014)

50 Active monitoring of international developments may be a useful action for stakeholders. "Task 25" of the IEA's Wind Implementing Agreement is a principal source of expertise in this area. See: http://www.ieawind.org/task_25.html.

consequence of improved techniques, but also of increased visibility of output, which may be achieved through the use of control centres (Box 2).

Spain uses multiple forecasting companies, and produces ensemble forecasts based on the historical accuracy of forecast companies in those particular weather conditions. Alternatively, one can use a single forecasting company that produces dozens, even hundreds of forecasts by altering inputs into the forecast.

Again, historical data are used to "train" the forecast. The use of historical data highlights the need to be sure that times of curtailment and lost production from unscheduled or scheduled outages, from a turbine to the whole plant, be accounted for. Otherwise, "bad" data would be used for training the forecast, with a corresponding impact on forecast accuracy.

8.4.3. Forecasting in India

The CERC, in its Indian Electricity Grid Code of 2010, mandated forecasting and scheduling for grid-connected wind power plants of 10 MW or more commissioned after May 2010, the intention of which was to provide state LDCs with more visibility of wind power generation.

The power plants concerned are to provide a schedule for each 15-minute operational block. This schedule can be updated a number of times, but within three hours of the time of delivery, no further updates are allowed, and deviations from the final schedule may not be greater than 30 percent, subject to penalties. This cut-off point gravely interferes with forecasting, effectively removing persistence-based forecasting from the forecasting toolbox. This forecasting requirement is suspended at the time of writing.

The CERC has also introduced a Renewable Regulatory Fund Mechanism in 2013, designed to provide support to states having to procure (expensive) balancing power, or paying high UI penalties, in the balancing of variable power plants. At the time of writing, the commercial framework under the Renewable Regulatory Fund Mechanism has been suspended.

Wind power developer concerns expressed by stakeholders were essentially twofold: (1) that forecasting is required at the level of the individual pooling station, rather than at the state level, for example, and (2) that deviations from schedules were too costly.

As highlighted above, forecast accuracy is greater over larger areas. Stakeholders suggested therefore that forecasting ought to be at the state level, rather than the "pooling station" level as currently required. It might also be added that forecasts should be integrated into overall planning of system operation, rather than being managed in isolation. However, the necessary resources in state LDCs, not to mention the establishment of REMCs, may be prerequisite.

Stakeholders pointed out that aggregating forecasts at the state level might complicate the allocation of penalties. Still others suggested that this might be resolved – along with the financial burden on developers generally – by socialising the costs of imbalances. There are a number of approaches to paying for imbalances worldwide. Generators in Denmark are paid the spot market price for imbalances that support overall system balance, and charged for imbalance that exacerbates system imbalance.

Secondly, the extent of penalties arising from deviations from schedules has caused apprehensions among developers, to the extent that in many cases the requirement is simply ignored. Indeed, such was the distrust of the mechanism that according to the system operation stakeholders, even during the test period for the mechanism, during which no penalties were payable, it was ignored.

International experiences suggest that the value of forecasting to system operation in India is clear. The more it is integrated into system operation practises, the easier it will be to manage a system with large shares of wind and solar power. The priority given to its implementation should not be subject to decisions on how the costs of imbalances should be allocated (i.e., the market value of forecasting should not be confused with the benefit to system operation).

Finally, it should be added that forecasting is only as good as the underlying data. Good quality meso-scale wind and solar data are needed, with a reasonably fine geographic resolution.

8.4.4. Impact of the Banking Mechanism

Under the banking mechanism, large consumer owners of captive power plants connected to the grid elsewhere (i.e., not behind-the-meter) are able to "bank" electricity in the grid. This means that they may consume electricity when their power plant is not producing, and vice versa, subject to a schedule.

This mechanism is particularly valuable to wind power plants, whose output cannot easily be controlled. Indeed, preferential banking charges for wind power plants have been used as an indirect financial stimulus to their deployment in, for example, Tamil Nadu, where more than a third of installed wind capacity is of the captive variety.

Similarly, OA contract holders can take advantage of the same mechanism to manage inconsistencies between production and consumption schedules.

In both cases, the system operator is left with the responsibility for balancing this temporary discrepancy. It may therefore be appropriate for OA generators to provide data to the operator for visibility and forecasting. If OA contracts multiply for RE, it may also be appropriate to consider the additional balancing resources to manage their output.

As it is the Discom (or the Transco in the higher-voltage transmission system) that establishes the rules for banking (under the oversight of the SERC), this may help explain why OA has had limited success at the intrastate level: Discoms may see VRE OA contracts as a source of additional complexity, and thus undesirable.

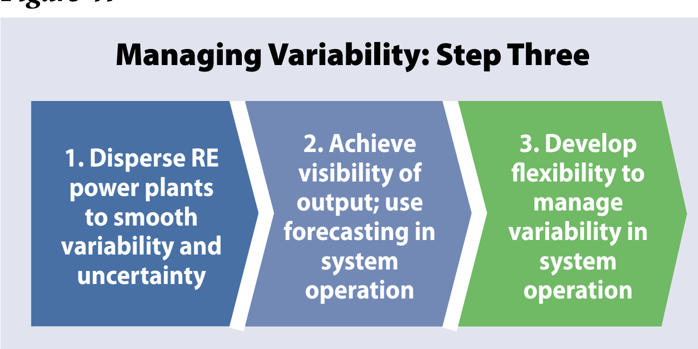
8.5. Managing Integration With Greater Flexibility

Chapter 7 focussed on the importance of dispersal of VRE power plants, to smooth variability and uncertainty to an extent that corresponds with the scale of the area over which plants are dispersed. So far in this chapter, stakeholder views on the importance of visibility and forecasting of output has been the focus.

There is a third step in the management of wind and solar power plants as highlighted below. This is to make available a maximum of flexible resources for balancing. These flexible resources are already present to manage demand-side variability. However, their availability for use in managing supply-side variability and uncertainty will be limited by grid congestion and market design.

The variability and uncertainty associated with increasing shares of wind and solar generation necessitate the cycling of other power generation plants to keep the electric grid in balance. Put simply, 1 MW of variability in the "net load," up or down, requires a commensurate response of 1 MW increase or decrease of supply and/or consumption in the same balancing area.[51]

Figure 47



That response is known as "flexibility," and a truly flexible power system is one in which all the major constituents – generators, consumers, and transmitters – operate dynamically in concert, responding to changes in one another. In India at present, the opposite is now true. As one stakeholder put it, "Unconventional and conventional segments… operate as two separate, water-tight compartments."

