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Addressing Quality Gaps in India's Rooftop Solar PV Program

Lessons for the country from a year-long study in Gujarat

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List of Abbreviations

ACDB	Alternative Current Distribution Board
AMR	Automated Meter Reading
CDMS	Centralized Data Monitoring Systems
CEA	Central Electricity Authority
CFA	Central Finance Assistance
DCDB	Direct Current Distribution Board
DCU	Data Concentrator Unit
DLMS	Device Language Message Specification
ACDB	Alternative Current Distribution Board
EOI	Expression of Interest
GEDA	Gujarat Energy Development Agency
GERMI	Gujarat Energy Research and Management Institute
GUVNL	Gujarat Urja Vij Nigam Limited
MMS	Module Mounting Structure
MNRE	Ministry of New and Renewable Energy
PGVCL	Paschim Gujarat Vij Corporation Limited
PPA	Power Purchase Agreements
PR	Performance Ratio
RTPV	Rooftop Photovoltaic
SLDC	State Load Dispatch Centre
SNA	State Nodal Agencies
SPD	Surge Protection Device
TPI	Third Party Inspections
TPL	Torrent Power Limited
UGVCL	Uttar Gujarat Vij Corporation Limited

Executive Summary

Our study shows that the current RTPV program instituted by the MNRE is on the cusp of a high growth scenario. However, there are significant issues related to quality of the installed systems that must be recognized and corrected at an early stage. If not done, this could significantly impact India's success on the path towards the 40 GW RTPV target.

Quality compromises are being exacerbated by the current bidding process that lays undue emphasis on the financial quote of the bidders and does not adequately take into account other factors such as engineering best practices and consumer satisfaction. These 'softer' non- financial factors are crucial and need to be captured into the bidding framework in order to promote and reward companies that have a long-standing history of best engineering practices. This will reward quality and performance of the RTPV systems and lead to a much more quality driven RTPV market in India.

The major fault noticed in our study was the lack of cleaning solar modules. In many cases consumers were not educated by the EPC companies that modules must be cleaned on a regular basis. This points to the fact that most EPCs operate on a "fit-and-forget" scheme and are not genuinely concerned of their actions (or inactions in this case). There is a dire lack in consumer education on this front. It was observed that most consumers are not aware of the basic functioning of the system and have no sense of how many units they can expect their system to generate.

The other major faults were found in the positioning of inverters (usually placed in direct sun), cables not properly routed, substandard MMS material and poor engineering practices (incorrect azimuth and tilt). These drawbacks significantly affect the performance, durability and safety of the RTPV systems. While some of these faults affect short-term performance of the systems (example: not keeping the modules clean affects the generation) and can be captured and corrected, many affect the long-term durability of the system (example: poor quality of MMS) and other factors affect safety of life (example: unavailability of surge protection devices). All the three categories severely jeopardize the long-term sustainability of the market and can engender negative consumer attitudes towards rooftop solar PV systems. Policies and regulations have not insofar addressed these core issues adequately.

Based on our observations and discussions with various stakeholders, GERMI recommends a three pronged approach to tackle the issue of quality in RTPV systems in India.

One, incorporate a stringent third party inspection and audit system to ensure EPCs maintain tender protocols. In the event an EPC flouts this, the company and its promoters must be penalized and even debarred from participating in any further tenders across India for a minimum period of five years.

Two, incorporate a centralized data monitoring system and mandate that every solar PV system above the size of 3 kW must have data loggers or smart meters that report data to a server hosted by the nodal agency in the state. This data is crucial to evaluate real-time performance and can be used to re-calibrate subsidy schemes. It can also be useful for the grid operator to better manage demand and supply in the state as the penetration of RTPV systems increases over time.

Three, reform the bidding framework to incorporate technical competencies and consumer feedback of the EPC. This would prevent companies with little experience or poor adherence to quality standards from quoting unviable prices in an attempt to capture the market. Having a points based system that emphasizes both the financial bid and the technical bid in a balanced manner can ensure that the right companies are rewarded and the price discovery mechanism is more robust.

In our view, this three pronged approach although by no means complete can go a long way in improving the quality of India's rooftop solar PV program and ensure that kW installed leads to kWh generated. The RTPV segment is crucial if India intends to decarbonize its economy in a distributed, socially equitable and democratic way.

CHAPTER 1

Suspicions on Quality

1.1. Background

Owing to its geographical location, about 58% of India's total land area receives an average Global Insolation of 5 kWh/m²/day. Leveraging this advantage, the country has set itself a national target to achieve 100 GW of solar energy by 2022. Out of this 100GW, 60GW is earmarked for ground-mounted solar plants and the remaining 40GW for Rooftop Photovoltaic (RTPV) plants.

The RTPV sector in India has installed just over 2.5 GW until March 2020. Clearly, there is a lot to be done in order to accelerate the deployment of RTPV systems in India. The Government recognizes this and the Ministry of New and Renewable Energy (MNRE) has launched Phase-II of Grid Connected Rooftop Solar Programme for achieving a cumulative capacity of 40,000 MW from RTPV projects by the year 2022.

The Phase-II Programme's Central Financial Assistance (CFA) for the residential sector has been restructured with the availability of 40% CFA for RTPV systems up to 3 kW capacity and 20% for RTPV system capacity beyond 3 kW and up to 10 kW. The program will be implemented with the total central financial support of Rs.11,814 crore. The generous subsidy model is set to increase the adoption of rooftop solar programs across the country, especially among the smaller, low-income segment.

What is evident is that the pace of deployment of RTPV systems in India has accelerated in the last year. India added the highest ever capacity between FY 19 and 20 with a capacity addition of 1.2 GW (see graph below).

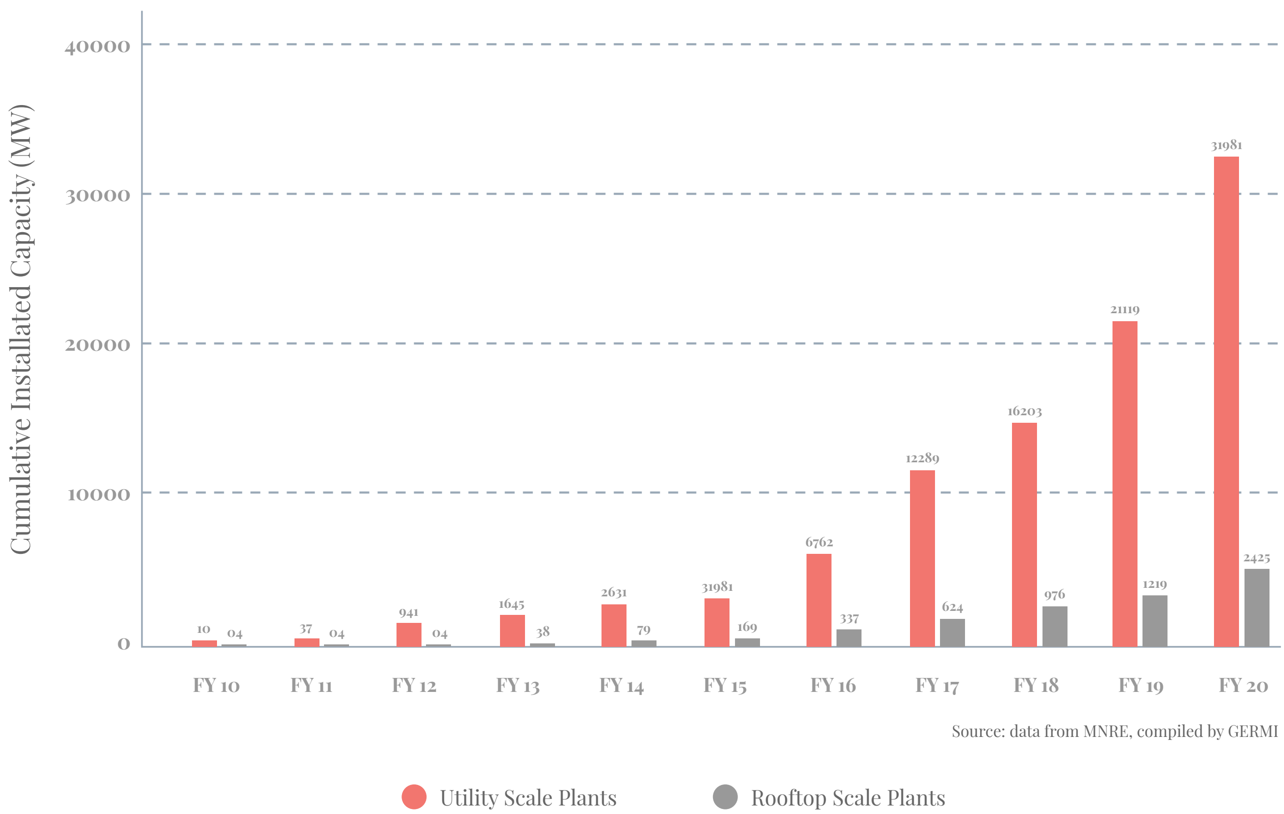
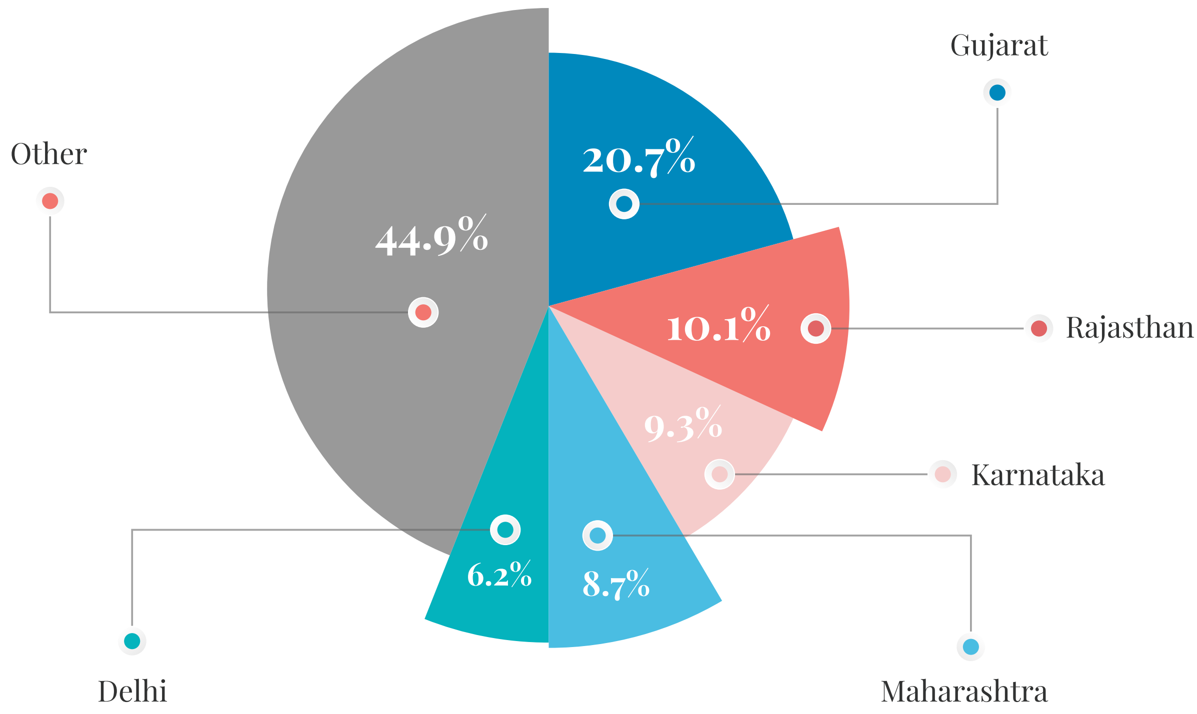


