Roadmap for System Integration of Renewables in India's 3 high RE States

Volume 1.

Maharashtra Power System Transformation Workshop Report

Report Date**: August 2020**

Workshop Date: **18th February 2020**

Workshop Venue: MSEDCL, Head Office, Prakashgad, Bandra East, Mumbai

Workshop context

The International Energy Agency (IEA), in partnership with NITI Aayog and Prayas Energy Group, organized the Maharashtra Power System Transformation Workshop on 18th February 2020 to inform the state government's actions for system integration of solar and wind power. This workshop was the first of the series of 3 workshops supported through the IEA Clean Energy Transitions Programme (CETP), particularly thanks to the contribution of the United Kingdom (UK) Government Foreign and Commonwealth Office, British High Commission. The workshop built on IEA analysis and national and regional India workshops since 2018, as seen in the following timeline of approach.

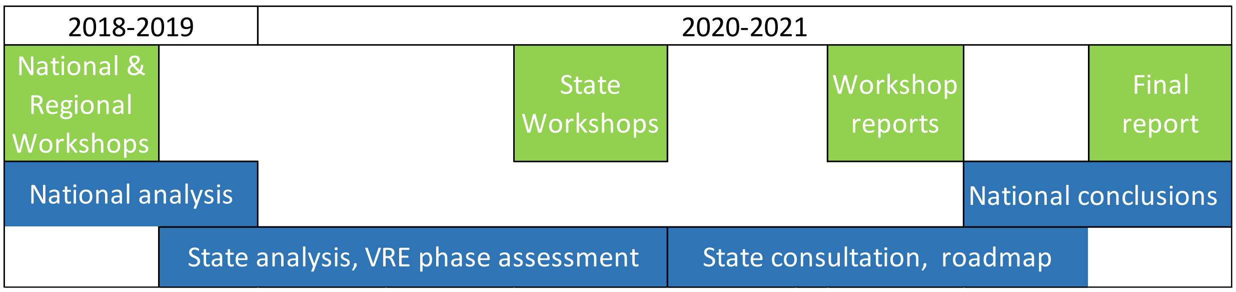

Figure 1: IEA India Renewables Integration work: timeline & approach

The Maharashtra workshop was the first time when the key local and international power sector stakeholders shared ideas and identified renewables (RE) integration related challenges and opportunities on a single platform. The objective of the workshop was to plan grid integration of high shares of wind and solar in Maharashtra, while prioritizing and deploying flexibility that could ensure cost effective system planning and operation in an evolving energy mix. The workshop attracted 80 participants from various organizations and stakeholders across the electricity value chain and particularly relevant to system integration of renewables in Maharashtra. The participants engaged actively in the 10 presentations (available for download at the IEA website here) that were set throughout the day.

The workshop concluded with a roundtable panel discussion on policy and regulatory measures that Maharashtra could consider for system transformation as the shares of RE integration increase. Interventions were made by stakeholders (attached list of participants in annex) including MERC, POSOCO-WRLDC, MSETCL, MSLDC, MSEDCL, Mahagenco, Prayas Energy Group, Idam Infra, CER, IESA, TERI, RAP and GIZ, Tata Power and Adani Power. The workshop highlighted policy actions to unlock flexibility resources, improve institutional co-ordination and prepare for integrated planning, performing advanced studies to plan for high shares of variable renewable energy etc. This summary note provides highlights from and insights into the workshop and analysis based on comprehensive stakeholder consultations, including a set of key priorities and proposed way forward.

Maharashtra state overview

Maharashtra has a total installed electricity generation capacity of 51 GW, with a 54% share of coal, a 18% share of renewable energy sources and a further 6.5% share of large hydro. Maharashtra supplied a total of 152 TWh in 2019 and with a large portfolio of state capacity it is in a power surplus scenario since 2018, which allows it to meet the energy requirements. Maharashtra also has a large potential for RE, estimated at around 114 GW (NITI Aayog), and currently has an installed RE capacity of 9.3 GW, which includes 4.8 GW of wind and 1.6 GW of solar. Under the 2015 state RE policy, Maharashtra had an RE target of 14.4 GW by 2020, but it is yet to reach this target. Due to low RE prices amongst other things, Maharashtra Electricity

Regulatory Commission (MERC) in December 2019 set a high Renewable Purchase Obligation (RPO) target of 25% by 2025 (detailed in Table 1).

	Quantum of purchase (in %) from Renewable Energy sources (in terms of energy equivalent in kWh)		
Year	Solar	Non-Solar	Total
2020-2021	4.5%	11.5%	16.0%
2021-2022	6.0%	11.5%	17.5%
2022-2023	8.0%	11.5%	19.5%
2023-2024	10.5%	11.5%	22.0%
2024-2025	13.5%	11.5%	25.0%

Table 1. Maharashtra RPO targets by 2025, Source: https://www.merc.gov.in/mercweb/faces/merc/common/outputClient.xhtml

Today the maximum instantaneous RE generation as % of demand met is 23% in Maharashtra (based on POSOCO data), which is higher than the India average of 19.4% but lower than many renewable rich states such as Karnataka, Tamil Nadu, Rajasthan, Andhra Pradesh and Gujarat.