8.5.1. Sources of Flexibility

Flexibility is traditionally considered to reside in the ability to vary the output of certain "dispatchable" power plants (e.g., coal, gas, hydro). Coal-fired power stations in India are generally considered to be inflexible, although further data are required as to their technical abilities to ramp up and down, against time. Options exist to retrofit coal-fired power stations for lower minimum stable operating level capability.

Stakeholders in Tamil Nadu noted that the slow ramping ability of coal plants was the principal cause of the curtailment of wind power plants. Unable to leave the state for market design reasons, wind power can ramp up only to the maximum extent to which coal stations can ramp down – their minimum stable operating limit. Beyond this level, with no further space in the system for wind power, it is curtailed.

Power plant cycling includes ramping up and down, shut down and start up, and operating the power plant at part load. European values of the cycling parameters of some conventional technologies are shown in Table 6.

Power plants are dispatched not only based on their marginal cost of operation, but also according to their ability to respond to changes in system requirements. Cycling can introduce additional wear and tear on thermal power plant equipment, resulting in increased costs, and also leads to changes in emissions. The extent of these impacts on costs and emissions depends on technology and power plant characteristics.

According to Western Wind and Solar Integration Study, which analysed the impacts of up to 33-percent variable renewables penetration in the Western Interconnect of the United States, the increase in fossil power plant emissions per unit output from cycling to accommodate variable renewables were minor, and more than offset by the overall reduc-

51 The term "net load" in this context is used to signify the demand (load) that remains to be supplied (by other sources of power, such as coal-fired plants or imports) or reduced by demand response, once VRE output has been accounted for.

Table 6

Generation Characteristics of Selected Conventional Technologies

	Nuclear	Coal	Lignite	Natural Gas Combined Cycle Technology	Pumped Storage
Start-up time "cold"	~ 40 hr	~ 6 h	~ 10 h	< 2 h	~ 0.1 h
Start-up time "warm"	~ 40 hr	~ 3 h	~ 6 h	< 1.5 h	~ 0.1 h
Load gradient "nominal output"	~ 5%/min	~ 2%/min	~ 2%/min	~ 4%/min	> 40%/min
Minimal shutdown time	None	None	None	None	~ 10 h
Minimal possible load (% of maximum capacity)	50%	40%	40%	< 50%	~ 15%

Source: EurElectric data 2011

tion of CO_2, NO_x and SO_x. Operating costs of fossil power plants were shown to increase by two to five percent per kWh on average, which were small compared to the overall fuel savings associated with wind and solar generation.

However, results are likely to differ in jurisdictions with different generation mixes, especially those with very large shares of coal generation. Whereas hydroelectric power plants are capable of fast ramp rates, there are limitations to hydro ramping to protect aquatic systems and downstream communities. Integration studies could significantly contribute toward the understanding of such costs and impacts to the overall system.

Existing gas plants in India are currently operating well below capacity owing to high fuel cost. The value they offer in terms of flexibility may offset some of the difference in cost. For example, the Dabhol plant (22 GW LNG plant in Maharashtra built by Enron) is presently subsidised Rs 3 to 3.5 crores per annum, and has never generated above 40-percent rated capacity.

Flexibility can also be found on the demand side, reducing demand in response to availability of supply. The load-shedding experience of India is highly relevant in this regard, although demand-side response in the balancing context is perhaps better thought of as interrupting supply of electricity without interrupting the services it supplies.

For example, short, staggered interruptions of supply to commercial cooling applications over a wide area could have considerable short-term reduction in aggregated demand, with no impact on the service provided as the cool store is insulated against heat loss. As with a power plant, the cost to the consumer of providing this service could be monetised and marketed.

Stakeholders in Maharashtra revealed interesting experience in shifting time-of-use of electricity to more convenient times, albeit in a longer-term, less dynamic manner than that described above. To manage fast-growing industrial load, the SERC has brought about cheaper nighttime rates for industrial consumers (from 22 hours to 6 hours).

The intended and achieved effect has been to shift industrial demand into the nighttime hours to some extent. But it has also been beneficial to manage peak wind output, which tends to be higher at night. As the nighttime tariff is still higher than the wind FIT, the Discom does not suffer reduced revenue, and there is little difficulty with absorbing present levels of wind power production in the state.

Finally, energy storage technologies may be available in India in the form of pumped hydro, which can be charged when electricity is in surplus, and discharged when fast flexibility is needed. Given that such resources are rare in India, and spatially restricted, it should be noted that storage is far from being the only solution to the integration of wind and solar power, as is often claimed.

8.5.2. Using Flexible Resources Better

Flexible resources must be available when they are needed. Transmission congestion was cited most frequently by stakeholders as the main potential constraint on flexibility (See Chapter 7 discussion), although there is insufficient evidence as of yet to prove that the ISTS is in fact congested. If not, then just a few percent of ramping capability in coal power plants around the country could represent an enormous flexibility resource.

Grid congestion aside, stakeholders consistently pointed out that collaboration among balancing areas will not only reduce aggregated variability and increase accuracy of forecasting, but also offer the chance to share flexible resources in the balancing challenge.

Collaboration among balancing areas is of particular value when system operators have access to reserves they can call on. For example, in the United States, in numerous analyses the sharing of balancing resources among previously distinct balancing areas has been shown to reduce the need for them, on one timescale or another.

But Indian state LDCs do not maintain reserves in this way. Indeed, almost all power plant generation is tied into long-term PPAs that emphasise maximum output over all other benefits. And not surprisingly, given the chronic power shortages in the country.

If greater balancing resources are needed already to manage wind and solar electricity, then it may be necessary somehow to extract some of that PPA-bound electricity from existing agreements in order to keep it available for balancing purposes.

This may be less problematic than it may appear. Many stakeholders have pointed to recent experiences of the conventional utility in Germany, RWE, which has recently posted losses for the first time since it was established in the 1940s, as well as to the first signs that in India the conventional base-load, around-the-clock, 24/7 business model also may be being undermined by increasing penetrations of prioritised wind and solar electricity.

Such conventional power plants – and for the remainder of their operating lives – will remain important for the very large capacity they represent. Consequently, losses in terms of reduced electricity production might need to be compensated by new revenue streams.