Figure 1: Overview of capacity addition in the solar PV sector in India

Among all the states in India, Gujarat has outperformed other states in the implementation of the RTPV program. It is the state with the maximum number of installations in the country and has contributed to approximately 21 % of the total installed capacity in India.

Top 5 states RTPV capacity (till March 2020)



Source: data from MNRE compiled by GERMI

Figure 2: Top 5 states showing the percentage of total capacity installed

In this study, our focus area is the state of Gujarat - mainly owing to the fact that it is the leading state for RTPV installations across the country. The aim of the study is to evaluate the quality of the installations in Gujarat so far.

1.2. What led to the suspicion of quality?

The increase in the number of RTPV installations in Gujarat can also be attributed to the state government's effort in making the technology cost-effective. The state has used reverse auctions to 'discover' a market price. This has led to a transparent and an extremely competitive market. The flip side of this is that it has raised eyebrows on the quality of solar installations. Several EPC companies submitted that the newly discovered prices are simply not feasible without significantly sacrificing the quality of components and the installation. There were three main factors that sparked the 'quality doubt'. One, the dramatic fall in discovered EPC prices. Two, unavailability of generation data to disprove an assumption that the systems were indeed performing to expectations. Three, several observers and market participants frequently complained of poor quality.

Factor 1: Drastic fall in the benchmark price of RTPV in Gujarat

Gujarat is the leading state in the country in terms of cumulative RTPV installations. This has been accompanied by the increasing number of empanelled installers under the solar rooftop subsidy program. In this market situation, Gujarat has witnessed a major decrement in the prices of the per kW benchmark prices, owing to vibrant competition. Figure 3 shows a sharp decrement of 33% in prices between FY 2017-18 to FY 2018-19. The key question for many market observers was, "Are these prices realistic?". Several EPC companies initially insisted on withdrawing their bid and participation entirely from the tender. This was the rooftop program of FY 2018-19 when the L1 price of INR 48,300/kWp was discovered. However, many startups and comparatively new EPC companies agreed to match with the L1 prices, in order to get empanelled and be eligible for the CFA subsidy scheme. The "Herd Effect" led the remaining market to acquiesce to the L1 prices as well. The informal sense though was that these L1 prices are "impossible without sacrificing quality." In comparison, figure 4 shows the difference in benchmark prices between MNRE and Gujarat.

Cost of 1kW Rooftop Solar System in Gujarat or past 3 years

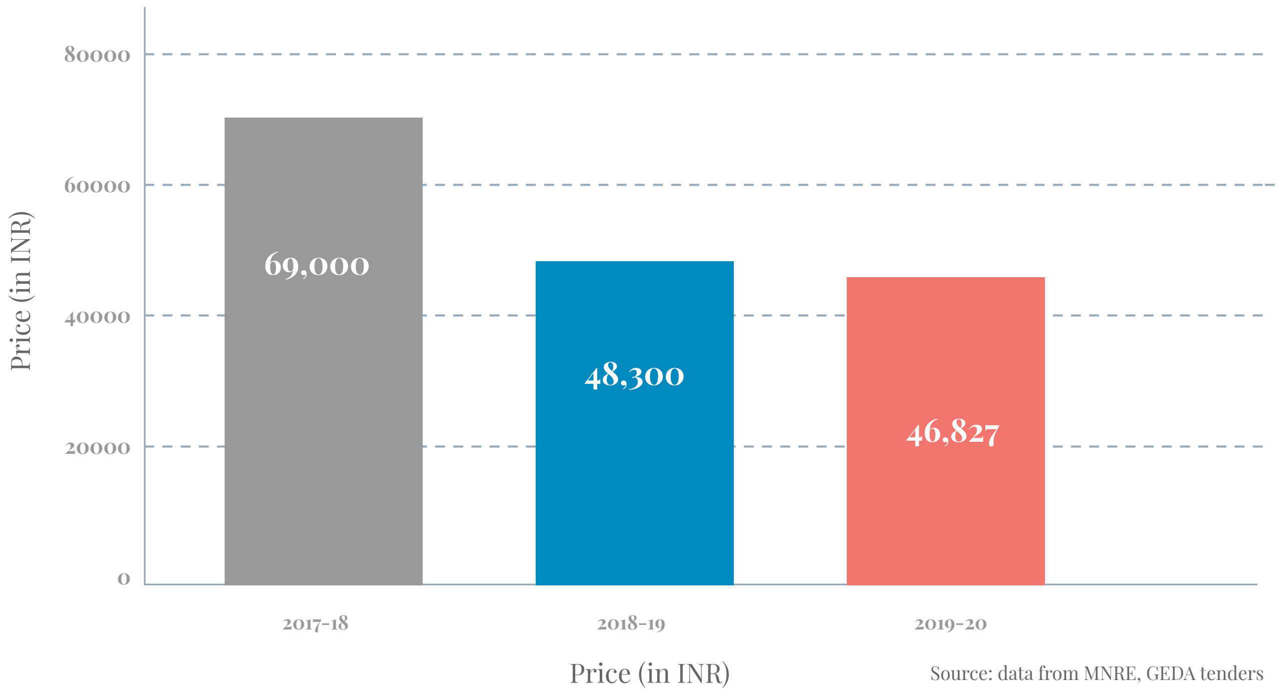


Figure 3: Comparison of benchmark price in Gujarat

Factor 2: Lack of energy generation data

None of the RTPV systems commissioned in the Gujarat program or indeed anywhere across the country is mandated to have generation data monitored on a regular basis. This data is also not being actively collected by the state nodal agency. Yes, the data is being measured by the DisCom for financial settlements, however it is not in the interest of the DisCom to ensure that the systems are operating optimally over a period of time. Subsidies are not linked to generation. Therefore, there is simply no way of checking if the systems sanctioned in the 2017-18 tender tranche are operating well. Our team decided to inspect a few sites in Gujarat to ascertain whether or not the systems were functioning. The results of this are reported in later chapters confirming fears of non-performance.

Factor 3: Market Suspicions

Quality concerns in India's solar sector have been raised not just in the RTPV sector but also in the utility sector. These concerns often appear during our informal interactions with consumers, government officials and installers. However, there have also been reports that reflect these informal views. In particular, the PI Berlin report strongly states "Strong price pressure, inexperience and lack of awareness about the sector and its risks, extreme climatic conditions, and lax requirements from the government have all resulted in poor quality solar projects". One of the reasons quoted for the poor quality of the systems is the lower benchmark price of the per kW system under the subsidy program.