Instead of focusing on RE the following IEA analysis and this report focusses on wind and solar defined as variable renewables (VRE) because the amount of VRE on the system is the most important measure of challenges related to RE integration. The increasing annual share of solar and wind energy generation in Maharashtra up from today's 6.5% will redefine how the state's power system should be organized, planned and operated. The extent of the challenge is visible by looking at the daily maximum instantaneous share of solar and wind generation that is expected to increase to over 60% by 2025 from the current level of just over 20 %.

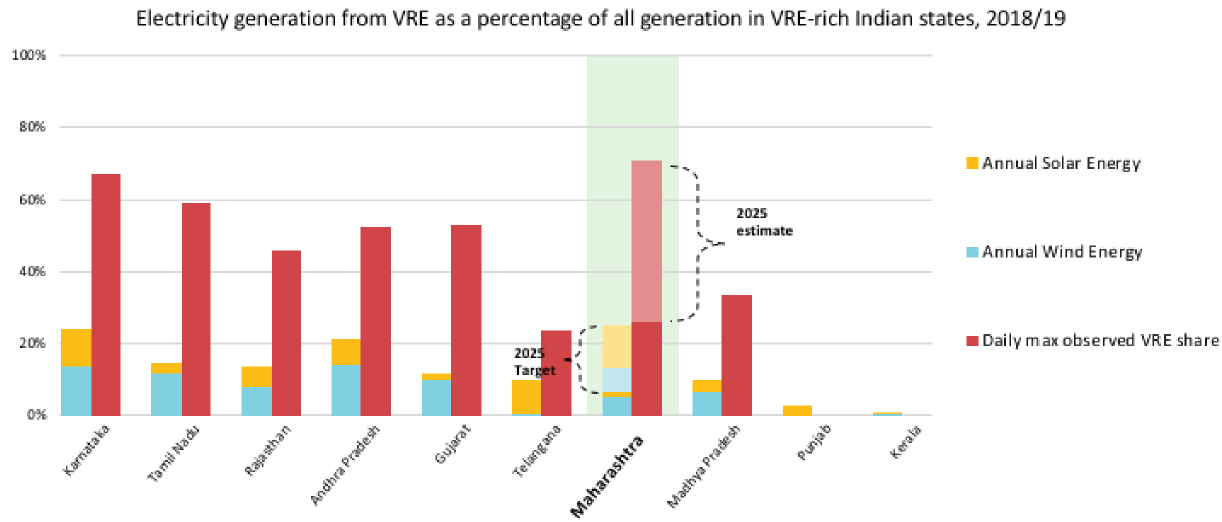

Figure 2. Solar and Wind generation and instantaneous solar and wind share in RE rich States of India, Source: IEA analysis, 2020,

Source of data:
CEA (2019d), actual VRE electricity generation form April 2018-March 2019, MNRE (2019), VRE Installed Capacity as on 31st March 2019.
Daily max observed VRE: https://eal.iitk.ac.in/
2025 estimate, Maharashtra demand projection: https://mhsec.mahadiscom.in/.

Outcomes of the Workshop

Takeaways from IEA's power system transformation framework

The IEA presented its global work on power system transformation. This framework categorizes renewable integration into six phases, with suggestions on how renewables integration can be successfully managed in each Phase. Various phase-specific challenges can be identified in the deployment of VRE, and this framework can be used to prioritize different measures to support system flexibility. These phases are described in detail (IEA, 2017) and recent examples and insights are highlighted (see IEA & 21CPP, 2019).

Currently Maharashtra is in renewables integration phase 2, thus VRE today has a minor to moderate impact on power system operations. The current flexibility capacity is sufficient to manage the existing RE generation of the state. In achieving the renewables target beyond 2025, Maharashtra will be entering Phase 3 (possibly by 2022 to 2023 considering the RPO targets), where VRE generation will start determining the operation pattern of the system due to greater variability of net load and changes in power flow patterns.

As seen in below table other countries internationally and other Indian States like Gujarat, Karnataka and Tamil Nadu are already in phase 3 and 4; and are already facing challenges to integrate the high shares of variable renewables. The workshop and this roadmap highlights what the state of Maharashtra may learn from the international experiences of high VRE countries such as UK, Ireland, US and Australia and how these learnings can fit into the Maharashtra system transformation process.