Stakeholders suggested that these new revenues may be found by operators of conventional (and even variable) power plants through participation in an ancillary market for reserve power. Such a market does not exist today and it is not clear as of yet that it is needed, but in theory at least this could provide an opportunity to maintain adequate reserves of power (on a timescale of seconds to hours) through a capacity/availability payment (and possibly an energy payment).

Numerous examples of such markets exist around the world. One good example is the Grid Control Collaboration in Germany. But what about capacity needs over the longer term? The extent of financial damage to the German utility is so great that there are concerns that a large number of power plants essential for meeting long-term peaks in electricity demand may be mothballed or even permanently retired.

Where this is at risk of happening (and in India as a whole, this day may still be far off) it may be necessary to establish a market for long-term flexible capacity. Such markets already exist and are under development, or under consideration, in an increasing number of countries seeing large-scale renewable energy investment.

When in electricity deficit, or with enormous demand growth – both of which are the case in India as a whole – such revenue issues are unlikely to be a problem: there is more than enough load to go around. The state of Gujarat, however, is in surplus. It has exceeded its RPO, so that prioritised renewable energy is eating into the revenues of its conventional power plants. In additional, large consumers are moving to OA (see Chapter 6) and buying from outside the state either bilaterally or through the exchanges. Consequently, existing conventional plants are being backed down to the extent that in March 2014 the state forbade the purchase of electricity from outside the state.

8.5.3. Costing Additional Flexibility Needs

There remains however the task of assessing how much flexibility exists at present and how much is needed to provide for balancing the targeted deployment of renewables. This is a complex task that would require close collaboration between system operators and would require complete transparency of the performance data gathered by the operators of renewable power plants as well as data on the technical capabilities of conventional power plants on a unit-by-unit basis.

A number of studies have been carried out in the United States, for example, in recent years, including the Western Wind and Solar Integration Study, and the Eastern Wind Integration and Transmission Study carried out for NREL. More recently, the PJM Regional Transmission Operator recently published a comprehensive impact assessment of increased penetrations of wind and solar generation resources on the operation of the PJM grid. The footprint of the PJM Regional Transmission Operator covers all or part of 13 states in the northeastern United States.

The main objectives were to determine the operational, planning, and energy market effects of large-scale integration of wind and solar power in the PJM balancing area. The study modeled the impacts of up to 30 percent wind and solar electricity share in overall electricity, produced by more than 100 GW of installed capacity, as perceived possible by 2026. Although the study highlighted a number of transmission upgrades and operation aspects, it found that no additional operating reserves would be required.

The implication of this is very important: that the reserves already in existence to manage variability and uncertainty in the system can also be used to manage new variable power plants. This is quite contrary to the views expressed by some stakeholders, in India and beyond, that dedicated back-up is needed.

8.6. Local System Benefits of RE

This chapter has focussed on the challenges of managing variability and uncertainty. But stakeholders also acknowledged the benefits of distributed generation, including distributed renewables, in supporting the distribution grid in which they are embedded, for example:

Voltage Support: Voltages at the end of long feeders – distribution lines – can sag problematically. In Maharashtra distributed renewables are providing valuable voltage support at weak points, feeders that may be as long as 40 to 50 kilometers.

Reliability through Island Mode: Distributed generation can support local reliability in other ways. If discreet parts of the distribution grid can operate in "island" mode when the surrounding grid is in fault/blackout, thanks to the presence of distributed generation, this is of enormous benefit to consumers.

But as one stakeholder put it when referring to the benefits of renewable energy, "Nobody focuses on the reliability part." In this regard, a study of the value of distributed generation would be valuable, which might compare distribution voltage profiles with and without distributed generation. This may be particularly relevant as solar PV costs continue to decline and deployment increases.

As solar PV has scaled up dramatically in the German electricity sector, its ability to produce certain local system benefits has been required. This is partly because of the fact that almost all of the installed PV has appeared at the low- and medium-voltage grid level. As in India, typically the lower-voltage grid network is not actively managed, unlike the high-voltage network. But since 2010, PV power plants in Germany connected to the medium-voltage grid (10 kV to 110 kV) have had to comply with certain standards. These include voltage support and active power control, and from 2011, fault ride-through capability also.

8.7. Summary

Overall, the physics of integrating VRE is less well understood in some quarters than financial or market aspects. Stakeholders often pointed out that the design of financial support mechanisms should account for the resulting impact on system operation. This may be positive as well as negative, as experience with distributed solar PV in some areas has shown.

Stakeholders agree that variable renewable power plants such as wind and solar PV do not introduce into power system operation any characteristics that are intrinsically new. This is borne out by international experiences that highlight the fact that, although changes will be required with large shares of such power plants, the existing resources of power systems are to a large extent up to the task.

It is also recognised, however, that the Indian system operators do not yet have at their disposal the significant human, technical, and financial resources that are present in most other large countries with major renewable ambition. Much discussion revolved around the concept of REMCs mooted recently by the MoP. International experiences suggest that such an approach will have great value if it is properly resourced, and closely integrated in power system operation.

In addition to planning the dispersal of power plants, to reduce the aggregate variability and uncertainty of their output, a number of tools exist in the operational timeframe and could be implemented affordably.

First of all, although some stakeholders showed some reluctance in this regard, it is essential that state LDCs have visibility of the output of renewable power plants. This should be supplied in real time at the unit level. With more complete knowledge of real-time performance, state LDCs can develop their own experience of these technologies.

Forecasting of output is essential for the planning of system operation. Its value in terms of quantifying and apportioning balancing costs should not be confused with the latter. Stakeholders felt strongly that although forecasting should have high granularity, forecasts should be aggregated tat the state level. Transmission congestion aside, this should make possible a more realistic view of the balancing challenge.

Load shedding at present represents the sum total of the tools in use by the system operator for balancing, although this is currently controlled by the Discoms. It is not yet known what reserves could be made available to state LDCs, nor the level of reserves required to meet targeted deployment of renewables.

Many stakeholders expressed the value of collaboration among state LDCs, in effect to share the balancing of overall fluctuations in the supply–demand balance. International experiences suggest that this can have considerable value, which can be monetised, and would increase the flexibility value of coal-fired power plants generally considered to be inflexible. However, such collaboration would require strong central leadership to overcome political and other barriers.

9. Policy Recommendations

The RE Roadmap Initiative's broad stakeholder process held under the Chatham House Rule allowed for frank and thoughtful conversations about the opportunities and barriers to RE as seen by diverse policymakers and stakeholders in India's power sector. The results were enriched by consideration of international experience (successes and setbacks), and by feedback from international experts. Although there was not complete consensus, there was significant agreement on the challenges and obstacles facing a rapid scale-up of RE in India and the principles that would be the foundation for any solutions. On this foundation, this paper suggests a framework for an integrated policy strategy for rapid RE implementation that complements both the existing and planned conventional power projects.