Cost of 1-6kW of Grid-tied Rooftop solar benchmarks price comparision

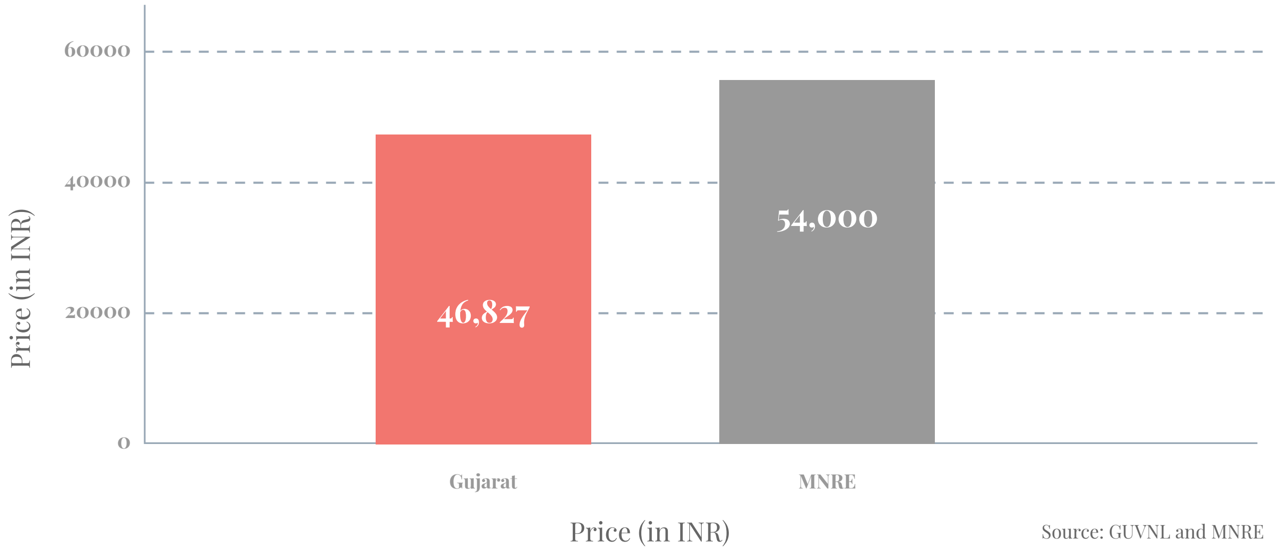
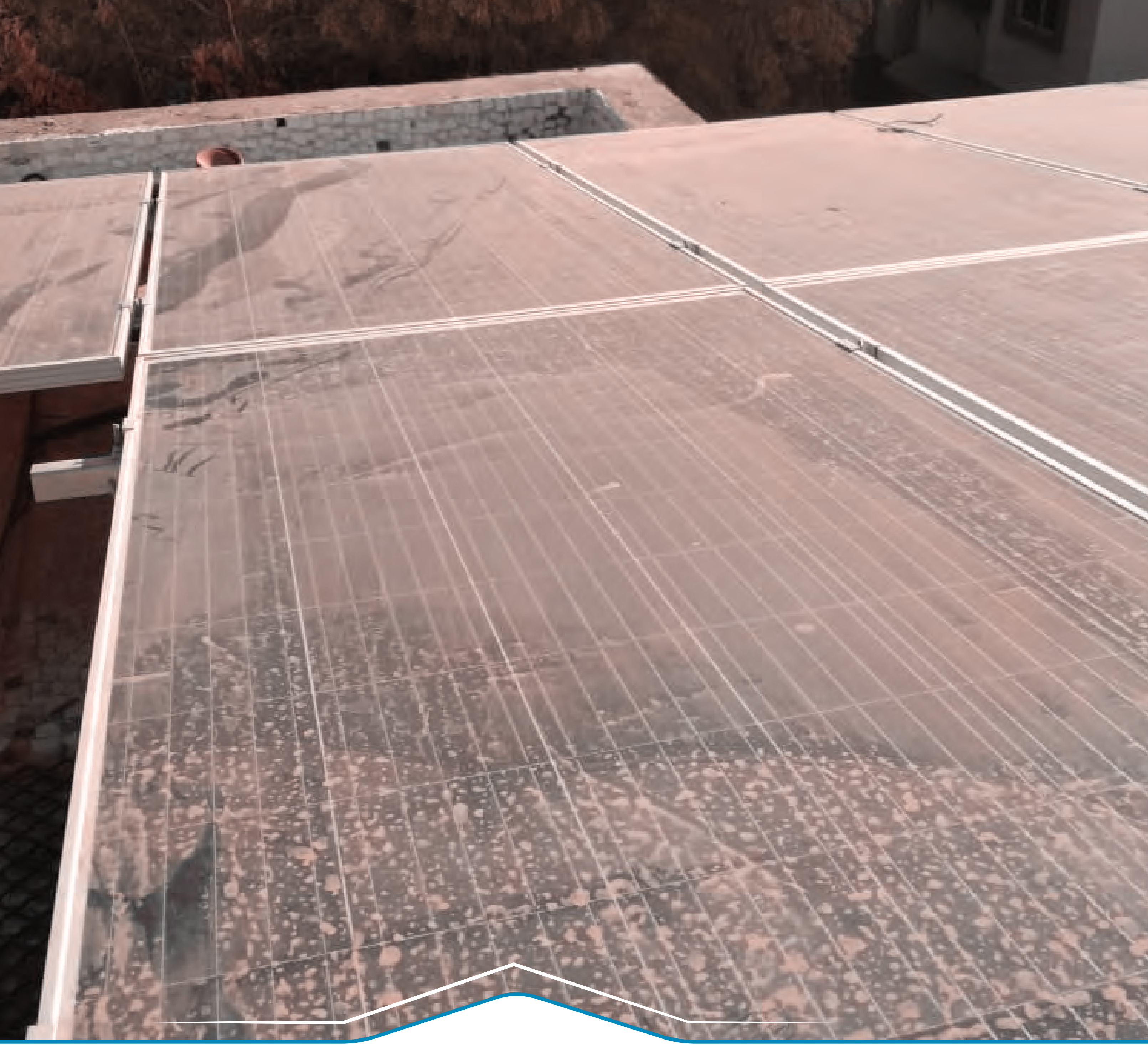


Figure 4: Cost-comparison of benchmark price of 1-6kW of RTPV discovered in Gujarat and MNRE



CHAPTER

2

Validating Quality Suspicions

2.1 On-ground site inspections

To validate these suspicions, GERMI took a pragmatic approach of inspecting those systems installed under the 2018-19 tender floated by Gujarat Energy Development Agency (GEDA), the State Nodal Agency (SNA) at that time. A team of GERMI inspected 111 RTPV sites distributed across Gujarat. The sites were covered under three different utilities namely Paschim Gujarat Vij Company Limited (PGVCL), Uttar Gujarat Vij Company Limited (UGVCL) and Torrent Power Limited (TPL). The sites were chosen randomly based on a list of RTPV sites installed in FY 2018-19 obtained from the GEDA as part of the inspection contract to GERMI.

In order to capture and analyze the aspects of quality of the RTPV systems, a simple checklist was formed. This checklist covers all the components of an RTPV system and checks whether these components have followed the guidelines and standards mentioned in the state tender. Table 1 summarizes the inspected components in the RTPV system:

Photovoltaic modules	Module make, model
	Power rating (Wp)
	Type (Crystalline technology, thin film technology)
	Cleanliness of PV module
Inverter	Inverter make, model
	Power rating (Wp)
	Type of inverter (Single phase, Three Phase)
	Placement of inverter (indoors, outdoors)
	Anti-islanding protection
	Built-in data logger availability
	DC-disconnect switch availability
Cables	Solar DC and AC cables
	AC & DC cable thickness
	Cable insulation
Module Mounting Structure	MMS Material
	MMS thickness (in mm)
	MMS grouting/foundation
Earthing and Lightning Arrestor	Presence of an earth pit
	Availability of lightning arrestor (>10 kWp)
Design parameters	Tilt angle
	Azimuth angle
	Minimum clearance of PV modules from the ground (in mm)
Alternating Current Distribution Board(ACDB) and Direct Current Distribution Board (DCDB)	ACDB and DCDB Installation
Surge Protection Device (SPD) availability	SPD installation

Table 1: List of parameters of different components of RTPV system that were inspected

2.2 Methodology of On-ground Site Inspections

Our aim was to quantify the “quality parameters” that were lacking in the RTPV system while inspecting RTPV systems under. As discussed earlier, based on our initial study from various reports and articles as well as interaction with industry players, we noticed that installers were not following sound engineering practices. With that in mind, we designed a checklist which was simple but thorough, and would reflect any deviations from guidelines and standards outlined in the tender for every component of the RTPV system. We selected.

he on-ground site inspections were divided into the following four steps :

Step 1: Selection of sites based on random sampling

The list of sites to be inspected was provided by GEDA (data for systems installed in 2018-19). Out of this, 111 sites were selected based on random stratified sampling.

Step 2: Use of a google form checklist to capture site data

A google form consisting of a checklist was developed by GERMI, to verify if the standards and guidelines of the tender for each component of RTPV plant (mentioned in Table 1) are followed. This aided the collection and capture of data. The form consisted of nine sections, covering detailed inspection parameters of the components of RTPV systems.

Step 3: Site Inspection

Based on the survey form, 111 sites were physically inspected to verify various parameters listed in the checklist.

Step 4: Data Analysis

The data gathered from the site inspections were compiled and analyzed to understand the areas where a compromise on quality might have occurred.

2.3. Results of the Inspections

The results of the site inspection study clearly revealed that there are some serious quality concerns in the rooftop installations and there is an urgent need to address these issues. The table below lists the highlights of our observations on each parameter.