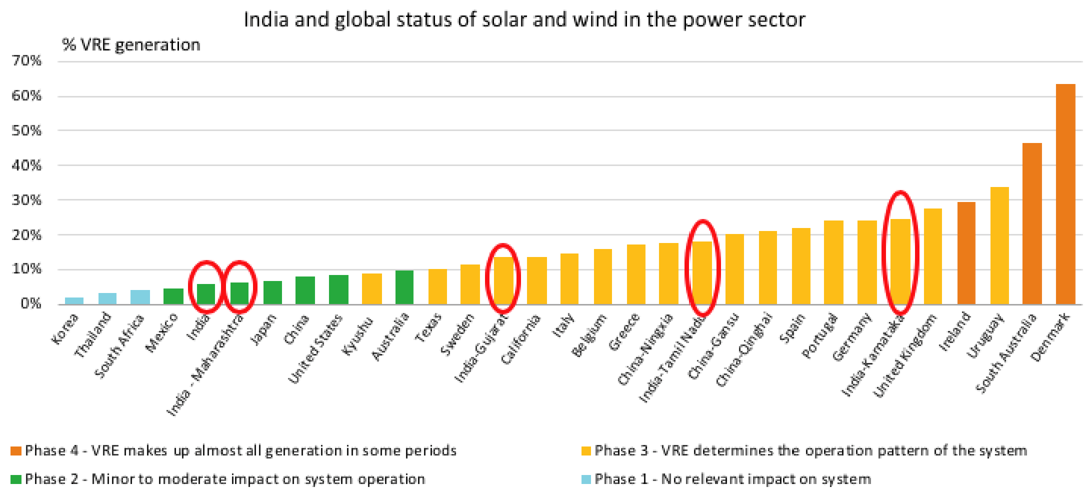

Figure 3. Countries and Regions in Phases of Renewables Integration, Source: IEA analysis, 2019

The following roadmap describes what are the key system integration challenges seen in 2020 and what can be the key priorities for meeting these challenges beyond 2025.

2020: The key RE integration challenges in Maharashtra

The workshop attendees highlighted that the workshop was very timely considering the new RPO regulation by MERC, as RE has become a critical topic of discussion in the state. There was a general stakeholder agreement on the need for more “flexible” systems, especially given the MERC RPO mandate.

- There is a lack of studies informing area-wise realizable RE potential within the state, and studies need to be developed beyond copper plate assumptions to look in-depth at grid issues.
- The variability of demand and variability of solar and wind show that flexibility is the need of the hour. Other existing issues are large frequency excursions and lowered inertia in the system, these can increase in frequency and significance with higher shares of solar and wind.
- There is an inevitable need to harness flexibility from the existing large conventional power plants.
- Due to the longer time period for development of transmission infrastructures relative to solar and wind power projects, some transmission infrastructures can become stranded when RE projects are not realized.

- With 25% RPO targets, the costs involved in operating the grid with higher shares of RE may present difficulties. The Maharashtra example shows that transmission costs are significant and all efforts need to be made to ensure total wire costs are under control.
- Stakeholders raised the issue of projection of real cost of RE integration, considering that RE is integrated at low utilisation factors into the grid. Further there is a challenge of socialization of costs and difficulties allocating costs that include grid charges.
- The existing policies incentivise significant distributed solar deployment. But there is a lack of visibility of these distributed solar resources for both distribution and transmission companies. This lack of visibility can lead to significant uncertainties of net demand forecasts as the share and magnitude of distributed solar will increase. (Net demand being defined as demand minus solar and wind.)

2025 and Beyond: Key priorities for the state and way forward

Through presentations and multi-stakeholder interactions, the event created an increased level of awareness of the changes needed in the electricity sector to facilitate the transition to higher shares of solar and wind power. The participation of MERC, MSEDCL, MSETCL and WRLDC allowed for enhanced development of effective policies that facilitate clean energy transition in Maharashtra.

Stakeholders agreed that a power system with higher share of renewables is technically achievable for Maharashtra in a secure manner.

Relevant international experience shows that systems in Phase 3 and 4 with declining inertia manage the transition towards higher shares of solar and wind with technical solutions such as the deployment of synchronous compensators and synthetic inertia provided by grid-forming converters (further details in IEA workshop on Technical secure integration of large shares of converter-based power sources, March 2020).

The workshop identified the following key priorities for Maharashtra and Indian institutional stakeholders:

a**) Gain further insight into the behaviour, constraints and potential of systems with high shares of variable renewable energy and how these apply to Maharashtra**

- Detailed analysis for system integration is needed, taking all costs into consideration and developing production cost models to capture costs from project, transmission and integration costs to socialization costs.
- Prayas (Energy Group) presented three production cost modelling scenarios a Business as usual scenario with 30% RE and two scenarios with 50% RE by 2030. The model showed that it is technically feasible to meet demand in 2030 without new additions of coal capacity, low curtailment, without unrealistic coal plant retrofits and at lower societal costs. It also highlighted that system operational flexibility is important for both scenarios.