The intent of this chapter is to outline a small number of specific near-term steps that the Government of India, state governments, and stakeholders could take to begin the power sector retooling process that will accelerate the country's deployment of RE. These recommendations were finalized during the fall of 2014 after circulation and solicitation of comments from many of the original stakeholders in the Roadmap Initiative process.

9.1 What is Holding RE Back?

Stakeholders involved in the roadmap process were very clear in identifying the key problems constraining the rapid development of RE in India. Chief among these roadblocks is the absence of a comprehensive and coherent national framework for RE in either legislation or policy. The absence of a long-term vision as well as policy-certainty is holding back much-needed investment in infrastructure and RE generation. In addition, policy that does exist is limited by weak enforcement or low ambition (e.g. some RPOs), poor design (GBIs, AD, FiTs) or uncertainty (e.g. capital subsidies, other incentives).

Furthermore, there are simply not enough willing and credit-worthy buyers. Stakeholders said that discoms, the primary purchasers of RE, perceive that the cost of RE is more than they are willing to pay, and developers and financial institutions perceive high levels of credit risk with discoms in general. While the latter is clearly a broader power sector issue, it has a strong negative effect on the development of RE, as most of the dedicated RE developers do not have significant investment resources.

Developers felt that the overall RE project development environment is unnecessarily and prohibitively difficult. Key among the issues raised by stakeholders is the lack of coordination among key institutions — grid operators, discoms, state revenue departments, and environmental permitting agencies — that leads to time and cost overruns in project development. Unnecessarily high transaction costs resulting from the lack of coordination are especially prevalent in the areas of land acquisition, transmission interconnections, and environmental clearances.

Finally, most stakeholders agreed that there is a dire need to expand grid infrastructure and upgrade state, regional, and national grid technology and operations procedures to integrate intermittent RE into the grid. And in conjunction with the technology and operations upgrades, there was a consensus that regulators and policymakers need to develop and implement mechanisms to procure and reasonably compensate ancillary and balancing resources.

9.2 Core Principles for Overcoming Barriers to RE

There will, of course, be many specific alternative approaches and strategies to achieving a successful RE policy. But the five core principles discussed below must be at the heart of any of those new efforts. These principles have been synthesized from the best thinking of Indian stakeholders and international experts. They, and the logic for their inclusion, are presented below:

- **Treat RE as a resource of national and strategic importance**
  - Many of the most important macroeconomic and environmental benefits of a large-scale transition

to RE accrue to the nation as a whole. As a result, a significant central role in the support and coordination of RE is required. Without a strong central role, many of the benefits will simply not be recognized, nor realized, resulting in lack of action by states.
  - Like coal, RE occurs in some places and not in others. A large-scale transition to RE needs a national marketplace with a national grid (analogous to a national railway system for coal transportation) so that electricity generated in one region can be consumed in other regions when and where it is needed.
- **Mandate RE as a significant component of the power sector**
  - Decades of professional experience, along with national and state financial, legal and technical support have created the current power system and its operating ecosystem (e.g., engineers, consultants, regulators and bureaucrats). To overcome institutional inertia, and to capture the benefits of a rapid transition to RE, it will be necessary, at least for the first few years, to give RE a legal and policy preference by making RE a mandatory component of the power sector.
- **Take an integrated approach to power sector planning, including generation, transmission, and distribution**
  - As fuel prices become increasingly volatile and renewable options become more and more cost-competitive, the danger of building-out the wrong system and having significant "stranded future investment" becomes increasingly higher. At a minimum, national authorities should provide their perspectives on the relative financial, operational, social and environmental merits of different generation, transmission and distribution options (both on supply-side and demand-side) on a long-term risk-adjusted basis to all power sector stakeholders on an annual or biannual basis.
- **Make buyers indifferent between conventional and RE resources until grid parity is achieved**
  - Given the federal structure of India's power system, state and local buyers can choose to buy, or not to buy, whatever power they want, independent of the preferences of the national government. In order to rapidly scale RE as a national resource, buyers, at least until grid parity is achieved, need to be made indifferent between the cost of renewables and the cost of traditional (fossil-based) alternatives.
  - All efforts should be made to reduce the upstream costs of RE development and deployment, so that the incremental cost facing buyers is as low as possible.
- **Give small-scale/distributed RE, close to end-users, priority equal to large-scale/centralized RE**
  - Given the experience and current expertise of most existing power sector participants, the benefits of small-scale and distributed RE may not be apparent to them. To keep implicit and explicit institutional and legal impediments from obstructing the rapid rollout of small-scale distributed renewables, new policy and law needs to give equal treatment to small-scale distributed renewables from legal, policy, engineering, financial and governance perspectives.

9.3 Policy Recommendations

The principles described above are the foundation for the recommendations that follow. India needs an integrated policy strategy for rapid RE implementation that complements both existing as well as planned power projects. The four key recommendations presented here target:

- legislative/policy framework
- implementation support mechanisms
- grid integration of RE
- off-grid RE

9.3.1 National RE Law and/or Policy

A comprehensive, transparent, long-term, and definitive legislative/policy framework for RE should be implemented by amending existing laws/policies (e.g., address electricity-related aspects from the Electricity Act) and/or creating a new laws/policies (e.g., dedicated to renewable energy as whole). The laws/policies need to establish a clear and overarching independent rationale for RE. They also need to stress the importance of RE relative to fossil fuel-based generation. In addition, similar to fossil fuel resources (coal, oil, natural gas, etc.), RE could be considered a "resource of national importance" as it addresses several fundamental national objectives such as energy security, reduction of trade deficit, enhanced land/water availability for non-energy purposes (e.g. agriculture), cutting-edge industrial and RD&D (research, development and deployment) growth, increased employment, and others. Some essential features of a potential RE policy/legislative framework are presented below:

Targets

The law/policy should establish national RE targets that would incorporate an appropriate but measurable metric (e.g. generation, capacity, share of consumption, etc.) to monitor progress in achieving the targets. All states would be equally responsible to meet a common national uniform target. The law/policy should include appropriate "sunset" provisions that would allow regular opportunities (say, every five years) to update the law/policy in light of the evolving set of issues pertaining to RE.

