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Tapping Every Ray of the Sun

A Roadmap for a Significant Role of Solar in India

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A policy brief on 'Tapping Every Ray of the Sun: A Roadmap for a Significant Role of Solar in India'.

The views expressed in this report are those of the authors and do not necessarily reflect the views and policies of the Council on Energy, Environment and Water.

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The Council on Energy, Environment and Water (http://ceew.in/) is an independent, not-for-profit policy research institution. CEEW addresses pressing global challenges through an integrated and internationally focused approach. It does so through high quality research, partnerships with public and private institutions, and engagement with and outreach to the wider public. The International Centre for Climate Governance has ranked CEEW as India's top climate change think-tank two years in a row. In 2014, the Global Go To Think Tank Index ranked CEEW 1st in India in three categories.

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ABOUT CEEW

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In four years of operations, CEEW has engaged in more than 60 research projects, published more than 35 peer-reviewed policy reports and papers, advised governments around the world over 80 times, engaged with industry to encourage investments in clean technologies and improve efficiency in resource use, promoted bilateral and multilateral initiatives between governments on more than 30 occasions, helped state governments with water and irrigation reforms, and organised more than 75 seminars and conferences.

CEEW's major completed projects: 584-page National Water Resources Framework Study for India's 12th Five Year Plan; India's first report on global governance, submitted to the National Security Adviser; foreign policy implications for resource security; India's power sector reforms; first independent assessment of India's solar mission; India's green industrial policy; resource nexus, and strategic industries and technologies for India's National Security Advisory Board; $125 million India-U.S. Joint Clean Energy R&D Centers; business case for phasing down HFCs; geoengineering governance (with UK's Royal Society and the IPCC); decentralised energy in India; energy storage technologies; Maharashtra-Guangdong partnership on sustainability; clean energy subsidies (for the Rio+20 Summit); reports on climate finance; financial instruments for energy access for the World Bank; irrigation reform for Bihar; multi-stakeholder initiative for urban water management; Swachh Bharat; environmental clearances; nuclear power and low-carbon pathways; and electric rail transport.

CEEW's **current projects include**: the Clean Energy Access Network (CLEAN) of hundreds of decentralised clean energy firms; the Indian Alliance on Health and Pollution; low-carbon rural development; modelling long-term energy scenarios; modelling energy-water nexus; coal power technology upgradation; India's renewable energy roadmap; energy access surveys; energy subsidies reform; supporting India's National Water Mission; collective action for water security; business case for energy efficiency, and emissions reductions in the cement industry; assessing climate risk; modelling HFC emissions; advising on run up to climate negotiations (COP-21) in Paris.

CEEW's **work covers all levels of governance**: at the national level, resource efficiency and security, water resources, and renewable energy; at the global/regional level, sustainability finance, energy-trade-climate linkages, technology horizons, and bilateral collaborations, with Bhutan, China, Iceland, Israel, Pakistan, Singapore, and the US; and at the state/local level, CEEW develops integrated energy, environment and water plans, and facilitates industry action to reduce emissions or increase R&D investments in clean technologies.

ABOUT THE AUTHORS

Poulami Choudhury

Poulami Choudhury works as a Programme Officer with the Council on Energy, Environment and Water (CEEW). She has done extensive work on decentralised renewable energy projects which includes formulating a roadmap for scaling off-grid energy in India; documenting applications of renewable energy beyond electricity (with the WWF) and drafting recommendations for DERC's Net Metering Guidelines. She has also worked on assessing green industrial policies for grid connected solar and wind power in India.

She is a post graduate in Natural Resources Management from The Energy and Resources Institute (TERI) and has done her graduation in Microbiology from the Institute of Home Economics, Delhi University. Following post-graduation, she had a short stint at J.M. EnviroNet Pvt. Ltd. where she worked as a consultant for Environment Impact Assessment (EIA) projects. She went on to work for C40, in partnership with the Clinton Climate Initiative (C40-CCI) as a Program Analyst for two years. During her tenure with C40-CCI, she was involved in developing models for calculating greenhouse gas emission reductions resulting from various waste management projects, developing questionnaires, ward monitoring plans and Request for Proposals and Concession Agreements for the East Delhi Municipal Corporation. She has also worked extensively on developing material for C40-CCI's Knowledge Platform on solid waste management, wherein she assembled a comprehensive database and generated profiles for global cities (C40 cities) to better characterize their solid waste management systems that would facilitate city-to-city solid waste networks and help identify opportunities to improve municipal waste management in various cities. In addition to these Waste projects, Poulami also conducted other work for the Solar team of the Clinton Climate Initiative, such as preparing papers and reports related to Rajasthan solar park and technical specifications for CSP projects planned under National Solar Mission.

She has co-authored a research paper entitled, "Optimization Studies for hybrid and storage designs for parabolic solar trough systems with the System Advisor Model" which was published in the journal of Environmental Progress and Sustainable Energy in 2011.

Shalu Agrawal

Shalu Agrawal is a Research Analyst at the Council on Energy Environment and Water. Her research interests include Renewable Energy Policy, Energy Access and Renewable Energy Finance.