It displayed the advantages of the solar feeder scheme that shifts the agricultural load from night time to day time, which significantly helps solar absorption. Demand response was highlighted as essential to avoid sudden shortages.

- Detailed studies are needed to identify area-wise realizable RE potentials within the state, which allow for a more structured and rigorous RE procurement approach. This involves measures for system friendly VRE deployment, where solar and wind may be able to offer flexibility services (upward and downward dispatchability vs curtailment). Making sure outputs of different technologies are complementing each other, and smoothening the variability through geographical spread. Future studies should include a detailed consideration of grid issues that involve detailed transmission planning with the 50% RE scenarios. The modelling study should also consider uncertainties in the system through consultation with the system operator.

b) Planning and investing in diversified flexibility resources will be important to cope with higher shares of renewables.

Connecting RE Phases with flexibility resources at different time-scales

The flexibility of a power system refers to the extent to which a power system can modify electricity production or consumption in response to variability, expected or unforeseen. Flexibility can therefore refer to the capability to change power supply or demand of the system as a whole or a particular unit. Flexibility can be provided at different time scales (speeds, startup times etc) highlighted in below table. According to IEA phase assessment framework different flexibility resource types acting at different time scales will be more pronounced at different phases of renewables integration.

<table>
<tr><th>Flexibility type</th><th>Ultra short term flexibility</th><th>Very short term flexibility</th><th>Short term flexibility</th><th>Medium-term flexibility</th><th>Long-term flexibility</th></tr>
<tr><td>Timescale</td><td>Subseconds to seconds</td><td>Seconds to minutes</td><td>Minutes to days</td><td>Days to weeks</td><td>Months to years</td></tr>
<tr><td>Issue</td><td>Ensure system stability (voltage, transient and frequency stability) at high shares of non-synchronous generation</td><td>Short-term frequency control at high shares of variable generation</td><td>Meeting more frequent, rapid and less predictable changes on the supply/demand balance</td><td>Addressing longer periods of surplus or deficit of variable generation</td><td>Balancing seasonal and inter-annual availability of variable generation</td></tr>
<tr><td rowspan="2">Most relevant integration Phase and example regions</td><td rowspan="2">Phase 4
Several VRE rich states by 2025</td><td>Phase 3</td><td>Phase 2
India as a whole, Maharasthra in 2020</td><td rowspan="2">Phase 4</td><td>Phase 5</td></tr>
<tr><td colspan="2">Gujarat, Karnataka, Tamil Nadu in 2020</td><td>Phase 6</td></tr>
</table>

Figure 4. Flexibility at different time-scales and Phases, Source: IEA analysis, 2020

Maharashtra, being is Phase 2 today the system operation flexibility need is greatest for resources that provide flexibility from minutes to days. Later, beyond 2023 in Phase 3 more focus on very short term flexibility capabilities will be required in order to provide flexibility within seconds to minutes. Beyond 2025 in Phase 4 when the share of solar and wind will increase even further more focus will be needed on ultra-short and medium term flexibility and then in Phase 5 more focus can shift towards flexibility over months to years often referred to as seasonal flexibility.

The type of resources that can typically provide flexibility in these timeframes (and connected Phases) are included in detail in the table below. These power system flexibility enablers can be generation, transmission, storage assets, demand-side management and sector coupling.

Flexibility timescale / Flexibility resource	Ultra-short term (subseconds to seconds)	Very short term (seconds to minutes)	Short term (minutes to hours)	Medium term (hours to days)	Long term (days to months)	Very long term (months to years)
State-of-the-art VRE	Controller to enable synthetic inertia; very fast frequency response	Synthetic governor response; AGC	Downward/ upward reserves; AGC; ED of plants including VRE	ED tools; UC tools; VRE forecasting systems	UC tools; VRE forecasting systems	VRE forecasting systems; power system planning tools
Demand-side resources	Power electronics to enable load shedding	Demand-side options including electric water heaters, electric vehicle chargers, large water pumps and electric heaters; variable-speed electric loads	Air conditioners with cold storage and heat pumps; most equipment listed under very-short-term flexibility	Smart meters for time-dependent retail pricing	Demand forecasting equipment	Demand forecasting equipment; power-to-gas
Storage	Supercapacitors; flywheels; battery storage; PSH ternary units	Battery storage	Battery storage; CAES; PSH	PSH	PSH	PSH; hydrogen production; ammonia or other power-to-gas/liquid
Conventional plants	Mechanical inertia; generation shedding schemes	Governor droop; AGC	Cycling; ramping; AGC	Cycling; quick-start; medium-start	Changes in power plant operation criteria	Retrofit plants; flexible power plants; keeping existing generators as reserve
Grid infrastructure	Synchronous condensers and other FACTS devices	SPS; network protection relays	Internodal power transfers; cross-border transmission lines	Internodal power transfers; cross-border transmission lines	Control and communication systems to enable dynamic transmission line ratings; WAM; HV components such as SVC	Transmission lines or transmission reinforcement

Notes: AGC = Automatic Generation Control; CAES = compressed air energy storage; FACTS = flexible alternative current transmission system; SPS = special protection schemes; SVC = static var compensator; WAM = wide area monitoring system.