Category	Ideal Condition	Observations
Photovoltaic modules	Cleaned PV panels according to the soiling intensity for optimum performance of the system	55% of total sites had dirty PV modules on the day of inspection.
Inverters and data loggers	Data logger must be installed	Built-in data loggers were not available or functioning in 30% of total sites for remote monitoring.
Surge protection device (SPD)	SPDs need to be installed both on the DC and AC side in the solar plant to prevent accidental power surges/voltage luctuations.	SPDs were absent on either side of the inverter in 28% of total sites.
MMS (module mounting structure)	MMS should be made up of Hot Dip Galvanized Iron(HDGI). The MMS should be properly grouted. The thickness of the structural material used should be ≥2.5mm	25.20% of total sites had improper structure installation. Most of these sites had poorly welded joints and in severe rare conditions, mild steel was used for MMS degrading the total life cycle of RTPV plants. Unavailability of properly grouted structure Compromise in the thickness of the structure material.
Cables	Cables should be insulated and terminated properly throughout the RTPV system.	Improper cable insulation and open cables were observed in approximately 18% of total sites.
Azimuth angle	Azimuth angle for solar plants in Gujarat should be 1800 from true north for maximum energy yield	Variations in the azimuth angle were observed up to 500 from true south in 16% of total sites.

Table 2: Guidelines to be followed vs actual conditions

Figure 5 summarizes the most critical faults as a percentage of the overall system inspected.

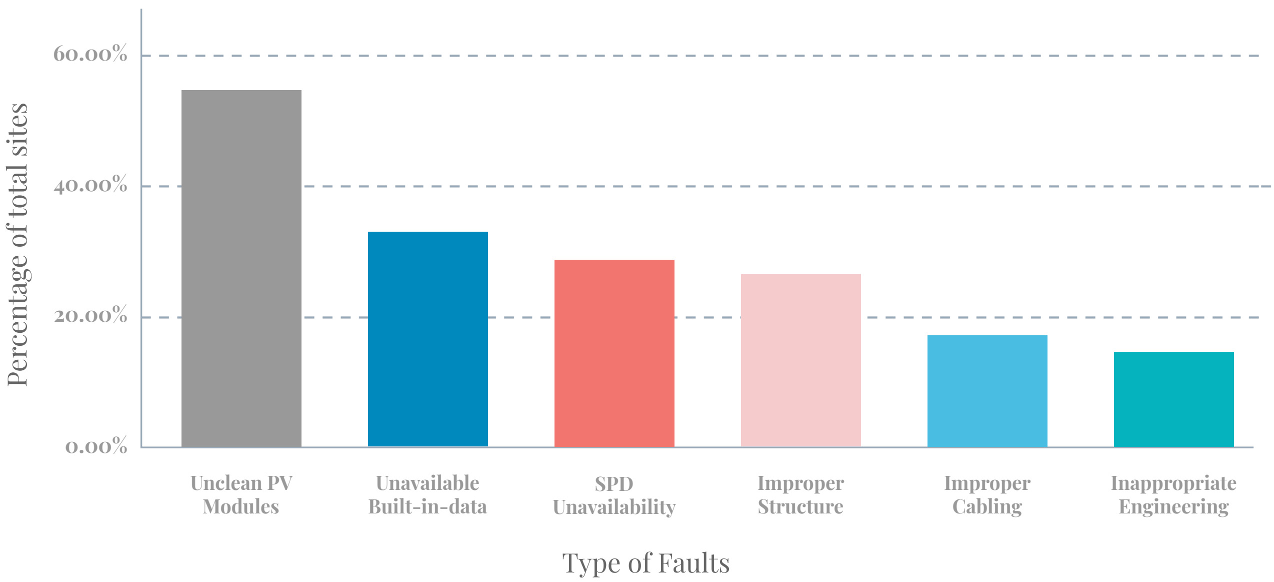


Figure 5: Major flaws as a results of the on-ground inspection

These flaws were further classified into three categories based on their short-term versus long-term impacts. These are:

1. Parameters affecting solar generation: Where the impacts are directly observable and measurable in terms of reduced energy generation form the RTPV systems.

2. Parameters affecting system durability: Where the impacts on energy generation may not be observable immediately, but would start-showing up in the long-term.

3. Parameters affecting safety: Where there are likely to be no direct impacts on the energy generation, but can have serious repercussions on safety to life.

Parameters affecting solar generation	Parameters affecting system durability	Parameters affecting safety
Uncleaned modules	Improper	Unavailability of SPD
Cabling issues	grouting/foundation	Earthing issues
Deviation in azimuth angle	Deviation in thickness of MMS	
Incorrect placement of	Cabling issues	
inverter	Material of Fasteners	
	Unavailability of built in data logger	

Table 3: List of parameters affecting solar generation, durability and safety of solar system

As a result of the TPI, the biggest flaw in commissioned RTPV systems that was observed was uncleaned modules. As is self-evident, this has the most immediate impact on the energy generation of the RTPV system. Out of 111 RTPV sites inspected, less than half, that is, only 45% of the sites had clean modules on the day of inspection. Inadequate cleaning cycles and accumulation of dirt on solar modules lead to soiling losses which results in short-term losses of 1-2% in energy generation. Additionally, scientific studies show that unclean modules may lead to very high degradation rates. This suggests that these systems may not last for the prescribed life-time of 25 years.

Improper maintenance of RTPV system post installation in terms of a regular cleaning cycle can be attributed to the lack of consumer awareness about the technology and failure on part of installers to educate customers. Also, failure in good engineering practices by the EPCs have led to such installations of RTPV systems where the modules are installed in a way that they are inaccessible for cleaning purposes. We realised that the policies and frameworks have failed in incorporating these 'soft' interventions of education and communication. One of the root-cause lies in the way the current bidding procedures are set up. The bidding framework gives excessive emphasis on the financial quote and neglects several technical and engineering aspects of RTPV system installation. There is also a complete lack of a rating and ranking system to reward performance and customer satisfaction.

Based on the outcomes of our inspections, three recommendations arise, which are treated in detail in the following sections. One, there is an urgent need to incorporate an independent third-party audit system across the country to ensure that the RTPV systems are installed as per specifications in the tender. Two, establish a centralized data monitoring system to track the performance of these systems to bring accountability as well as understanding on how effective subsidy programs are.Three, a radical revision of the current bidding process to incorporate technical and 'softer' factors such as consumer feedback.

CHAPTER 3

Potential Solutions | Third Party Audits

3.1 Why Third Party Inspection (TPI)?

Utility solar systems are structured as financial investment products and tend to be better maintained and operated. Moreover, these projects are bound by strict Power Purchase Agreements (PPAs) that hold investors accountable for the energy generation from these systems. On the contrary, the RTPV sector has no strict check or regulations that mandates energy generation from the systems, which makes it susceptible to a "fit-and-forget" approach among both owners and installers. Additionally, the market is highly subsidized and heavily decentralised and is at the verge of exponential growth (see graph below) which makes it the right point in time to ensure that the subsidy is earnestly spent and that TPIs ensure stringent quality checks.

Solar RTVP Installations In Gujarat

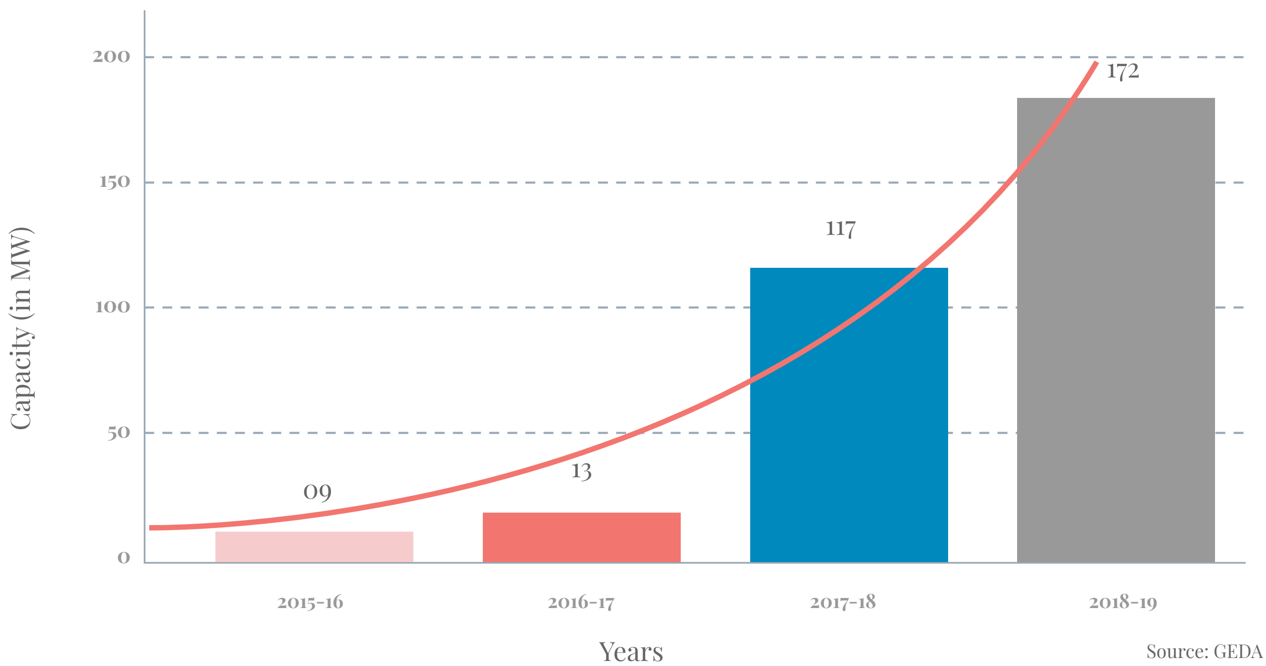


Figure 6: Growth in RTPV systems in Gujarat

The importance of ensuring well engineered and safe RTPV systems is underlined in such a scenario where the market is now growing exponentially. Hence, it is the right point in time to understand these quality gaps in the RTPV program and address it, aligning the market towards quality driven RTPV installations. In the later sections of this chapter, we provide an overview of the TPI program of FY 2018-19 of Gujarat followed by the common quality gaps observed among 2015 sites audited by GERMI as part of Gujarat's TPI program.