Shalu is researching on finding potential ways to promote solar technologies in India. She has worked on CEEW's research and policy projects involving mapping of the financial ecosystem for solar sector in India, exploring the potential of innovative financing mechanisms to scale up renewable energy and engaging with financiers to understand the barriers and opportunities in investing in clean sector.

She is currently working with the modelling team at CEEW to explore cost effective solutions for meeting India’s energy demand by 2050. She has also researched on ways to enhance access to energy through effective deployment of LPG. She participated in Centre for Science and Environment's "Challenge of the balance" programme (2012) which focused on environmental management in the developing world and managing the impact of climate change on South Asia. During this program, she also served as the editor of the participants' environment magazine.

Shalu holds a B.Tech in Electrical Engineering from Indian Institute of Technology (IIT) Roorkee. She has also worked as intern at Schlumberger Asia Services Ltd. (Wireline segment) and Control & Switchgears Ltd (low voltage protection elements, assembly line).

Kanika Chawla

Kanika Chawla is a Junior Research Associate at the Council on Energy, Environment and Water (CEEW), India. Prior to her association with CEEW she has worked at the Renewable Energy Policy Network for the 21st Century (REN21) Secretariat in Paris. Kanika has worked extensively on distributed renewable energy in developing countries, urban energy policy and investment in sustainable energy. She specializes in international cooperation and sustainable energy policy.

She has researched energy policy issues in developing countries around the world with a specific focus on renewable energy, energy efficiency and gender. She has previously also worked with GIZ on sustainability reporting.

Kanika holds an M.Sc in Economics and Development Economics from the University of Nottingham and an undergraduate honors degree in Economics from Miranda House, University of Delhi. She is fluent in English and Hindi and speaks basic French.

Rajeev Palakshappa

Rajeev Palakshappa is an Associate Fellow focusing on Business and Innovation related projects. Rajeev has worked on facilitating stakeholder engagement during the Joint Clean Energy R&D Center Funding Call round as well as conducting & overseeing research for CEEW's work on solar. He is one of the co-authors of the reports on solar and through the course of these projects has built an extended network of stakeholders within the solar ecosystem in India. Rajeev is currently leading work looking at the potential for a country-wide alliance to support and facilitate upscale of off-grid renewable energy solutions.

Rajeev's broader experience covers a mix of project management and consulting across business, energy and climate change related issues. This includes working with multi-stakeholder groups across government, business and NGOs. Past projects and roles include working on the implementation of the EU Emissions Trading Scheme in the UK; helping Deloitte New Zealand establish a climate change and sustainability service offering; and working with The Climate Group, a UK based NGO, in India on corporate engagement and developing awareness of climate change related challenges amongst the finance sector.

Rajeev holds an Honours degree in Managements Systems and Finance. He is fluent in English and Kannada and speaks conversational Hindi.

Karthik Ganesan

Karthik Ganesan is a Senior Research Associate at the Council on Energy, Environment and Water (CEEW), India. He most recently graduated with a Masters in Public Policy from the Lee Kuan Yew School of Public Policy at the National University of Singapore. Prior to his association with CEEW he has previously worked on an array of projects in collaboration with various international institutions, with a focus on sustainable development and energy security. Some of these include the valuation of health impact of air pollution from thermal power plants (with the Asian Development Bank), Carbon Capture and Storage in SE Asia (ADB), technical feasibility of metropolitan siting of nuclear power plants (National University of Singapore, book expected) and scenario modelling for the interplay between natural gas and coal usage in India (Centre for Asia and Globalization, NUS Singapore). Karthik brings an analytical edge to the team at CEEW, drawing on four years of international consulting experience with the aviation sector in high-end quantitative techniques and modelling.

As a member of the team at CEEW he is leading our efforts on research in the climate change mitigation area through a project titled 'Climate Change and Business Leadership in Indian

Industry'. The project currently focuses on the cement sector and the options for the industry to take up sustainable manufacturing processes and cutting back on GHG emissions.

Karthik has an M.Tech. in Infrastructure Engineering and a B.Tech in Civil Engineering from the Indian Institute of Technology, Madras in Chennai.

Arunabha Ghosh

Arunabha Ghosh is CEO of the Council on Energy, Environment and Water (CEEW), an independent, policy research institution in India. Arunabha conceptualised and has led CEEW (http://ceew.in), since its founding in August 2010, to the top-ranked climate think-tank in India for the last two years in a row. In 2014 CEEW was ranked first in India across three categories in the Global Go To Think Tank Index. With experience in 35 countries and having previously worked at Princeton, Oxford, UNDP and WTO, he advises governments, industry and civil society around the world on: energy and resources security; renewable energy; water governance; climate governance (including financing and technology); energy-trade-climate linkages; and international regime design. He is a World Economic Forum *Young Global Leader*, Asia Society *Asia 21 Young Leader*, and fellow of the *Aspen Global Leadership Network*. He is also a founding board member of the the Clean Energy Access Network (CLEAN). He writes a monthly column, Inflexion Points, in the *Business Standard*.