Figure 5. Flexibility solutions offered at different time-scales. Source: IEA, 2018

Existing flexibility resources in Maharashtra

According to the workshop presentations and interventions, upgraded operating procedures, as well as policy, market and regulatory measures and incentives are required to unlock flexibility from the existing Maharashtra system assets. This can enable effective utilization of existing flexible resources such as coal, gas, hydro and pumped storage generators.

- With 25% RPO targets, stakeholders highlighted that the current transmission network can technically handle integrating this level of RE. At the same time participants opined that the transmission costs are imposing an increasing burden in Maharashtra (costs have more than doubled in the last decade both in long-term and short-term charges), there will need to be a paradigm shift in transmission planning and innovative methods to improve transmission assets and manage costs. Further more needs to be done on how these costs will be allocated among the different consumers.
- Hydro already provides significant system flexibility: Koyana Hydro Power Station (1956 MW, 18 Units), Ghatghar Pumped Hydro Power Station (2 x 125 MW), Small Pumped Hydro Power Stations (2 x 12 MW) and Uran Gas Power Station (672 MW). These stations will be co-optimized with other flexibility sources in the future.
- Further flexibility will be needed from thermal fleet as they can reach MERC's foreseen 55% operating minimum requirements (down from the current 70% technical minimum). However, the feasibility of meeting these requirements for thermal plants was contested by some stakeholders as retrofits of plant design can lead to higher costs. Based on the results of ongoing pilot projects, participants highlighted the difficulties in retrofitting older coal plants, as it can be costly (*loss in efficiency, increased start-up costs, operating costs and loss of useful asset life*) and raise concerns over safety. Older power plants account for the majority of thermal power plants of MahaGenco. 12 plants are over 25 years old and 3 more are over 16 years old out of the MahaGenco's 28 plant fleet, representing a total of 4 GW out of 9.75 GW. International experience (US, Germany and Japan) suggests that clarification of cost sharing and compensations for increased flexibility can be embedded in regulation or market rules. These topics need further discussions across all Maharashtra stakeholders.

New and additional flexibility resources in Maharashtra

- As international experience shows (such as UK, Australia, USA) specific market and regulatory innovations are required to access the flexibility from many new and innovative power sector assets and solutions such as solar, wind, demand response, storage and batteries (IEA Commentary, 2019). To reach equal access to compensation for flexibility for these new players authorities may need to review and possibly reform the current state regulation and market rules. Identification of barriers to competition for these new technologies can be the first step for the MERC. As international experience shows, removing barriers to competition is a long term often even decade long process.

- The falling costs of both solar PV and batteries favour the deployment of hybrid PV and battery systems. In Phase 2 in Maharashtra more focus may be on connection and flexibility requirements for new solar and wind deployment. Following Phase 3 there is an increasing role emerging for flexibility from grid-scale battery storage, smart charging of EVs and synthetic inertia. Another question for further investigation is whether storage including battery and EVs will face barriers to enter and compete in the current regulatory setup, for example will battery investors be eligible for fixed cost payments as thermal assets?

- Thermal storage can also provide system flexibility benefits by using surplus solar output during the day and alleviate the strain of peak cooling demand on the electricity system in the evening. Based on the IEA Future of Cooling Report in India 2400 GW thermal cold storage in 2050 allows around a fifth of total PV output to be stored during the day and used to meet around 15% of cooling demand after sunset.

- Introducing new business models (getting the right price + policy + regulation combination), giving incentives for flexibility from demand side response through the retail pricing and the wholesale market and enabling the participation of third-party players such as aggregators and behind-the-meter load shift providers will provide further system flexibility.

c) Improve system operations, expand balancing areas and upgrade grid operational protocols.

- Adopting a four step approach: (1) Enhancing the footprint of diverse technologies in the energy mix, (2) Putting these technologies in use for mandated primary response, which can allow to narrow down and help maintain the frequency band, (3) Enhancing the access to the market and increasing liquidity in the system that would allow for passive balancing through identifying imbalance price signals (Deviation settlement mechanism rates can be coupled to day ahead market rates), (4) Make sure there are enough capacity reserves to make active use of ancillary services for balancing

- Ensuring effective scheduling and dispatch at the state level and enhancing power exchanges with neighbouring states can allow for better access to least-cost generation. Larger than state level balancing areas can help reduce variability and facilitate balancing between supply and demand, making the system easier to manage. However, due to jurisdictional issues, regulation and management is being done at state level. International examples to consider include EU, Australia and China (with more details in the IEA workshop presentation).