3.2 TPI Program in Gujarat

In the GEDA TPI program, GERMI got a contract to inspect 20% of total RTPV systems installed by every empanelled installer under the 2018-19 tender. GERMI inspected about 2015 RTPV systems in the span of four months from February to May, 2019 under GEDA's mandate. Since these sites only consisted of residential sectors, the RTPV systems were widely spread across five utilities and 33 districts in the state of Gujarat. In the interest of time and manpower required to inspect all of these sites, it was instead decided upon to inspect 20% of total RTPV sites installed by every empanelled installer/channel partner under the 2018-19 tender.

The inspection evaluated every component of the system such as modules, inverter, cables, distribution boxes and other components, based on parameters such as standards and guidelines which are to be qualified as outlined in the tender. GERMI utilized the checklist prepared as a part of this research project to evaluate those 2015 sites. Furthermore, since optimal energy generation from these decentralised systems can be linked with better system design and maintenance; so along with inspecting structural and components' quality, parameters linked to energy generation like instantaneous Performance Ratio (PR) were also measured and calculated to check the system integrity and to ensure optimal performance.

3.3 Observations

The results from 2015 sites validated the quality comprises that were highlighted earlier as part of the conclusion of on-ground site inspections. This data assisted the decision makers to design the next tender guidelines such that workmanship is at par for quality assurance. The following five major drawbacks need to be addressed in future programs.

1. Uncleaned PV modules

2. Unavailability of DC disconnect switch in inverter

3. Unavailability of Surge Protection Device (SPD)

4. Improper structural material

5. Improper cabling and earthing

After analysing data from a few hundreds of sites, it was again obvious that most sites were found uncleaned. In worst-case scenarios we encountered sites where cleaning of modules seemed impractical, mostly because the MMS and solar modules were installed in an elevated position (as a shade), making it impossible to access them in order to be cleaned.

In the TPI audit program in Gujarat, a report of every inspected site is generated based on the performance analysis of various components and technical parameters specified in the tender as outlined in Table 2. If any site is found to have any faults or deviations, the SNA sends a warning letter to the respective installer mentioning the fault and asks the company to rectify the problem in three weeks. The installer is also obliged to reply to that warning letter by sending a photo of the system after resolving the issue. Failing which, the subsidy amount for that particular RTPV system is withheld as a penalty.

However, our study shows that penalty has not proved as a strong disincentive to maintain quality and often is not being imposed with great strictness. Further, re-evaluating this site leads to further manpower costs to the state nodal agency, which is again prone to subjectivities. One potential way to ensure that EPCs ensure quality is to set up a very high disincentive. We recommend that the company and the promoters be barred from participating in any further tenders in the state (or perhaps even across the country) in case of repeated quality breaches for a minimum period of five years. For instance after three repeated quality breaches, a company and its promoters can be disqualified from participating in tenders. This should provide a strong disincentive to compromise on quality.

CHAPTER 4

Potential Solutions | Centralized Data Monitoring System

4.1 What is a Centralized Monitoring Data System?

A Centralized Monitoring Data System (CDMS) is a cloud based online framework for monitoring the energy generated by the installed RTPV plants. It enables utilities, customers, installers and government bodies and regulators to monitor, study and evaluate the data of the RTP systems installed under a common scheme remotely.

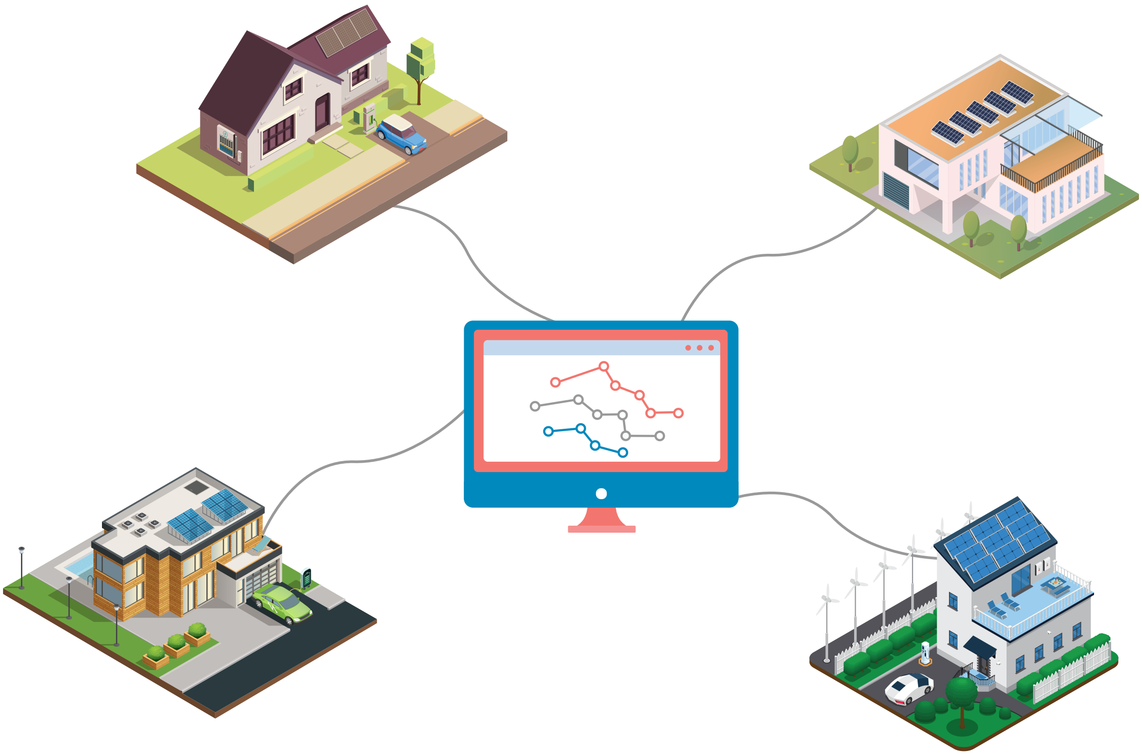


Figure 7: Architecture of CDMS

4.2 Why should CDMS be implemented?

The CDMS has a very vital role to play in enabling stakeholders to monitor the performance of the RTPV systems and get access to valuable data that can help improve the rooftop solar programs. The following section does a stakeholder analysis for each of the following stakeholders in the RTPV value chain:

1. **Utilities**
2. **Installers**
3. **Government Bodies/Regulators**
4. **Customers**

1. Tracking energy generation

With 2.5GW of RTPV systems installed across India, there is no centrally available data on the actual generation from these PV plants. This energy is crucial to utilities to better manage their demand-supply scenarios, especially as RTPV penetration increases.

2. Better Asset Management

Utilities have a range of assets (like transformers, transmission lines, etc.) under their portfolio which involves a recurring cost due changing behaviour of the grid and RTPV integration. A constant monitoring can help us to study affecting parameters through RTPV on these appliances which can thereafter result in better asset management.

3. Automated Meter Reading (AMR)

CDMS would automatically be integrated with automated meter reading, which can significantly reduce manpower costs.

4. Faster and effective control of customers giving remote access to the power supply

The grid management can be done in an efficient way, thus helping utilities to provide a better customer service. Utilities can remotely disconnect the power connection for defaulters.

5. Better predictions of load can help to reduce the power purchase cost

The CDMS would help utilities to get an accurate picture of the load pattern, helping to forecast the data more accurately in return playing a supplementary role in reducing power purchase cost, especially peaking costs for the utilities.

Installers and Private Companies

1. Better Performance Control

While most EPC already have access to their data, this is at the inverter level. Moreover, different inverters have their own portals. An integrated data portal makes it much easier for companies to monitor their installations especially when there might be performance guarantees. This would drastically improve energy generation of the RTPV systems.

2. Analysis of the components

Having a unified portal would help EPC make better engineering decisions such as component selection and system design. This would benefit not just the company, but also the consumer and the sector as a whole as overall engineering best practices can be evolved.

Government bodies / Regulators

1. Efficacy of subsidies and performance based incentives

Having access to the energy generation of RTPV systems can help the government track the efficacy of subsidies. Are subsidies actually resulting in useful assets?

2. Forecasting

The data obtained from the data monitoring portal can then be utilized by the State Load Dispatch Centres (SLDCs) to forecast the energy demand of the region.

1. Improved reliability of power supply

When utilities would be able to better forecast the load pattern they can pass the benefits to the customers providing reliable power supply mitigating the frequent use of DG sets or other power supply alternatives.