Dr Ghosh is member of Track II dialogues with the United States (co-chair of the taskforce on economic relations for the Aspen Strategy Dialogue), Bhutan, Israel, Pakistan and Singapore. He formulated the Maharashtra-Guangdong Partnership on Sustainability. Dr Ghosh is associated with Oxford's Global Economic Governance Programme and Oxford's Smith School of Enterprise & the Environment. He was Global Leaders Fellow at Princeton's Woodrow Wilson School and at Oxford's Department of Politics and International Relations. He was Policy Specialist at the United Nations Development Programme (New York) and worked at the World Trade Organization (Geneva). He is on the Board of the International Centre for Trade & Sustainable Development.

One of his most recent publications is *Three Mantras for India's Resource Security*, on the foreign policy imperatives for India. Others include: *Understanding Complexity, Anticipating Change* (India's first report on global governance, submitted to the National Security Adviser); *National Water Resources Framework Study* (for India's 12th Five Year Plan); *Strategic Industries and Emerging Technologies* (for the National Security Advisory Board); *Laying the Foundation of a Bright Future* (first evaluation of India's solar mission); *Making the UN Secretary General's Climate Summit Count*; *India's Resource Nexus* (also for NSAB); *Governing Clean Energy Subsidies*; *RE+: Renewables Beyond Electricity*; *Urban Water and Sanitation in India*; *Institutional Reforms for Improved Service Delivery in Bihar* (on irrigation); *Harnessing the Power Shift* (on climate finance); *International Cooperation* *and the Governance of Geoengineering* (for the IPCC); *Collective Action for Water Security and Sustainability*; and three UNDP *Human Development Reports*. He has also led research on trade, intellectual property, financial crises, development assistance, indigenous people, extremism and conflict.

Dr Ghosh has presented to heads of state, India's Parliament, the European Parliament, Brazil's Senate, and other legislatures; trained ministers in Central Asia; and hosted a documentary on water set out of Africa, *Diary of Jay-Z: Water for Life*, honoured at the Webby Awards. His op-eds have appeared in the *Times of India, The Hindu, India Today, Indian Express, Financial Express, Mint, Seminar, and Tehelka*. He has delivered public lectures in several countries, and commented on All India Radio, ABC (Australia), BBC, CNN-IBN, NDTV (India) and Voice of America, among other broadcasters.

Arunabha has been consulted by the Asian Development Bank, Commonwealth Secretariat (London), DFID (UK), IDRC (Canada), International Energy Agency, International Finance Corporation, IPCC, Oxfam International, Transparency International, UK Ministry of Justice, USAID, and the World Bank. He co-chaired the international governance working group for the UK Royal Society's Solar Radiation Management Governance Initiative. He has been an Editor of the *Journal of Human Development and Capabilities*.

Arunabha holds a doctorate and M.Phil. in international relations from Oxford (Clarendon Scholar and Marvin Bower Scholar); an M.A. (First Class) in Philosophy, Politics and Economics (Balliol College, Oxford; Radhakrishnan Scholar); and topped Economics from St. Stephen's College, Delhi University.

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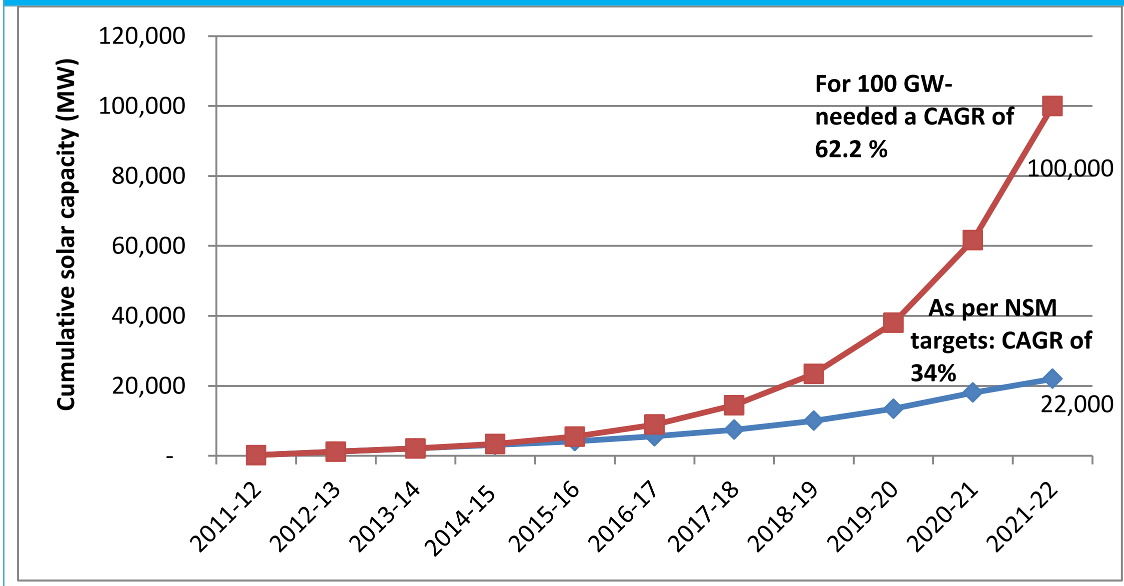
1. INTRODUCTION – RAISING THE AMBITION LEVELS

India's average solar irradiance at approximately 5.1 kWh/m^2 is one of the highest irradiation received by any country in the world. As a result, the theoretical potential of annual power generation from solar is about 5000 trillion kWh, which is equivalent to the cumulative solar capacity of 600,000 GW. Whilst this large potential assessment is entirely theoretical, the opportunity that solar energy offers is undisputed. In order to draw on the potential of solar power, the Government of India launched the National Solar Mission (NSM) in 2010, with the aim of installing a cumulative solar capacity of 20 GW by 2021-22. Could India aspire to a higher ambition, making solar a critical part of its energy mix?