- Adopting advanced decision-making and control systems will enable system operators to respond significantly faster under changing grid conditions. The adopted state of the art automated load and satellite-based renewables forecasting mechanism integrated within the system operation can reduce uncertainty and allow for more efficient system operations. Maharashtra was one of the first states to utilise Renewable Energy Management Centers (REMCs). Continued improvements of the Renewable Energy Management Centers will improve VRE forecasting, scheduling and dispatch and can lead to the optimized use of ancillary services.

- Making sure that distributed solar is visible and predictable for system operators (SLDCs) will be key. International experience (such as UK, Australia or US Hawaii) suggests visibility on the demand side can be required in connection requirements embedded in Discom and/or transmission connection codes.

d) Market, regulatory and tariff reforms

- From an institutional perspective, stakeholders called for improved co-ordination between regions and states to ensure efficient short-term trade of electricity across the entire country. The launch of the Real Time Market (RTM) on 1st June 2020 can facilitate improvements in market operations closer to real time and complement VRE integration. Participants opined that RTM will be a huge opportunity for distribution companies and generators to reoptimize their portfolio for cost effective procurement of electricity.

- Regulatory and policy aspects will need to be strengthened with strong co-ordination among various stakeholders. Maharashtra needs to build a pyramid of all the stakeholders for integrated planning towards green energy. For example: Participation of all stakeholders (incl. Renewable Energy players) in planning process at State, Regional and National level. Coordinated planning and prioritisation framework between state transmission utilities and central transmission utility for state/regional network.

- International experience suggest that the review of market rules and regulations will be needed on a regular basis on both national and state levels. Unlike traditional power plants, newer technologies such as batteries and demand response may have smaller individual outputs, respond more accurately and quickly, and absorb as well as deliver energy. With these qualities they can provide flexibility services, but their deployment can be limited by rules and regulations that do not account for some of their unique characteristics.

- International experience shows that the tariff system may need revision with increasing share of renewables as the timing of the system use for different consumers will become critical, especially in high solar generation times.
- The tariff review may include expanding the time of day pricing to customers of over 5-10 kW, adjustment of peak tariff slots, adjustment of default end user tariffs. For example in its Maharashtra analysis the Prayas model incorporated 4000 MW of non-monsoon

night-time agricultural load moved to day time by FY30 in line with Maharashtra's solar feeder policy. The results show that the solar feeder day time agricultural load can help with solar absorption. The complete regulatory and tariff aspects of this and other seasonal, time of use tariffs may be considered by MERC in further analysis.

- An international example of how tariff system can better align solar generation with peak demand is the Time of Use (TOU) rates policy change in 2020 in California. The TOU rate have been available as a choice for many years but very few consumers actually switched to use these rates. In 2020 the state's three investor-owned utilities have shifted their 22.5 million residential consumers to default TOU rates, making the TOU rate the default choice as opposed to the previous flat rate. During the pilots the utilities demonstrated that for every 10% increase in price ratio of the TOU rates, peak demand decreased with 6.5-11%. The policy change was made available by the widespread use of residential smart meters, something not readily available in India today, but something that is set to change with the increase of transport electrification and EVs in India. To effectively enable TOU rates more focus on deploying smart meters would be needed.