The rationale for setting the targets should account for the various benefits and costs described previously — e.g., reducing the trade/fiscal deficit, environmental protection, energy security, reducing water requirements, etc.

Financial Support Required for Achieving Targets

The law/policy should clearly identify the source, level, and distribution mechanism for financial support for reducing the incremental cost of RE (includes both generation and integration costs) to the ultimate buyers as compared with the already subsidized fossil fuel-based generation. The incremental cost-assessment should also include various components, including: the comparison of new fossil fuel-based generation with RE, cost of energy, capacity value of RE (e.g., a resource is considered to have higher "value" if its availability coincides with high demand periods and locations), associated risks (e.g., fuel cost and availability for fossil fuel-based generation), externalities (e.g., land/water availability relative to other non-energy purposes), and others.

Integrated Energy Resources Planning

Comprehensive and analytically sophisticated planning exercises should be undertaken routinely in order to assess the benefits and costs of various aspects of the electricity sector, including supply-side resources (e.g., coal, hydro, gas, nuclear, RE), the transmission and distribution networks and their operation, and demand-side resources (e.g., energy efficiency, demand response, etc.). All possible benefits and costs should be considered irrespective of their direct relationship to the electricity sector, ease of quantification and monetization, etc. These planning exercises should explicitly and systematically account for various risk factors such as fuel availability, fuel costs, and others.

Programmatic Approach

The new requirements for the entire power system consist of a portfolio of two complementary policy approaches:[1]

- A restructured and enforceable RPO that incorporates a mandatory national uniform obligation on all bulk buyers (i.e., discoms and open access consumers). The RPO mechanism can be structured to allow all possible generation project developers — pure-RE developers, discoms, consumers, etc. — to participate in the growth of RE capacity. As the cost of RE continues to fall, the RPO mechanism allows for an increasing share of RE in future consumption.
- A mandatory mechanism combining net metering (NEM) with a feed-in tariff (FiT) for behind-the-meter RE generation (e.g. rooftop solar photovoltaic). This requirement would apply to all distribution service providers. Electricity generated under the NEM/FiT mechanism would count toward the RPO. The NEM/FiT mechanism encourages the addition of RE generation close to the point of use thereby minimizing the costs of transmission and distribution and associated losses.

9.3.2 Support for Compliance

With strong policy/legislation in place, the focus on implementation support will be even more desirable. The government – both at the central and state level – will need to support compliance with mandatory requirements regarding RE on the power system through the following functions. For each function we have suggested two options – either through existing institutions or by creating new institutions. Preferred approaches are described below; alternatives are in footnotes:

1 An additional program that could be considered is a mandatory Renewable Generation Obligation (RGO) for all new fossil fuel-based power projects. The RGO mechanism would explicitly link a portion of RE capacity addition to growth in fossil-based capacity addition. As a result, all electricity buyers will buy a percentage of RE generation as all new electricity generation will, by default, include RE. This mechanism leverages the strong financial health of developers of fossil fuel-based generation. Additional synergies such as generation efficiency, transmission interconnections, transmission utilization, and grid integration could further reduce the overall cost of new RE to all buyers. Electricity consumed under the RGO would also count toward the RPO.

"One-Stop Shop" for Standardized Contracting: Currently, buyers (e.g. discoms) and RE sellers contract bilaterally under the oversight of the relevant regulatory commissions. In an information-poor environment, buyers (and regulatory commissions) either follow a long and costly contract negotiation process or, using their monopsony[2] power, force a biased contract on the sellers. Streamlining the contracting process (e.g., standardization of contracts), and making available relevant information (e.g., that could lead to a more transparent price discovery process) in a centralized manner could significantly reduce contracting-related transaction costs and project risks. This should be achieved by establishing a new CERC-regulated intermediary institution that centrally procures RE from developers at an auction-price and sells to bulk buyers.[3]

Financial Support and Disbursal Mechanism: Currently, RE developers receive subsidies under multiple mechanisms.[4] The potential redundant overlaps among these subsidies, constant revisions, and the wide range of variations — especially in financial support from the states — have created an uncertain investment and project development environment. A uniform, simple financial support and disbursal mechanism targeted to buyers that is transparently designed and provides certainty over a reasonable period of time could significantly help in expediting RE growth. The financial support could be disbursed through the new Intermediary Institution – described previously – that ensures that bulk buyers are indifferent between new RE and new fossil fuel-based generation.[5]

Streamline Project Development: One of the major constraints on rapid RE development is the lengthy and costly project development process that includes investment-grade RE resource assessments, access to land (either acquisition or leasing), supporting infrastructure development (e.g. roads, water, transmission interconnections, etc.), etc. Some of these aspects are under state jurisdiction while others are under central jurisdiction; coordination among the two is necessary to minimize project development-related transaction costs. A newly formed states-center committee should lead the facilitation process to reduce soft costs in project development (e.g., siting, permitting, supporting infrastructures) with technical and logistical support from the Intermediary Institution described above.[6] This is largely aimed at de-risking the sector and fast-tracking RE deployment.

Low-Cost Financing: RE technologies, unlike fossil-based energy technologies, have high capital costs but very low operating costs spread over 25 to 30 years. Thus, the cost of finance (currently ranging from 12–14% in India) forms a significant component of the power tariff from these sources. Buying down the rate of interest for RE projects would reduce tariffs and hence scale-up demand for RE. The cost of finance in any country is typically driven by multiple factors including inflation rates, economic conditions, state of financial markets, etc. and hence, it is neither desirable nor possible to make interventions in financial markets. The interventions thus have to be sector (RE) specific. Further, it is desirable to reduce cost of capital at multiple stages viz:

Stage 1: Reducing the risk perception of the sector by de-risking (as mentioned in several other interventions above) and hence managing/ reducing investors' return expectations (both debt and equity).

Stage 2: Increasing the quantum of money available and reducing the cost of such money

- Allowing special green bonds — such as tax-free, and/or capital gains tax-exempt bonds — in line with infrastructure bonds
- Bringing RE under priority sector lending
- Allowing pension funds, insurance companies, and sovereign funds with long-term horizons to invest in RE projects through securitization markets
- Lowering the sovereign guarantee fee for non-banking financial companies (NBFCs)/public-sector entities involved in financing RE projects

2 A market form in which only one buyer interfaces with many sellers.

3 Alternatively, existing entities such as an expanded Solar Energy Corporation of India (SECI) and/or the Power Exchanges could be assigned the responsibility of establishing a centralized platform.