Until July 2014, India had installed 2.75 GW of solar capacity. Much of this capacity was installed on the back of declining panel prices, high share of overseas funding and proactive solar policies by some states. However even as many of these favourable factors are on the decline, or at best stalling, such as the plateauing of solar prices and the downward trend in overseas financing, there is still a huge opportunity for solar power as the price of coal (particularly imported coal) continues to soar and the constraints to expanding conventional power capacity become more acute.

Figure 1: Growth Trajectory of Solar Power in India – Current and Proposed



Source: CEEW analysis

Power from solar energy contributed only 0.41% of overall power demand in India in 2013-14. However, given the large untapped potential of solar energy in India and the opportunities ahead, the right set of policy incentives and a supportive ecosystem could increase solar's share significantly.

A **cumulative installed capacity (CIC) of 100 GW of solar power by 2021-22 would help scale up India's solar capacity to 9% of total power demand. However, meeting such an ambitious goal would also mean a high compounded annual growth rate (CAGR) in solar capacity addition of 62.2% between now and 2021-22 (see Figure 1).**

Such a rate of growth is much higher than the 34% CAGR needed to achieve the earlier NSM goal of 20 GW. While the more ambitious goal is feasible, it would test the resolve of policymakers, project developers, engineering contractors, financiers, manufacturers and other stakeholders.

2. ONE (AMBITIOUS) GOAL BUT MANY ROUTES

The target of 100 GW of cumulative installed capacity from solar can be achieved through different combinations of solar installations (based on the scale, grid connected status or end use of each solar system).

Table 1 presents three different scenarios, each of which includes various solar installations in varying proportions. The different solar applications being considered include utility scale solar PV; residential rooftop PV systems (grid connected); non-residential rooftop PV systems (captive systems on public, commercial and industrial buildings); rural mini-grids; and solar pump sets.

Table 1: Different scenarios and investment requirements

Sector	**Scenario 1 "Utility heavy"**		**Scenario 2 "Rural decentralised heavy"**		**Scenario 3 "Rooftop heavy"**	
	Share	**MW**	**Share**	**MW**	**Share**	**MW**
Utility	80%	80,000	65%	65,000	50%	50,000
Rooftop – Residential (grid-connected)	3%	3,000	3%	3,000	20%	20,000
Rooftop– Non-Residential (captive)	10%	10,000	10%	10,000	25%	25,000
Rural Mini-Grid	2%	2,000	2%	2,000	2%	2,000
Solar Pump-sets	5%	5,000	20%	20,000	3%	3,000
Total Capital Investment	INR 802,500 crore (USD 133.8 billion[1])		INR 915,000 crore (USD 157.5 billion)		INR 8,83,500 crore (USD 147.3 billion)	
Evacuation Infrastructure Costs	INR 58,600 crore (USD 9.8 billion)		INR 47,613 crore (USD 7.9 billion)		INR 36,625 crore (USD 6.1 billion)	
Infrastructure Costs for Rooftop Grid Connection	INR 500 crore (USD 83 million)		INR 500 crore (USD 83 million)		INR 3,333 crore (USD 556 million)	
Total Capital Investment	**INR 861,600 crore (USD 143.6 billion)**		**INR 963,113 crore (USD 160.5 billion)**		**INR 923,458 crore (USD 153.9 billion)**	

Source: CEEW analysis

[1]Exchange rate of INR 60 per USD is used.

For comparison:

- 1000 MW of rooftop non-residential would imply 10,000 systems of 100 KWp each.
- 1000 MW of rooftop residential would imply 0.33 million systems of 3 KWp each.
- 1000 MW of rural mini-grid would imply 28,570 systems of 35 KWp each.
- 1000 MW of solar pumps would imply 0.27 million systems of 5 HP each.