Highlights – Solar and Wind Integration Roadmap for Maharashtra

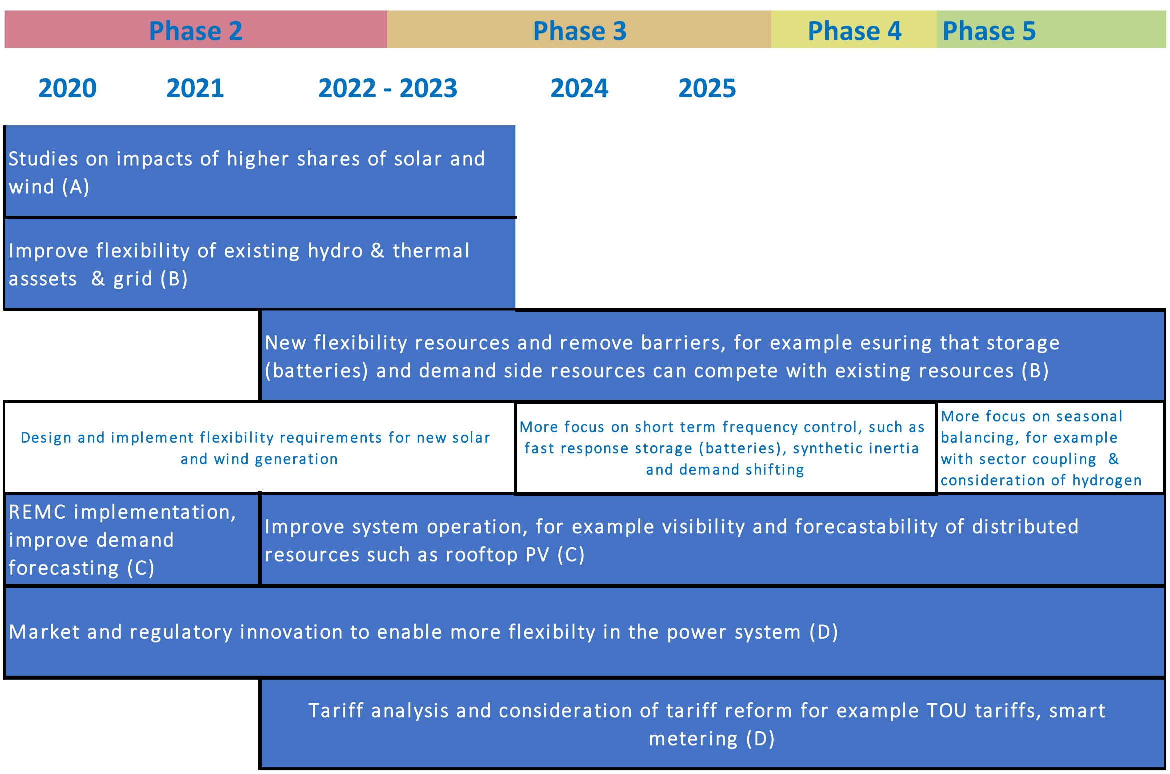

Figure 6. Highlights from Solar and Wind Integration Roadmap for Maharashtra, Source IEA Analysis, 2020

Next Steps

IEA and the NITI Aayog may share the outcome of this workshop with Maharashtra and India national stakeholders for furthering key priorities, recommendations and actions, which will prepare the state for increased shares of solar and wind. This summary will also form the basis for the upcoming workshops and analysis.

The second workshop of this series of 3 workshops under the IEA Clean Energy Transitions Programme (CETP) is proposed to focus on Gujarat State (in Phase 3 of SIR) and to take place as a virtual webinar format on 7th October 2020. The Gujarat workshop will also feature the Gujarat power sector model built by IEA and the Centre of Energy Regulation.

The third workshop is proposed to focus on Karnataka (in phase 3 of SIR) and to take place in a virtual webinar format by the end of 2020.

Following the completion of all 3 workshops, the State-level Power System Transformation report will be published on the IEA and NITI Aayog website. The launch of this combined report is foreseen for 2021. Some of the analysis may be featured in the IEA World Energy Outlook Special report on India to be published in 2021.

Preparation of the workshop and report

The preparatory analysis for this workshop was carried out from August 2019, followed by the IEA team's visits to India in September 2019 and between 18 and 19 February 2020. In Maharashtra the team met with central government officials and regulators, industry associations and stakeholders in the public and private sectors as well as other organisations and interest groups, all of whom helped the team identify the key challenges facing power sector. The IEA team is grateful for the hospitality, the high-quality presentations, the co-operation and the assistance of more than 80 people throughout the analysis, the workshop, and the visit (please see full list of workshop participants in Annex 1). Thanks to their engagement, openness and willingness to share information, the workshop was informative, productive and enjoyable. Our gratitude goes to the first organising partner NITI Aayog: Mr R.P. Gupta (former Additional Secretary), Mr Rajnath Ram (Adviser), and Mr Manoj Kumar Upadhyay (Senior Research Officer) and our second organising partner Prayas Energy Group, Mr Ashwin Gambhir (Fellow). The analysis, workshop and report has benefited from coordination and financial contribution of the UK Government Foreign and Commonwealth Office, British High Commission.

The report was prepared under the guidance of the IEA Head of System Integration of Renewables (SIR) Unit, Edwin Haesen. The analysis, the workshop and the report was carried out by Economics Lead at SIR, Ms Szilvia Doczi, Energy Analyst, Mr Kartik Veerakumar and Energy Analyst, Ms Zoe Hungerford and co-ordinated by India Programme Lead, Ms Nicole Thomas and Mr Tristan Stanley with the invaluable assistance of Ms Astha Gupta, who supported the analysis, the workshop and the drafting of the report, as IEA India programme member in New Delhi. The report was prepared by the IEA Secretariat and reviewed by NITI Aayog and Prayas Energy Group.