4 See, for example accelerated depreciation (AD) from Ministry of Finance, generation based incentives (GBI) and Viability Gap Funding (VGF) through MNRE, Feed in tariffs (FiT) from discoms, etc.

5 Alternatively, a portfolio of incentives could be directed to different parts of the value chain and disbursed through various existing institutions.

6 Alternatively, MNRE could initiate an RE-zone based project development process similar to that undertaken by the Power Finance Corporation (PFC) for developing UMPPs, and is also envisaged for solar UMPPs.

- Allowing tradable tax credits to be issued by developers who do not have corresponding set-offs against such tax benefits, so they can sell them to others who are eligible to do so
- Allowing longer-tenure loans from the Infrastructure debt fund to RE projects that meet well-defined criteria, even if they are not public-private partnerships (PPPs), or creating mechanisms that allow structuring of projects as PPPs

Stage 3: An existing central government entity such as IREDA or PFC could pool various sources of funds including commercial (banks, FIs, MDBs' lines of credits etc.) and non-commercial (National Clean Energy Fund {NCEF}, grants, subsidies, corporate social responsibility money, etc.) capital from domestic as well as international sources. This pool of funds could be administered and managed to lend debt (and even part equity, if possible) at lower interest rates.

9.3.3 RE Grid Integration and More Efficient Grid Operation

Finally, in addition to strong policy/legislation and supportive deployment environment, grid interconnection and integration of RE is equally critical. Technically, RE is typically described as an intermittent source of electricity. Intermittency consists of two distinct aspects:

- "Predictability/Uncertainty" refers to the lack of accurate knowledge about future RE generation (e.g., a sudden drop in wind power), which is not very different from fossil fuel- based generation/ transmission systems (e.g., an unforeseen failure of a fossil-based generator or a transmission line).
- "Variability" is the known natural variation in RE generation (e.g., wind peaking during monsoon and reduced availability in other seasons), just as we have on the demand side currently (e.g., low demand at midnight and high demand during late afternoon).

Internationally — where RE accounts for increasingly large shares of the power systems — various changes to grid design, technology, and its operation have been implemented that allow successful grid integration, i.e. minimizing and/or managing the variability and uncertainty aspects of RE. Many of these strategies are inherently useful for improving the overall efficiency of grid operations and reducing overall costs to consumers whether RE accounts for a large (e.g. >25%) share of the generation mix or not. Some of these changes are one-time changes while others would evolve over time as load shapes and the resource mix continue to change. These strategies are summarized in Table 7 above. The rest of this section describes these strategies in more detail.

Table 7

RE Grid Integration and Efficient Grid Operation Strategies

Strategy	Impact on Uncertainty	Impact on Variability
One-time		
Upgrade grid technology	Minimize	Manage
Upgrade grid operation protocols	Minimize	Manage
Expand "Balancing Areas"	Minimize	Minimize and manage
Upgrade grid planning practices	Minimize	Minimize
Ongoing		
Balancing resources – estimation, procurement, dispatch	Manage	Manage

These strategies can be classified into following sub-categories, in roughly ascending order in terms of cost per kWh.

- ***Upgrade grid technology:*** System operators at all levels (i.e. state, regional, and national) should have visibility of the grid status in neighboring balancing areas and also the ability to easily coordinate with them. Most of the transmission companies (i.e. central and state transmission utilities) and Load Dispatch Centers (LDCs) (i.e. POSOCO and State LDCs) have initiated grid technology upgrades in recent times –for example, the introduction of synchrophasors, smart-grid pilots, etc. These initiatives need to be significantly ramped up to deploy sensors for generating real-time high geographic resolution data on grid conditions. These data generation sensors need to be coupled with sophisticated analytical engines that provide the necessary information for grid operations. Centralized RE forecasting mechanisms need to be tightly integrated with system operations. Lastly, advanced decision-making and control systems need to be implemented that enable system operators to respond significantly faster to changed grid conditions.
- ***Upgrade grid operation protocols:*** Various aspects of system operations need to be updated. These include but are not limited to:
  - *Grid Codes:* System operators around the world —

especially those encountering a high share of RE on their grid – are continually updating their grid codes to ensure that RE additions do not affect the grid adversely. Grid codes need to explicitly acknowledge attributes unique to RE generators and, consequently, require appropriate capabilities (e.g., fault-ride through, etc.).

- *Scheduling and Dispatch:* Through both practice and theory, it has become evident that grids that are operated in a manner where scheduling and dispatch are implemented over short time durations (e.g., as low as five minutes) have significantly lower overall costs to consumers as the need for ancillary resources decreases. Currently, in India, scheduling occurs on a day-ahead basis while dispatch occurs on a 15-minute basis. System operations technologies and protocols need to be updated to enable five-minute scheduling and dispatch of all resources connected to the grid and automated incorporation of RE forecasts. It should be noted that accuracy of RE forecasts is significantly higher the closer they get to dispatch. Consequently, the ancillary service requirements will also be lower.

- ***Expand Balancing Areas:*** It has been seen globally that larger balancing areas (or the ability to coordinate among balancing areas) have significantly lowered the overall cost to consumers as ancillary services requirements are reduced substantially. Over several decades, neighboring balancing areas have evolved various forms of coordination ranging all the way up to merging several balancing areas into one and doing centralized dispatch, such as the creation of Independent System Operators (ISOs) in the US. Currently, balancing areas in India — specifically, states — neither have the visibility of their neighbors' grid condition nor the ability to coordinate with them. A single national-level load dispatch center that is non-profit, independent, and regulated by CERC is sufficient for managing the entire national grid.[7]

- ***Promote flexible demand and supply resources:*** Power systems, especially those with a high share of RE, require access to sufficient flexible resources (e.g. demand response, gas turbines, hydroelectricity, etc.) to ensure continued stability of the grid at each moment. Currently, there are no mechanisms in India to ascertain the amount of balancing resources needed and how these can be procured and dispatched. Grid simulations that are used to identify resource pools (both built and unbuilt), specifically for providing various types of flexible resources including ancillary services, should be conducted routinely. Procurement mechanisms need to be implemented to ensure these resources are connected for use in assuring grid stability. Finally, mechanisms for fair price discovery and compensation of flexible resource (e.g., ancillary services) providers need to be established. The relevant LDC should be made responsible for procuring ancillary services to ensure grid stability. The procurement process should be similar to the usual competitive bidding process used by discoms for procuring energy. The compensation could be cost-plus as approved by the relevant regulatory commission and paid by all the buyers to the LDC.[8]