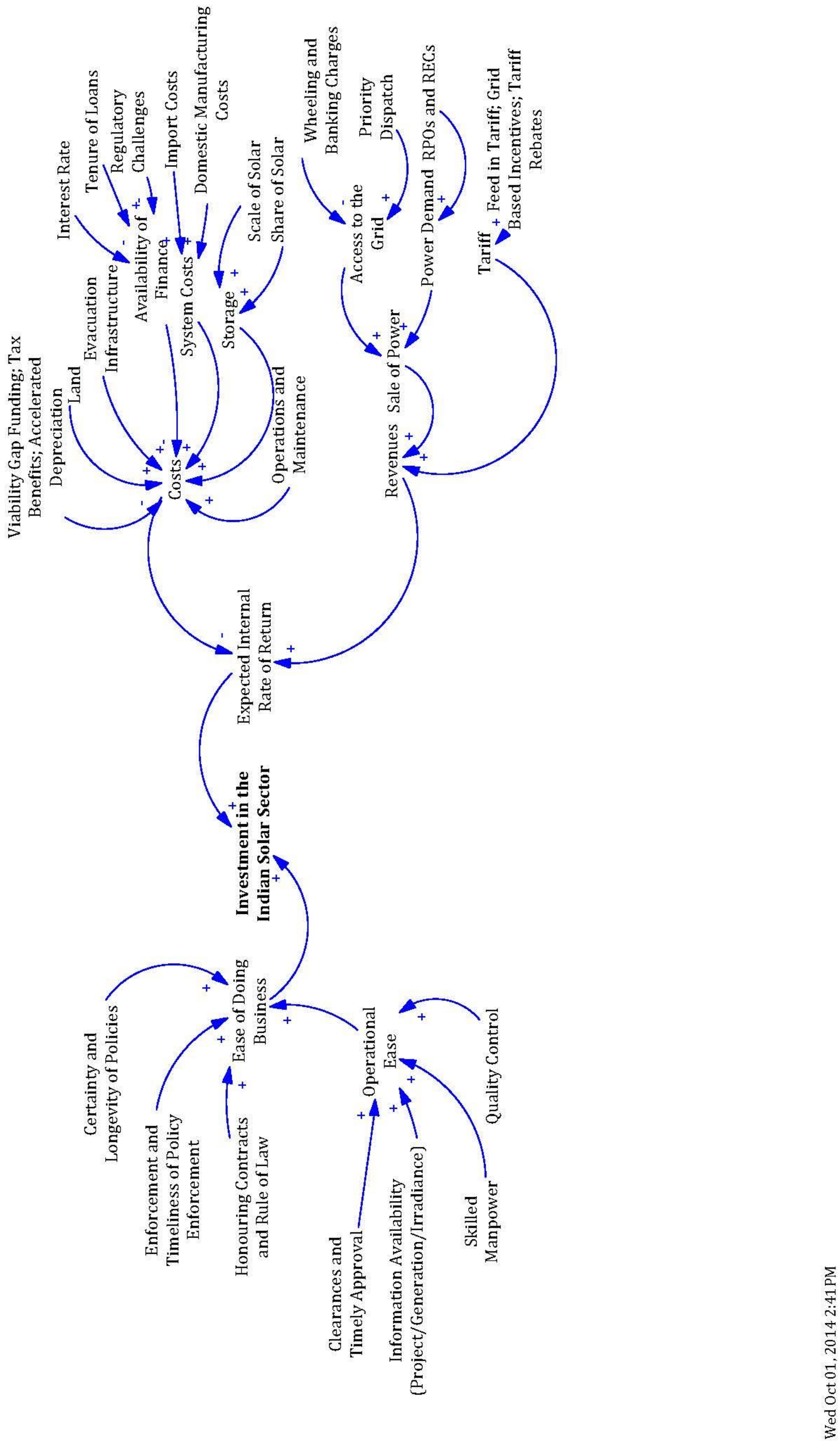
Scenario 1, being **utility focussed**, gives utility scale projects the most dominant role, accounting for 80% of the 100 GW CIC in 2021-22.

Scenario 2, the **rural decentralised energy** scenario, envisions 20% of the cumulative installed capacity (or 20 GW) coming from solar pump sets. In order to reach the target, 5.3 million solar pump sets of 5 HP each would need to be installed by 2021-22. While this is a huge leap from the current 11,000-odd solar pumps that exist, comprising only 40MW of capacity, it is a small proportion of the total number of pump sets in use in the country (approximately 27 million).

Scenario 3 focusses on **rooftop solar installations**, both residential and non-residential. In our analysis, residential rooftop systems are considered as grid-connected systems, governed by a net metering system, and comprising 20% of the total CIC. In order to add 20GW of residential rooftop capacity, 6.67 million rooftop systems of 3kWp each would need to be installed by 2021-22.

Non-residential rooftop systems include PV systems installed on public, commercial and industrial buildings, where power generated is consumed entirely on-site and need not be fed into the grid, thanks to large on-site captive demand. Non-residential rooftops are considered to add 25% of the capacity or 25 GW. In order to reach this target, 0.25 million systems of 100kWp each, need to be installed by 2021-22.

Figure 2: Framework to evaluate investments in the solar sector



Source: CEEW analysis

3. WHAT DRIVES INVESTMENT IN THE SOLAR SECTOR?

As table 1 shows, irrespective of the route followed, India requires an investment to the order of INR 860,000 crore to INR 960,000 crore (~USD 140-160 billion) to achieve the target of 100 GW. Figure B illustrates a causal of factors affecting and governing the investments in the solar sector. Investments are driven by the **expected rate of return** and the **ease of doing business.** In the solar sector, the expected returns on investment (internal rate of return) are a function of the costs involved and the revenue generated.

Costs are determined by various factors, including:

- Cost of the system (solar panels and balance of system with incentives like viability gap funding helping to reduce costs);
- Cost of finance, itself affected by regulatory incentives, interest rates and loan tenure;
- Cost of land;
- Cost of evacuation infrastructure;
- Cost of storage (affected by share and scale of solar); and
- Operations & Maintenance.