2. User friendly and transparent system

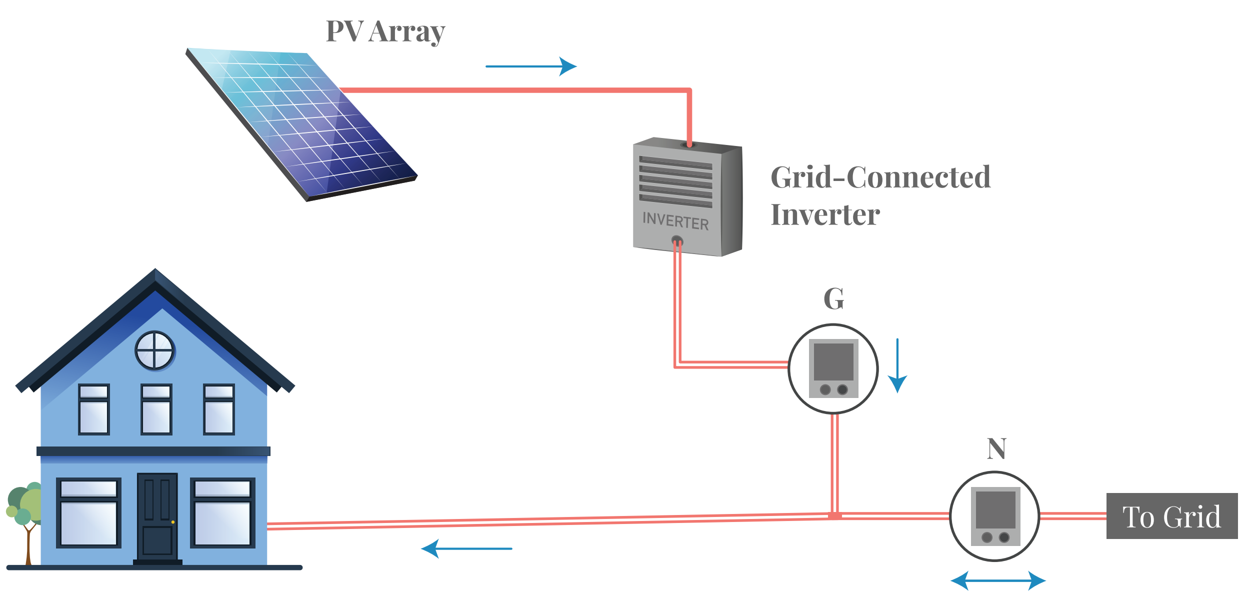
The data access point for the utilities and customers would be the same thus improving transparency in the system.

3. Improved quality and energy generation of system, leading to greater savings

Having access to data and understanding it can promote better behaviour and engender ownership among consumers.

4.3 How can the CDMS be implemented?

There are two broad ways in which a CDMS can be implemented. The difference arises from the components used to obtain the energy data. The first approach is to use data loggers from the three data sources i.e. inverter, generation meter and the net-meter. The second approach is to use smart meters that come with in-built data logging and communication capabilities. The figure below shows a typical schematic of a grid-connected RTPV system with two meters, which is a standard installation in Gujarat.



Source: Best Practices Manual for Implementation of State-Level Rooftop Solar Photovoltaics Program in India

Figure 8: Schematic of RTPV plant

1. By using a Data Concentrator Unit (DCU)/modem with the meters

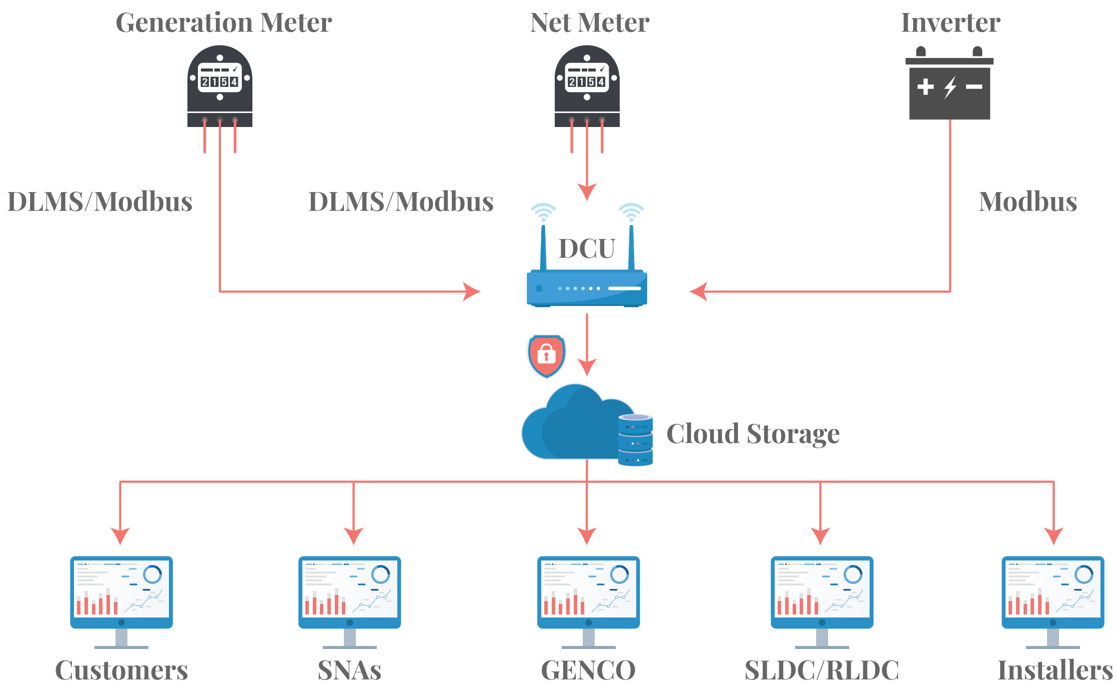


Figure 9: Schematic of CDMS architecture using a DCU

The key components involved in this architecture are sixfold:

The entire system includes existing three devices:

1. Solar generation meter

2. Bi-directional net meter

3. Inverter(s)

In addition to the above three components, we recommend the addition of the following:

1. Data Concentrator Unit (DCU)

2. Cloud server

3. Centralized portal

The existing RTPV system logs data from the inverter(s) of the system. The inverter comes with a remote data logger which sends the data to the server of the inverter manufacturer , owner of RTPV system and to the installer. This data is not considered 'reliable' as it is not from a tested meter as per the Central Electricity Authority (CEA) guidelines. DisComs use the meter data as the basis for financial adjustments (and not inverter data). In the current RTPV scheme, disComs usually manually read the net meter and the generation data for their financial adjustments.

In the proposed structure, we recommend an additional component called Data Concentrator Unit (DCU). DCU acts as a modem to collect, store and communicate the energy data of the customer to the stakeholders involved (i.e EPCs, utilities and customers). The energy data from the energy meters is transmitted using wired technology, which is then stored in the DCU. The DCU then transfers the data wirelessly using a GSM or NB-IoT technology to the cloud server. The server then fetches the data from the cloud server using an energy management software which assists in the visualization of the data.

1. By using Smart Meters

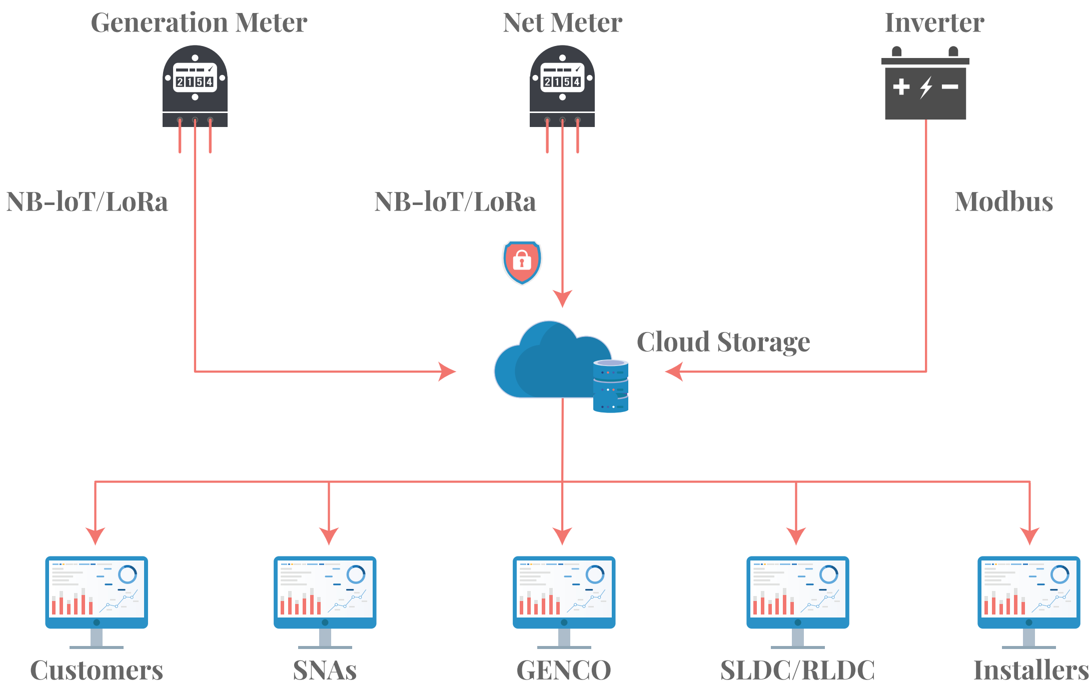


Figure 10 : Schematic of CDMS architecture using smart meters

The key components involved in this architecture are:

The entire system includes the three existing devices from the rooftop solar system:

1. Smart solar generation meter

2. Smart Bi-directional Net meter

3. Inverter(s)

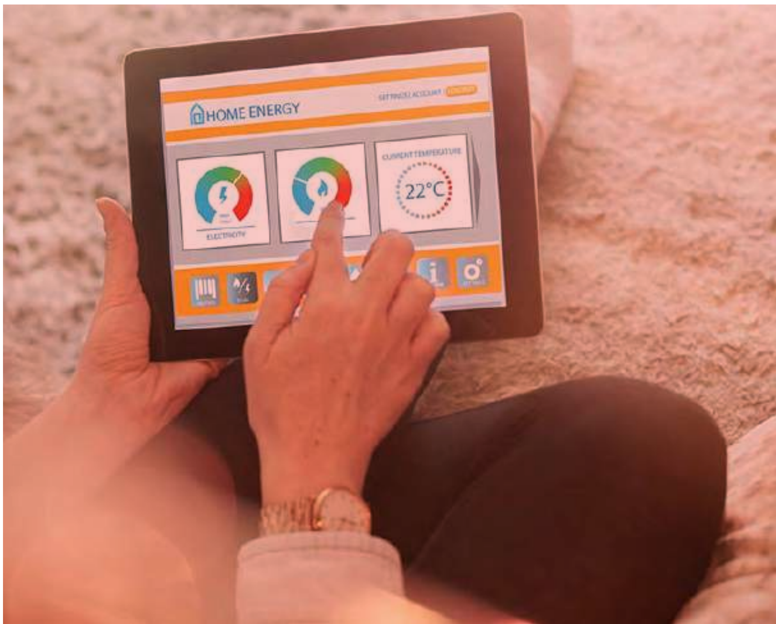
The proposed structure includes :

1. Cloud server

2. Centralized portal

A smart meter here means an energy meter that enables the meter to read, store and communicate energy data (such as energy consumption, voltage, current, frequency and other possible parameters). It can also be used to analyse the consumer's energy usage profile and link it with billing (i.e automatic meter reading technology or AMR)

This proposed framework includes communication with the central server with a data logger using the communication protocols such as MODBUS and Device Language Message Specification (DLMS) and using technologies such as NB-IoT or LoRA. The smart meters will in turn communicate with the cloud server using GSM/GPRS technology. The parameters required (listed in the next section) can be tracked online by all the stakeholders such as installers, utilities, SLDC, MNRE etc.



4.4 Key Functionalities of the CDMS architecture

The key functionalities/parameters which can be retrieved from the CDMS architecture are mentioned below:

- **Automated Meter Reading (AMR)**
- **Parameters evaluation such as voltage levels, energy usage, current levels, consumption profile, etc.**
- **Detailed analysis of each RTPV plant**
- **Geographical information system**
- **Power quality management**
- **Outage management system, warnings and alarms**
- **Customer feedback and complaint registration system**

Can existing plants be retrofitted and integrated in the CDMS architecture?

Yes, existing plants can be retrofitted and integrated to the CDMS using the DCU model where the existing inverters and meters can be connected to a DCU and then be integrated in the CDMS architecture.

4.5 Financial Analysis

The key question when it comes to implementing a CDMS based on either of the above approaches is cost to the consumer. An indicative financial assessment for each of the two approaches has been done based on initial market estimates. These numbers must be treated as incipient and are likely to change based on make/technology and volume.

Since the price of the CDMS is usually very sensitive to volumes, we have made an assumption of implementing the CDMS for 1,00,000 RTPV systems initially under a single tender. A CDMS typically has two broad costs – an upfront hardware cost and an ongoing data and cloud/server cost. We propose that the upfront (CAPEX) cost be integrated into discovering the L1 price in tenders, while the recurring costs be apportioned to every customer and can be charged as an addition in the electricity bill.

Tables 7 and 8 summarize the costs involved in both options. The detailed explanation of all the components used in our calculations is listed in Annexure I.

Assumptions			
No. of sites = 1,00,000		Operational years = 5	
Option 1: Conventional-meters with DCU			
One-time costs			
Entity/Service	**Cost/mete (INR)**	**Quantity**	**Total Cost (INR lakhs)**
Meters	2,000	2 lakh	4,000
Data Concentrator Unit	2,500	1 lakh	2,500
Software development cost	-	-	40
Data management cost	-	-	30
Sub-Total(1)		**INR 6,570 lakhs**	
Recurring cost			
Service		**Total Cost (INR lakhs)**	
Communication charges		250	
Cloud storage charges		1,200	
Sub-Total(2)		**INR 1,450 lakhs**	
Total cost of the system (1+2)		**INR 8,020 lakhs**	
Approximate cost per customer		**INR 8,020**	

Table7: Financial analysis of conventional meters with DCU technology for CDMS

The upfront smart meter cost can be included in tenders while ascertaining benchmark price of the entire RTPV system. The recurring costs incurred can be charged to each consumer in their electricity bill (usually bi-monthly).

Secondly, it is also evident that the average cost incurred by using smart metering technology is more cost-effective and perhaps more robust than the DCU technology. Finally, the key question is do we impose CDMS on all consumer types? The answer to this question is determined by what is the percentage increase in costs as a proportion of overall system costs. That is to say, a CDMS costs the same whether implemented for a 1 kW system or a 100 kW system.

Option 2: Smart meter technology

One-time costs			
Entity/Service	**Cost/mete (INR)**	**Quantity**	**Total Cost (INR lakh)**
Smart Meters	3,000	2 lakh	6,000
Software development cost	-	-	40
Data management cost	-	-	30
Sub-Total(1)		**INR 6,070 lakh**	

Recurring cost	
Service	**Total Cost (INR lakh)**
Communication charges	400
Cloud storage charges	1,200
Sub-Total(2)	**INR 1,700 lakh**
Total cost of the system (1+2)	**INR 7,770 lakh**
Approximate cost per customer	**INR 7,770**

Table8: Financial analysis of Smart meter technology for CDMS

The table below shows the calculation for each system size. The system prices are taken from the latest PGVCL tender (2019-20).

System size (in kW)	Cost of System (₹)	Average cost of CDMS | With Smart meters (₹)	Percentage of the system price
1	46,827	7,770	16.59%
2	93,110		8.34%
3	1,39,011		5.59%
4	1,82,952		4.25%
5	2,25,150		3.45%

Table 9: Financial analysis of Smart meter technology for CDMS

Based on the table below, we recommend that CDMS would make sense only for system sizes above 3 kW (<5% of the system cost). For smaller systems, this would be an unfair price burden - especially given the fact that these could represent low-income families.

CHAPTER 5

Potential Solutions | Reforming the Bidding Framework

5.1 Existing Bidding Framework

TPI and CDMS are the types of solutions that apply post facto, that is once the system is already installed. But in order to ensure that quality metrics are emphasized before the installations, it is imperative to regulate the market by imposing quality driven aspects in the policies and regulatory framework. The state of Gujarat sets its own RTPV deployment target every year and accordingly floats tenders of specific capacity. These tenders help in ascertaining the benchmark price against which the CFA is disbursed. The idea is to reform the bidding framework to incorporate technical and quality parameters. This is against the current standard practice of awarding the L1 to the company that bids the lowest. Awarding and thereafter benchmarking the entire market against this L1 leads to questionable companies with little experience cornering the market. This is especially true in a new market segment like RTPV where there are several bidders who try to seize the market by underestimating costs and bid aggressively. Reverse bidding per se must be continued, however with a few changes to the selection procedure. This chapter outlines the required changes.

In order to highlight the deficiencies of the current bidding framework, we base our study on the current PGVCL tender (2019-20). The selection criteria is outlined below:

Particulars	Description
Tender issuing agency	PGVCL
Tender issued date	20/07/2019
Tender target capacity	600 MW
Tender validity	31/03/2020
Capacity slabs for which the quotes were invited	1 - 1.5 kW
	1.51 - 2.5 kW
	2.51 - 3.5 kW
	3.51 - 4.5 kW
	4.51 - 5.5 kW
	5.5 - 6 kW
	6 - 10 kW
	10 - 25 kW
	25 - 50 kW
	50 - 100 kW
	Above 100 kW
Bidder categories	**Category A:** companies who have experience of installation and commissioning of minimum aggregate 100 KW capacity of solar rooftop/Grid connected systems in any sector such as residential, social, industrial, commercial, government, etc. **Category B:** companies that are new entrepreneurs and/or those bidders who are not covered under Category-A. Only the bidders of Category A are considered to determine the benchmark price for the state.

Table 10: Brief Description of PGVCL tender 2019-20

In this tender, the current bidding framework in Gujarat is based on a two-step process **1) A pre-qualification criteria and 2) A financial bid.** Bidders have to pass the pre-qualification criteria since these technical requirements are obligatory. Essentially, the pre-qualification criteria is a proof of information by which every bidder showcases their eligibility for the financial bid.