7 Alternatively, system operations technologies and protocols need to be updated to allow all system operators to see the grid conditions in other balancing areas and a mechanism established (e.g. energy-imbalance market that is currently being implemented in the western US) for them to routinely coordinate with each other. In order to identify areas for cost-effective cooperation among balancing areas, the quantity of ancillary services available and needed (in terms of duration, frequency, location, etc.), and estimation of the costs and benefits of ancillary services, a "shadow market" approach could be undertaken. In the first phase, the "shadow market" could be simulated for the past day where the actual operation can be compared with a potentially optimal operation in terms of metrics such as overall costs/ frequency/duration/ extent of load-shedding, etc. In the second phase, the "shadow market' could be simulated in real-time in parallel to the actual operations in order to identify potential changes to the operations. As grid operators develop increasing confidence in the value of these simulations, in phase 3, the "shadow market" could be transformed into a "real" market that replaces the current way of operating the grid to ensure the benefits of optimal operations flow to consumers.

8 Alternatively, a market-based approach would consist of the creation of a wholesale ancillary services market similar to the wholesale energy market. At the market-clearing price, LDCs would acquire the required balancing resources for which all buyers served by the LDC would be charged. The relevant regulatory commission would allow for these payments to the LDCs. This approach would allow more flexibility among the balancing areas, but must be preceded by more understanding of system stability needs.

9.3.4 Energy Access and Off-Grid RE

One-third of India's population does not have access to electricity. Most of the discoms are struggling to provide minimum lifeline supply of 1 unit/household/day to the rural areas.

The scope of this Roadmap Initiative did not include an extensive consideration of the challenges of energy access or off-grid RE generation dynamics. However stakeholders concerned with these issues indicated RE sources could rapidly bridge India's energy access challenge in a cost-effective manner. RE could also accelerate achievement of India's universal service obligation, a mandate outlined in the Electricity Act 2003.

Some policy approaches to these ends were put forward during this Roadmap Initiative, although there was general agreement that these issues require their own in-depth stakeholder process.

For the record, these are the basic energy access and off-grid RE concepts that were suggested. In addition to the grid extension programs of the GoI, which are time and resource intensive, state utilities (and state governments) should be actively engaged and held responsible for:

- Immediately providing stand-alone off-grid systems in remote rural areas for home lighting and running other basic appliances. Over time, these systems could play the same role as that of rooftop systems in urban areas
- In parallel, developing district and block-level plans for providing electricity through deployment of micro-grids or mini-grids using RE resources

The creation and sustenance of the proposed systems would require new business models and private sector participation. Enabling policy and regulatory frameworks should be created at the central as well as state levels. The business models, policies and regulations thus formulated must allow for integration of these stand-alone and/or mini-grid systems with the larger grid system once the distribution grid reaches the inaccessible areas.

9.4 Summary and Conclusion

At the 21st Century Power Partnership Steering Committee Meeting on February 7th 2014, the Member (Energy) of India's erstwhile Planning Commission identified the Roadmap Initiative's goal:

"We should not get into the mindset that RE is the intruder and conventional energy is the main player. Why not consider RE to be main occupants of the "house" and then work out the rest of the system around RE, essentially, because RE is the future?"

This was and remains the key and critical question. For a hundred years, conventional fossil-fueled power plants were at the core of power systems around the world. Those systems had particular engineering and technical characteristics, and operating and governance institutions have been created, designed and operated for decades to support a system with those characteristics.

But renewables are different. For India to capture the benefits of renewables as "the main occupant of the house" will require the rethinking and reengineering of institutions, the redefinition of policies, the re-tuning of power grids and systems, and the replacement of old habits with new ones.

A rethink is unavoidable: renewables are different from the power technologies of the past. The enormous benefits they bring – zero fuel, electricity prices free from volatility and external influence, reduced imports, dramatically reduced pollution and water use – will not be had without significant effort.

Most renewables have zero fuel costs but they are more capital-intensive than conventional fossil power plants. India's renewable resources are abundant, but the output of wind and solar photovoltaic is variable, and in the case of wind in particular, subject to uncertainty. To capture the benefits, India would need to raise the necessary capital, and to get comfortable with managing the variability and uncertainty of renewable energy generation.

The policy framework outlined above would facilitate that rethinking; it was based on extensive inputs from stakeholders and international experience and specifically designed to overcome the barriers to success and to meet the renewables challenge.

To that end, then, both the purpose and the best use of this RE Roadmap Initiative report will be to assist policy-makers and stakeholders to grasp what is at stake, and what needs to be done to make a successful choice in favor of renewables at scale.

Annex 1
RE Roadmap Initiative Stakeholders

In alphabetical order within each category

Government of India Institutions
(Centre)

Bharat Heavy Electricals Ltd.
Central Electricity Authority
Indian Renewable Energy Development Agency
Ministry of Development of North Eastern Region
Ministry of Environment, Forests and Climate Change, Government of India
Ministry of Finance, Government of India
Ministry of New & Renewable Energy, Government of India
Ministry of Power, Government of India
National Load Dispatch Centre
National Thermal Power Corporation Ltd.
Petroleum Conservation Research Association
Power Grid Coropration of India Ltd.
Power System Operation Corporation Ltd.
Thirteenth Finance Commission, India

Regulatory Commissions, India
(Centre, followed by States)

Central Electricity Regulatory Commission
Bihar State Electricity Regulatory Commission
Gujarat Electricity Regulatory Commission
Himachal Pradesh Electricity Regulatory Commission
Karnataka Electricity Regulatory Commission
Madhya Pradesh Electricity Regulatory Commission
Maharashtra Electricity Regulatory Commission
Punjab Electricity Regulatory Commission
Uttar Pradesh Electricity Regulatory Commission
West Bengal Electricity Regulatory Commission

Government Institutions, India
(State and Other)

Bangalore Electricity Supply Company Ltd.
Bihar Renewable Energy Development Agency
Bihar State Power Transmission Corporation Ltd
Directorate of Energy, Himachal Pradesh
Government of Bihar
Government of Haryana
Government of Madhya Pradesh
Government of Maharashtra
Government of Punjab
Government of Rajasthan
Government of Tamil Nadu
Gujarat Eneregy Development Agency
Gujarat State Transmission Corporation
Gujarat Urja Vikas Nigam Ltd.
Haryana Renewable Energy Development Agency
Haryana Power Purchase Centre
Himachal Pradesh Energy Development Agency ("HIMURJA")
Himachal Pradesh Power Corporation Ltd
Himachal Pradesh State Electricity Board Ltd
Karnataka State Load Dispatch Centre
Maharashtra State Power Generation Company Ltd
Punjab State Transmission Corporation Ltd
Punjab Energy Development Agency
Satluj Hydro Power Project
SJVN Limited
Tamil Nadu Energy Development Agency
Uttar Pradesh New and Renewable Energy Development Agency
West Bengal Renewable Energy Development Agency