Revenues, too, are driven by several factors, which include:

- the demand for solar power (affected by the extent and enforcement of renewable purchase obligations);
- the tariff at which solar power is sold (which is again positively affected by feed-in tariffs, tariff rebates, generation-based incentives); and
- access to the grid (affected by wheeling charges and priority dispatch to the grid).

Ease of doing business in the solar sector is governed by:

- the certainty and longevity of solar policies;
- the timely enforcement of policies;
- the honouring of contracts and the strong presence of the rule of law; as well as
- the operational ease for the developer.

Operational ease for the developer is itself affected by several factors, such as

- approval time and number of clearances required;
- access to information (pertaining to projects, generation and irradiance);
- availability of skilled manpower; and
- the standards of quality control in the country.

Investment gets an impetus if there are long term guarantees on policy measures, if developers are assured of enforcement of obligations and incentive schemes and if a fast and fair legal framework exists to protect investments.

4. SCALING UP TO 100 GW BY 2022: CHALLENGES TO BE ADDRESSED

This section highlights roadblocks currently being faced in the implementation and scale up of solar in India. The key challenges fall in three categories:

- High upfront costs
- Uncertainty of adequate revenue generation
- Lack of ease of doing business

4.1 High upfront costs

Initial capital requirements for solar projects are significantly higher than conventional power plants. Solar projects currently range between INR 7 crore per MW for (utility scale) to 10 crores/MW for rooftop projects. For utility scale projects, the upfront costs comprise:

- System cost[2] ~86% (For non-utility scale projects the largest cost component is the solar system)
- Cost of finance ~8%
- Land costs ~3.5%
- Evacuation infrastructure cost ~2.5%

System costs

The solar system comprises the cost of solar PV cells/modules and balance of system (BoS) costs. The global prices of solar PV modules have stabilised after a dramatic decline in the last few years, with expectations of only a marginal price decline in the global price of PV modules in the short term. Our analysis suggests that given soaring solar PV demand across the world, the annual global manufacturing capacity of 50 GW (which is most likely by 2014) could support India's solar PV expansion plans until 2017-18 but would require a ramp up in the subsequent years.

India's domestic manufacturing capacity of modules and cells stood at 2.3 GW and 1.1 GW, respectively, on 31 March 2014. But module manufacturers prefer imported PV cells on account of their costs (price differential between domestic and imported modules is around INR 0.6/Wp) notwithstanding the depreciation of the domestic currency in FY 2014. However, given the recent government focus on the solar sector and its 'Make in India' programme, it is safe to assume that the manufacturing of domestic cells and modules will gain impetus.

At current prices and in the absence of expansion of domestic manufacturing capacity, solar imports worth INR 214,000 crores (USD 35.7 billion) would be needed to install 100 GW by 2021-22. However, if we were to assume a 6% decline in the global prices of PV panels as

[2] Includes cost of i) construction and commissioning and ii) Operations & Maintenance

well as a 1GW increment in India's manufacturing capacity of PV panels every year between 2015 and 2022, then the cost of solar imports would decline to INR 96,000 crores (USD 16 billion). While global supply can meet India's demand, reducing the import dependence would require much greater competitiveness from India's domestic cell and module manufacturing market.

Balance of Systems costs account for about 51% of the total system costs for utility-scale projects. However, being a relatively stable market, with components that are not specific to solar, achieving cost efficiencies in the domestic market in the short run would be challenging. Overall, system costs are expected to decline by ~4% for utility scale projects and around 5%-7% for rooftop scale and rural off-grid projects in the coming years.

Availability and cost of finance

The INR 900,000 crore (USD 142.2 billion) of investment needed to install 100 GW by 2021-22 stands in sharp contrast with annual investments in solar until now (INR 34,713 crore in 2013-14 was in fact the lowest since 2010). Therefore, the availability of finance would be a critical determinant of solar expansion in India. So would be the cost of finance, which forms a significant share (8%-10%) of overall project costs. Solar projects face finance challenges in the form of high rate of interest (which increases the cost of finance due to high up front cost), shorter tenure of debt (compared to the length of the payback period for solar projects), though budget 2014 has established provisions for longer term debt, and regulatory restrictions such as limits on bank's exposure to a sector and limits on overseas funding.

For utility scale and non-residential rooftop solar projects, cost of finance is the major hindrance, while for residential rooftop and rural decentralised projects, easy access to finance (hassle free, lower collateral requirements) is also an impediment.

Land costs

Even for utility scale projects, the physical availability of land is not a constraint, given that India has ~1.68 lakh sq. km of uncultivable wastelands.[3] The cost of land, currently about 3.5% of the overall project cost (~INR 2.4 million/MW), is likely to increase with greater demand and increased land speculation. Land acquisition is a significant challenge faced by solar developers. Numerous clearances, the need to manage various local stakeholders and ownership disputes often lead to project delays and cost overruns.

Cost of evacuation infrastructure

[3] For an estimate, even ~80 GW of utility scale solar projects would require only 1% of total barren and uncultivable land in the country (at 5 acres/MW).