Every bidder needs to submit the following documents in the pre-qualification criteria:

Pre-qualification criteria	Inclusions
Bidder categories	a.) EOI document fee amount by specific options, b.) Earnest Money Deposit amount by specific options
Technical offer documents	a.) Proof of company registration, b.) proof of 100 kW RTPV or Grid connected systems in any sector for category - A bidders only, c.) Turnover criteria for category - A bidder only, d.) Proof of having an electrical engineer as proprietor/ partner/ director/ Employee of the bidder and bio-data which includes the proof of academic qualifications, relevant certifications and work experience in years, e.) Declaration of relatives employees with any employee in the utilities

Table 11: Documents to be submitted under the Pre-qualification criteria

Once passed the pre-qualification criteria, the SNA, adopts an L1 price mechanism for the discovery of the capital costs of the RTPV systems. Every bidder has to quote rates for all eleven categories proposed in the tender. The lowest price (L1) forms the benchmark price for each system category that is uniformly adopted across the state. All subsidy disbursements are benchmarked against this price.

5.2 The need of reforms in bidding framework

The pre-qualification criteria as listed in the table 5 is perfunctory. It does not in any way distinguish companies with good engineering practices from companies that are clearly inadequate in their design and installation. Factors such as technical competence of manpower, performance of past RTPV installations and a good service network in the state are all missed out. Furthermore these pre-qualification criteria can easily be met by those companies that are not particularly technically competent. We believe that this is one of the most important points for reformation. In order to overcome this limitation, we propose a modified bidding framework, which is based on a points based system. Having a points based system can actually promote companies engaged in providing installations with good engineering practices.

5.3 Proposed Weightage-Based Bidding Framework:

To overcome the shortcomings of the existing bidding framework, the proposed bidding framework is divided into three categories: 1) Technical criteria, 2) Company profile and 3) Price bid. These three criteria have been further divided into subparts and weightage has been given to each subparts accordingly. Table 6 shows the structure of weightage-based bidding Framework. A detailed breakdown of the weightage-based bidding framework is given in the Annexure - II.

Sr no.	Category	Points	Comments
1	**Technical Criteria**	**50**	**Evaluates the technical strength of the proposal**
1.1	Qualifications of manpower	10	Evaluates the technical strength of the staff
1.2	Technical concept note	15	Evaluates the quality of the technical system design
1.3	Performance ratio of systems (historical data)	20	Evaluates the generation through the Performance Ratio (PR)
1.4	Customer Feedback	05	Evaluates the customer service quality
2	**Company profile**	**10**	**Evaluates the financial strength and capacity installed**
2.1	Financial strength	05	Evaluates the financial strength of the company
2.2	Capacity installed	05	Evaluates the experience of the firm in MW capacity installed
3	**Price bid**	**40**	**Evaluates the financial quotation of the proposal**
	Total	**100**	

Table 12: Weightage-based bidding framework structure

Explanation of Parameters

Technical concept note: includes a sample site evaluation where the details of a dummy site will be provided to all the bidder companies. For eg: Geographical data of a 50 kW sample site would be provided with the required criteria to all bidders. Bidders have to demonstrate reports of various stages of installation. The breakdown specifies the components and corresponding points to evaluate the score:

Categories	Comments	Points
PVSyst/SAM/PV-Sol site simulation report	Design Parameters, Components used, Energy generation in kWh	04
Shadow analysis	Sketch-up shadow analysis throughout the year	04
Data sheets of components/material	Modules, inverter, cables, ACDB, DCDB	05
Single line diagram	-	02

Table 13: Point breakdown of Technical concept note

In those states where the necessary manpower or skills in respective SNAs to evaluate the technical concept note is lacking, the task can be outsourced to consultants or research organizations.

Performance ratio of systems: stands for the average performance ratio of the RTPV system in the specified duration. This can be used once the CDMS system is deployed and data is available to make this evaluation.

Customer feedback: A feedback form will have to be filled by the customer just after the commissioning of the RTPV system. Customer feedback may be measured on a scale of 5.

Evaluation of Bid: The tender for the 11 different categories (as per Table 4) would be filled by every empanelled installers/channel partners according to the bidding criteria. The company that obtains the highest number of points out of 100 shall be marked as the winner of the tender. The price quoted by the installer is set as the benchmark price for the tender. Companies who would be ready to install at that benchmark price will be allowed to participate in the subsidy program. It is important to note that this entire weightage based bid evaluation is for category A bidders.

Category B companies, which are either entrepreneurs or new companies, will not bid financially and have to abide by the benchmark price ascertained by the category A companies. Furthermore, a specific limit of site installations (for eg. up to 200 kW) can be assigned to every category B company to reduce the risk of quality issues.

Note: For bidders who have past experience in installing RTPV outside the state of Gujarat, GUVNL will require a proof of specific generation and customer feedback in the form of a certificate from relevant state nodal agency / DISCOM to fit in the category A tendering process.

Annexure I

Description of the components used in Financial analysis of CDMS

Numbers of meters used in both models: Every RTPV system has two meters, namely generation meter and the bi-directional net meter. Therefore, 2 lakh meters are considered for the assumed 1 lakh systems in the analysis.

Data Concentrator Unit (DCU): A single DCU is required per site to collate and communicate data from both meters and the inverter installed at the site.

Software Development cost: The cost involved in developing a portal where all the data from the meters and inverter are integrated. Every stakeholder will have access to this data and shall be strictly protected by the SNA. The SNAs will keep the ownership of the data.

Data management cost: The cost incurred to build a tool to structurize and manage the different parameters received from meters and effectively sort and represent it on the backend side of the portal.

Communication charges: Considering the volume and the market price of communication charges offered by the telecom service providers, data communication charges from RTPV system to cloud server can be estimated at approximately INR 50/year/customer. According to this price, we estimate the total cost incurred in communication will be:

50*5 years*1 lakh customer=INR 2.50 Cr. for 5 years.

Cloud server storage charges: Third party cloud servers such as AWS, Google Cloud, IBM cloud gives scalability and reduces hefty upfront costs of server procurement. This study has taken indicative pricing of third-party cloud storage costs at approximately INR 240/year. Hence, the overall cost incurred would be INR 12 Cr. for 5 years.

Annexure II

Detailed Breakdown:

1	Technical Criteria	Points	Comments
1.1	Qualifications of manpower	10	This metric captures the importance of qualified personnel. Relevant experience i.e. in installing and maintaining solar PV systems is given the highest points followed by education qualifications and any certifications in rooftop solar PV. This qualification is considered for 2 employees of the company. The employee must have an assigned EPF in the name of the employee from the company.
1.1.1	Relevant experience in the field of RTS	05	
	>4 years	05	
	2 - 4 yearsars	03	
	0 - 2 years	01	
1.1.2	Educational qualifications	03	
	Diploma in a relevant field (Eg. electrical, Mechanical eng.)	01	
	B.E/B.Tech. in relevant fields	02	
	M.E./M.Tech. in relevant fields	03	
1.1.3	Additional certifications, trainings related to RTS	02	
1.2	Technical concept note	15	Each bidder must submit a technical concept note for a 50 kW grid tied system. The note or project report must contain an appropriate PV Syst or SAM simulation report, shadow analysis using sketchup, relevant data sheets of component used, SLD. This section will evaluate the overall accuracy of system design.
1.2.1	PVSyst or SAM simulation report	04	
1.2.2	Shadow analysis	04	
1.2.3	Data sheets of components material	04	
1.2.4	Single line diagram	02	
1.3	Performance Ratio of Systems	20	The performance ratio (PR) shall be measured over the entire year through the generation meter reading and using an average insolation at
	Annual PR above 80%	20	
	Annual PR from 75% - 80%	15	

	Annual PR from 70% - 75%	10	that site (or a nearest geographical location). Since the PR can only be measured from past data, the first tender to adopt this framework shall not have historical data to benchmark the PR. Therefore for the first time, 15 marks shall be given to each company.
	Annual PR from 65% - 70%	05	
	Below 65%	00	
1.4	Customer Feedback	05	Customer Feedback relies on historical data, but for the first tender 5 points will be awarded to all the bidders. Thereafter rating the bidder on a simple 3 point rating system: Happy Smiley - The customer service of the bidder was excellent (3) Straight Face Smiley - The customer service was OK (2) Sad Smiley - The customer service was poor (1)
	Excellent	05	
	OK / Average	03	
	Poor	01	
2	**Company profile**	**Points**	**Comments**
2.1	Financial Strength	05	
	Annual turnover in INR > 10 million	05	
	5 million < Annual turnover in INR < 10 million	2.5	
2.2	Capacity installed	05	The performance ratio (PR) shall be measured over the entire year through the generation meter reading and using an average insolation at
	Installed capacity > 900kW	05	
	Installed capacity > 700kW	04	
	Installed capacity > 500kW	03	
	Installed capacity > 300kW	02	
	Installed capacity > 100kW	01	

3	Price bid	Points	Comments
1	L1’	40	L1' stands for the lowest price quoted by the bidder for every category. L1' bidder will be awarded with 40 points. Subsequently, points are allocated with the price range with respect to the L1' price
2	L1'+ 2% of L1'	38	
3	L1'+ 3% of L1'	36	
4	L1'+ 4% of L1'	34	
5	L1'+ 5% of L1'	32	
6	L1'+ 5% to 7% of L1'	30	
7	L1'+ 8% to 10% of L1'	28	
8	L1'+ 11% to 13% of L1'	26	
9	L1'+ 14% to 15% of L1'	24	
10	> 15% of L1'	22	

*The historical data of performance ratio of systems and customer feedback will not be available to evaluate companies in this tender. Therefore, we suggest that these two categories be left out in the first round. However, it is suggested that these parameters are measured from the current tenders, so that these metrics may be available for future such tenders announced by nodal agencies. To be discussed in detail further in the document under the name of centralized data monitoring system.

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