Annex 1. Workshop participants

Name	Organisation
Ms. Rasika Athawale	Regulatory Assistance Project
Mr. Dheer Patel	Regulatory Assistance Project
Dr. Rahul Walawalkar	India Energy Storage Alliance
Mr. Balwant Joshi	Idam Infra
Mr. Raghav Pachouri	TERI
Dr. Indradip Mitra	GIZ
Ms. Anvesha Thakker	KPMG
Mr. Rajnath Ram	NITI Aayog
Mr. Prashant Badgeri	Deputy Secretary
Mr. Subhash Dumbare (IAS)	MEDA
Mr. Dinesh Waghmare (IAS)	MSETCL
Mr. Ravindra Chavan	MSETCL
Mr. Sanjay Taksande	MSETCL
Mr. Anil Kolap	MSLDC
Mr. Shashank Jewlikar	STU
Mr. Sachin Lomte	MSLDC
Mr. Sachin Pakkhide	MSLDC
Ms. Shaila A (IAS)	Mahagenco
Mr. Chandrakant S. Thotwe	Mahagenco
Mr. V K Shrivastava	WRLDC
Dr. Anoop Singh	Centre for Energy Regulation (CER)- IIT Kanpur
Mr. Ashwin Gambhir	Prayas Energy Group
Mr. Edwin Haesen	IEA
Mr. Kartik Veerakumar	IEA
Ms. Astha Gupta	IEA
Mr. Tirthankar Mandal	WRI
Mr. Mahesh Patankar	Regulatory Assistance Project
Mr. Pradyumna Bhagwat	Florence School of Regulation (FSR) Global
Mr Tom Mottershead	UK Government Department for International Trade, British Deputy High Commission, Mumbai
Mr. V N Roy	WRLDC
Mr. V Balaji	WRLDC
Mr. Vivek Pandey	WRLDC
Mr. Satish Chavan, Dir-Com	MSEDCL
Mrs. Kavita Gharat, CE-RE	MSEDCL
Mr. Nikhil Meshram, SE-RE	MSEDCL
Mr. Amit Bute, EE-RE	MSEDCL
Mr. P M Nikhare	Mahagenco
Mr. Ashok Udage	Mahagenco
Mr. Narayan Salve	Mahagenco
Mr. M M Joshi	Mahagenco

Mr. S D Joshi	Mahagenco
Mr. S. S Chinchmalatpure	Mahagenco
Mr. Abhijit Deshpande (IAS)	MERC
Mr. Popat Khandare	MERC
Mr. Pravin Ganvir	MERC
Mr. Vikas Patil	MERC
Ms. Rujuta Gadgil	MERC
Mr. Siddharth Arora	MERC
Mr. Rajendra Ambekar	MERC
Mr. Ghanshyam D Patil	MERC
Mr. Hawwa Inamdar	Tata Power
Mr. Manoj T. Kapse	Tata Power
Mr. Gunesh Kusurkar	Tata Power
Mr. Vismay V Rane	Tata Power
Mr. Abhaji Naralkar	Adani Electricity
Mr. Shrikant Yeole	Adani Electricity
Mr. Harshal Bhingare	Adani Electricity
Mr. Anoop Zachariah	KPMG
Mr. Manoj Pise	MEDA
Mr. Vishal Shivatare	MEDA
Mr. Suraj Waghmare	MEDA
Mr. Arif Shaikh	MEDA
Mr. Shantanu Dixit	Prayas Energy Group
Mr. Srihari Dukkipati	Prayas Energy Group
Mr. Sujoy Shah	Suzlon
Mr. Ajit Pujari	K Raheja Corp
Mr. Anant Sant	Idam Infra
Mr. Krishnajith M. U	Idam Infra

Annex 2. References

Maharashtra Workshop agenda and presentations

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IEA Future of Cooling Report, 2018

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Annex 3. Abbreviations, acronyms and units of measure

CEA	Central Electricity Authority
CEM	Clean Energy Ministerial
CER	Center for Energy Regulation
CERC	Central Electricity Regulatory Commission
CTU	Central Transmission Utility
DISCOM	distribution company (in India)
ESS	energy storage systems
GENCO	generating company
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IEA	International Energy Agency
IESA	India Energy storage association
IIT	Indian Institute of Technology
ISGS	Inter-State Generating Station
LCOE	levelised cost of electricity
Mahagenco	Maharashtra generation company ltd.
MERC	Maharashtra Electricity Regulatory Commission
MNRE	Ministry of New and Renewable Energy
MSEDCL	Maharashtra State Electricity Distribution Company ltd
MSETCL	Maharashtra State Electricity Transmission Company ltd
NITI Aayog	National Institution for the Transformation of India
OECD	Organisation for Economic Co-operation and Development
PGCIL	Power Grid Corporation India, Ltd.
POSOCO	Power System Operation Corporation, Ltd.
PPA	power purchase agreement
PSH	pumped-storage hydro electricity
PV	photovoltaic
RAP	Regulatory Assistance Project
RE	Renewables (solar, wind, hydro, biomass etc)
REMC	Renewable Energy Management Centre

RPO	renewable purchase obligation
SLDC	State Load Dispatch Centre
STU	State Transmission Utility
TERI	The Energy Resource Institute
VRE	variable renewable energy
WRLDC	Western region load dispatch center
21CPP	21st Century PowerPartnership