Report on India's Renewable Electricity Roadmap 2030

Toward Accelerated Renewable Electricity Deployment

Executive Summary

NITI Aayog
Government of India

CII
SHAKTI SUSTAINABLE ENERGY FOUNDATION
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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.

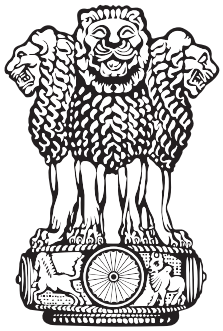
But renewables are different. For India to capture the benefits of renewables as "the main occupant of the house" will require the rethinking and reengineering of institutions, the redefinition of policies, the re-tuning of power grids and systems, and the replacement of old habits with new ones.

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 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.



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NITI Aayog

Government of India