The cost of evacuation infrastructure for solar projects is non-trivial. **For utility scale projects (> 10 MW size), the cost of connection with the nearest transmission line is at least 2.5% of the overall project cost** and would be higher for remotely located projects. For residential rooftop systems, the cost of grid interconnectivity (bidirectional meters and transformer relays) would also be approximately 2.5% of the project cost. Lack of access to sufficient and timely power evacuation, can and has delayed commissioning in the past.[4]

The sector still requires significant support and facilitation to ensure timely and adequate evacuation infrastructure. For instance, the green corridor project (proposed in August 2013), is facing multiple implementation challenges. The responsibility for execution of projects is split between multiple agencies and there are issues related to right-of-way, land acquisition and regulatory and environmental clearances.

4.2 Uncertainty of adequate revenue generation

Revenue from solar projects is often at risk and inadequate due to low demand for solar power, gap between the levelised cost of electricity (LCOE) and tariff available, and challenges associated with accessing the grid.

Lack of demand for solar power

The comparatively high LCOE of solar versus conventional fuels has previously meant low demand. Solar-specific Renewable Purchase Obligations (RPOs) are intended to increase generation in states with high solar irradiation and trading with other states, which have lower potential. However**, poor compliance with RPO mandates has implied that the supply of renewable energy certificates (REC) exceeds demand ten- or fifteen-fold on a monthly basis**. With a growing stock of unsold RECs, the future outlook for solar power demand looks bleak unless robust enforcement of RPOs begins immediately.

Gap between LCOE and available tariffs

Until grid parity is reached[5], there will be a gap between the tariff that DISCOMs are willing to offer to purchase power and the LCOE from solar projects (whether utility scale or rooftop projects). The gap can be filled via a variety of incentives such as a preferential Feed-in-tariffs (FiTs), Generation-based Incentives (GBI) or tariff rebates, each applicable or effective for different types of solar installations.

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[4] Arunabha Ghosh, Rajeev Palakshappa, Poulami Choudhury, Rishabh Jain, and Shalu Aggarwal (2014) *'Reenergizing India's Solar Energy Market through Financing'*, CEEW-NRDC Report, August

[5] CEEW analysis suggests that grid parity would not be reached at least until 2019 for utility scale projects and would only be reached in 2021 for non-residential rooftop projects, and 2023 for residential rooftop projects.

Challenges in accessing the grid

Wheeling and banking charges, along with cross-subsidy surcharges, are levied on power producers who feed power into the grid and add to the developers' project cost. Exempting solar producers from these charges could increase the expected returns on investment and is already being implemented in Karnataka. However, this would put some burden on the utilities, so the exemption should be extended only for a short time period (for Karnataka it is ten years). Moreover, without storage technologies, solar projects are vulnerable to intermittent power production unless they can access the grid and supply power on a priority basis.

4.3 Lack of ease of doing business

India's solar sector has seen delays in policy announcements (for instance, to launch Phase 2 of the NSM), frequent changes in policy guidelines including the type and quantum of incentives provided, and changes in the agencies overseeing policy implementation. Lack of information about projects commissioned, power generation and irradiance is cited by investors as a source of rising perceived risk. The large number of clearances required and time taken for their approval also deter investors. Lack of availability of skilled manpower also poses operational challenges as it directly impinges on project implementation and scale-up.

5. RECOMMENDATIONS FOR SCALING UP SOLAR POWER IN INDIA

If India is serious about scaling solar, in the minimum, policies have to be certain, predictable and long-lasting. Government targets and policies are indicative of the long-term solar power demand and are necessary, if not sufficient, to drive investments to support solar expansion plans.

Challenge to be addressed	What is to be done?	Who will implement?	What type of installation? Which scenario?	By when?
Return on Investment: High System Costs and Low Revenues	Provide incentives as a combination of accelerated depreciation (AD) and generation based incentives (GBI)[6]	Ministry of Finance, NVVN, MNRE, State DISCOMs	Utility Scale, Rooftop-Non Residential (Scenario 3)	By March 2015
	Provision of tariff rebates on grid electricity to consumers of rooftop solar power (captive), such that the number of units subsidised are linked to the capacity installed	MNRE, DISCOMs	Non-Residential Rooftops (Scenario 3)	By March 2015
	Announce net metering policies (e.g., Andhra Pradesh, Uttarakhand, Tamil Nadu, West Bengal)	CERC, SERCs	Rooftop Residential (Scenario 3)	By March 2016
	Provision of a Feed-in Tariff (FiT) for residential rooftop PV installations	State Finance Departments, SERCs, State REDAs	Rooftop Residential (Scenario 3)	By March 2016

[6] This combination is preferable over the existing combination VGF and AD as it has a higher potential to incentivise generation and is more cost effective (Source:

Challenge to be addressed	What is to be done?	Who will implement?	What type of installation? Which scenario?	By when?
Return on Investment: High System Costs and Low Revenues	Introduce differential subsidy for different sizes of solar pumps to give higher support to small and marginal farmers[7]: a. 75% capital subsidy and rest as loan for < 3Hp size pumps sets b. ~ 30% capital subsidy and rest as loan for > 3HP size pump sets	Rural Electrification Corporation[8], MNRE, NABARD	Decentralised energy systems (Scenario 2)	By March 2016
Land: Availability and Cost	Provide exemption on stamp duty on sale of private land (e.g., 50% exemption in Madhya Pradesh)	State Revenue Departments	Utility Scale	By March 2015
	Lease government land (wastelands) at concessional rates for project lifetime or 25 years, whichever is less (e.g., Rajasthan)	Under State solar policies	Utility Scale	By March 2016
	Allow leasing of private land to developers of solar projects (e.g., Karnataka)	Under State solar policies	Utility Scale	By March 2016
	Create land banks (e.g., Gujarat, Karnataka)	State Revenue Department, State REDAs	Utility Scale	By March 2017

[7] An outlay of INR ~97,580 crore (USD 16.3 billion) over a period of 8 years would be required to subsidise 7 million solar pump sets through the suggested differential subsidy, with the split between 3HP and 5 HP pump sets being in a 60:40 ratio, saving a total of 12.7 billion litres of diesel by 2021-22.

[8] REC has so far financed 55% of agricultural pumpsets in India

Challenge to be addressed	What is to be done?	Who will implement?	What type of installation? Which scenario?	By when?
Evacuation Infrastructure: Grid Up-gradation	Build evacuation infrastructure using the National Clean Energy Fund (NCEF)	Ministry of Finance, MNRE, Ministry of Power, State REDAs	Utility Scale	Continuous activity from March 2015
	Outline and publicly share detailed roadmaps for existing and new substations in solar intensive areas periodically	Ministry of Power, State Nodal Agencies	Utility Scale	By September 2015
	Expedite the implementation of the Green Corridor project with a single window clearance facility, if necessary	Power Grid Corporation Ltd. with State Agencies	Utility Scale	By March 2016
Availability of Finance: High cost of capital	Establish a Green Bank in order to provide low cost loans with long term tenure; initially capitalised by the NCEF	Ministry of Finance, IREDA, NABARD, Domestic Banks	Utility Scale, plus Decentralised Energy Systems (Scenario 2), Rooftop Systems (Scenario 3)	By March 2016
	Include renewable energy within priority sector lending	Reserve Bank of India (RBI), Ministry of Power, MNRE, Ministry of Finance	Utility Scale, plus Decentralised Energy Systems (Scenario 2), Rooftop Systems (Scenario 3)	By March 2017
	Channel infrastructure debt funds, insurance and pension funds in the solar energy	RBI, IREDA, Insurance Regulatory and Development	Utility Scale, plus Non-Residential	By March 2017

Challenge to be addressed	What is to be done?	Who will implement?	What type of installation? Which scenario?	By when?
Availability of Finance: High cost of capital	sector	Authority (IRDA), Ministry of Finance	Rooftop (Scenario 3)	
	Provide capital subsidy along with collateral free low cost loans for small and medium farmers to adopt solar pumps	MNRE, State REDAs, Rural Electrification Corporation	Decentralised Energy Systems (Scenario 2)	By March 2017
	Provide capital and interest subsidy to mini-grid developers using either the NCEF or funds allocated to the Differential Rate of Interest (DRI) scheme	MNRE, State REDAs	Decentralised Energy Systems (Scenario 2)	By March 2018
Power Demand: Poor enforcement of RPOs	Specify a roadmap for RPO implementation (e.g. Rajasthan)	State Utilities, SERCs, Ministry of Power	Utility scale	By March 2015
	Strengthen RPO compliance mechanism by integrating it into the Electricity Act, 2003	Ministry of Power, SERCs	Utility scale	By March 2016
Access to Grid: Costs associated with accessing the grid	Exemption from wheeling and cross subsidy surcharge	SERCs	Utility scale, plus Residential Rooftop Systems (Scenario 3)	By March 2015
	Priority dispatch for grid-connected solar rooftop projects	SERCs, DISCOMs	Residential Rooftop Systems (Scenario 3)	By March 2016
Ease of Doing Business: Operational difficulties	Create an information sharing platform for project and power generation data	MNRE, SECI, NVVN, DISCOMs, State REDAs	Utility Scale	By March 2015

Challenge to be addressed	What is to be done?	Who will implement?	What type of installation? Which scenario?	By when?
Ease of Doing Business: Operational difficulties	Establish single window clearance facility with time bound clearances (e.g., in Rajasthan)	State Governments	Utility Scale	By September 2015
	Design and institute a nationwide training programme for solar technologies under the National Skills Development Council (NSDC). The per capita cost of training is approximately INR 9000[9]	MNRE, the Ministry of Small and Medium Scale Enterprises (MSME), Advanced Training Institutes (ATIs), Industrial Training Institutes (ITIs)	Utility Scale, plus Decentralised Energy System (Scenario 2), Rooftop Systems (Scenario 3)	By March 2018

9 Approximate number of persons that need to be trained for O&M of grid-connected solar projects is 16,500 (Source: CEEW and NRDC (2014) *'Creating Green Jobs: Employment Created by Kiran Energy's 20 Megawatt Solar Plant in Rajasthan, India'* Issue Paper, August). Approximate number of persons that need to be trained for O&M of decentralised solar energy(mini grid) projects stand at 31,500 (Source: CEEW and USAID (2013), *Developing Effective Networks for Energy Access- An Analysis*, October 2013)

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