Civil Society, India

Ashden India Renewable Energy Collective
Center for Policy Research
Center for Science and Environment
Center for Study of Science, Technology and Policy
Council on Energy, Environment and Water
Himachal Pradesh Voluntary Health Association
Natural Resources Defense Council
National Institute for Rural Technology Development
Observer Research Foundation
Prayas Energy Group
The Energy and Resources Institute
Vasudha Foundation
World Institute of Sustainable Energy
World Wildlife Fund India

Private Sector

ABB LTD
ACIRA Solar
AF-Mercados Energy Markets India Pvt Limited
Agni Power and Electronics Pvt Ltd
Aisect University
Allianz Group LLC
Amarnath Kaushal Lucky Power PCs Ltd
Asian Paints Limited
Athena Infonomics India Private Limited
Axis Bank
Beckons Industries
Birla Corporation Ltd
BLA Shalvi Hydro Power Ltd
Bharat Renewable Energy Ltd
Bridge To India Energy
Cheema Boilers Limited
Chemtrols Ltd
CII-Green Business Centre
Coatec India
Continental Solar
Country Strategy Business Consulting
CRISIL
DAS India
Development Consultants Pvt Ltd
Emergent Ventures India
Enercon Ltd
Ernst & Young
Essel Group
Ethical Energy Petrochem Strategies Pvt Ltd
First Solar
Forum of Hydro Power Producers
GP Tronics
Green Infra Ltd
GreenTech Knowledge Solutions Pvt Ltd
Hansen Drives Ltd. (Sterling and Wilson)
Harsha Abakus Solar Pvt Ltd
HDFC Bank
HERO Future Energies
Himalaya Power Producers Association
Hinduja Group
Hindustan Unilever Ltd
ICICI Project Finance Group
Idam Infrastructure Advisory Pvt Ltd
IDBI Bank
IL&FS Energy Development Company
Inco Mechal Pvt Ltd
India Power Company Ltd
Indian Bank
Indian Banks' Association
Indian Energy Exchange
Indian Renewable Energy Federation
Indian Wind Power Association
Indian Wind Turbine Manufacturers' Association
Indo Solar
Inspira Enterprise India Pvt Ltd
International Copper Promotion Council (India)
Indian School of Business Mohali
Jackson Engineering
KPMG Advisory Services Pvt Ltd
Karnataka Bank
Khanna Paper Mills Limited
Krishna Hydro
Ladderup Corporate Advisory Private Limited
Leitner Shriram Manufacuring Limited
Linkage Technologies Inc.
Lubitech Enterprises
M N Dastur & Co
M Power Green
Meghraj Capital Advisors Pvt Ltd
MITCON Consultancy & Engineering Services Ltd
Moser Baer India Ltd
Omne Agate Systems Pvt Ltd
P B Electrotech
Paridhi Industries Unit - 2
Power Exchange India Limited
Rajasthan Electronics and Instruments Ltd
Rajendra EXIM
Regional Committee on Energy & Power
ReNew Power Ventures Pvt Ltd
Reliance Industries Limited
RRB Energy
Sahaj Solar Pvt. Ltd.
Sampurn Agri Ventures Limited
Satpura Power Pvt Ltd
SBI Caps
Shivalik Waste Management Ltd
Solace Renewable Energy Pvt Ltd
Solar Energy Society of India
Solar Pvt Ltd
Spark Electricals
SPML Infra Limited
Stup Consultants
Sugar Co-Gen Association
Sun Edison Energy India Pvt Limited
Super Smelters Ltd
Supreme & Co Pvt Ltd
Suzlon Group
Tata Cleantech Capital Limited
Tata Motor
Tata Power Solar Systems Ltd
Techno Electric & Engineering Co. Ltd
Traveni Engineering
Trident India Limited
Vardhman Textiles Limited
Vatsalyam Enterprises
Vijaya Bank
Vijayant Consultants
WARTSILA India Ltd
Wrigley India
Yash EcoEnergy Ltd
Yash Papers Ltd

Bi-lateral and Multi-lateral Institutions

Asian Development Bank
Consulate General of Brazil in Mumbai
Department for International Development, British High Commission
Economic & Commercial Office of Spain
GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit)
Japan International Cooperation Agency
Royal Norwegian Embassy
South African Consulate General
United States Agency for International Development
World Bank

Annex 2
International Review

Provided through the auspices of the 21st Century Power Partnership, an undertaking of the Clean Energy Ministerial

Doug Arent
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Sustainability Division
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NREL, retired
USA

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USA

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General Direction for Sustainability
Secretariat of Energy
Mexico

Executive Director
Mexican Wind Energy Association
Mexico

President
National Solar Energy Association
Mexico

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Report on India's Renewable Electricity Roadmap 2030

The executive summary and the full report are available online at the websites of CII, Shakti and RAP.
These will also be made available at NITI Aayog's website shortly.

About the Institutions

National Institution for Transforming India (NITI) Aayog

http://pmindia.gov.in/en/tag/niti-aayog/

The institution is the successor to the Planning Commission, and will serve as 'Think Tank' of the Government – a directional and policy dynamo. NITI Aayog will provide Governments at the central and state levels with relevant strategic and technical advice across the spectrum of key elements of policy. The latter includes matters of national and international import on the economic front, dissemination of best practices from within the country as well as from other nations, the infusion of new policy ideas and specific issue-based support.

Confederation of Indian Industry

http://www.cii.in

The Confederation of Indian Industry works to create and sustain an environment conducive to the growth of industry in India, partnering industry and government alike through advisory and consultative processes.

Shakti Sustainable Energy Foundation

http://shaktifoundation.in

Shakti Sustainable Energy Foundation works to strengthen the energy security of India by aiding the design and implementation of policies that encourage energy efficiency as well as renewable energy.

Regulatory Assistance Project

http://www.raponline.org

Regulatory Assistance Project is a global, non-profit team of experts focused on the long-term economic and environmental sustainability of the power and natural gas sectors, providing assistance to government officials on a broad range of energy and environmental issues.