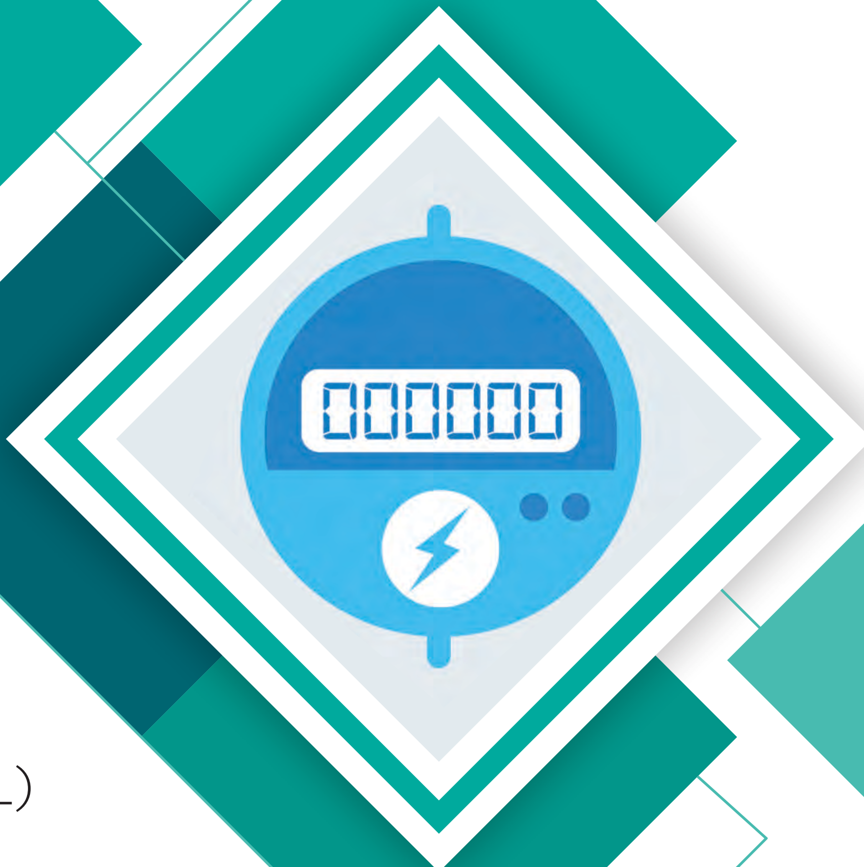
PARTNERSHIP TO ADVANCE CLEAN ENERGY DEPLOYMENT (PACE-D) TECHNICAL ASSISTANCE PROGRAM



AJMER VIDYUT VITRAN NIGAM LIMITED (AVVNL) SMART GRID PILOT PROJECT

CASE STUDY

USAID
FROM THE AMERICAN PEOPLE

National Smart Grid Mission
Ministry of Power
Government of India

PARTNERSHIP TO ADVANCE CLEAN ENERGY DEPLOYMENT (PACE-D)
TECHNICAL ASSISTANCE PROGRAM

AJMER VIDYUT VITRAN NIGAM LIMITED (AVVNL) SMART GRID PILOT PROJECT

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February 2018

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SECTION 1
EXECUTIVE SUMMARY

Smart Grid development is a key priority for the Government of India (GOI) – not only to curb power transmission and distribution losses but, also to improve reliability and quality of power supply and ensure power to all. Smart Grid technologies, by enabling grid automation, real time exchange of electricity and information, grid integration of renewable energy can transform the existing distribution grids to become more efficient, greener, self-healing, reliable and less constrained.

Over the years, the central government has undertaken several foundational, policy, institutional and regulatory measures to support Smart Grid development in India. These include implementation of select pilots by the GOI, the launch of the National Smart Grid Mission (NSGM), smart meter deployment goals under the National Tariff Policy, smart meter installation targets by states under the Ujwal DISCOM Assurance Yojana (UDAY) program, release of Smart Meter specifications by the Bureau of Indian Standards, announcement of Advanced Metering Infrastructure (AMI) specifications by Central Electricity Authority, etc.

In this respect, the United States Agency for International Development (USAID), through its Partnership to Advance Clean Energy- Deployment (PACE-D) Technical Assistance Program, has been involved in supporting various activities related to Smart Grid deployment in India undertaken by the by the NSGM, Ministry of Power (MOP).

One such intervention included a pilot project at Ajmer Vidyut Vitran Nigam Ltd. (AVVNL) to demonstrate benefits of Smart Grid functionalities viz. AMI for automatic energy audit and loss reduction analytics which includes energy theft monitoring and tamper alerts for ~1000 consumers. The project was implemented via an innovative Pay for Service ("or rental") model where the entire implementation was treated as a service rather than taking it as a one-time capital expenditure.

Pilot Journey – Inception to Closure

The aim of the pilot project was to demonstrate benefits of the smart systems and subsequently prepare a base for a larger roll-out of the project. The project commenced in January 2016 and ended in March 2017. In this duration, it helped in demonstrating a viable business case for utilities even on a small scale, and how smart systems can improve operational efficiency (elimination of manual meter reading, condition based asset maintenance) and financial performance (reduction in losses, improved service and reliability of supply) of the utility. The AVVNL project became the first successful GOI pilot to demonstrate the benefits of Smart Grid.

The journey of this pilot from inception to closure with key activities undertaken is summarized in Figure 1.

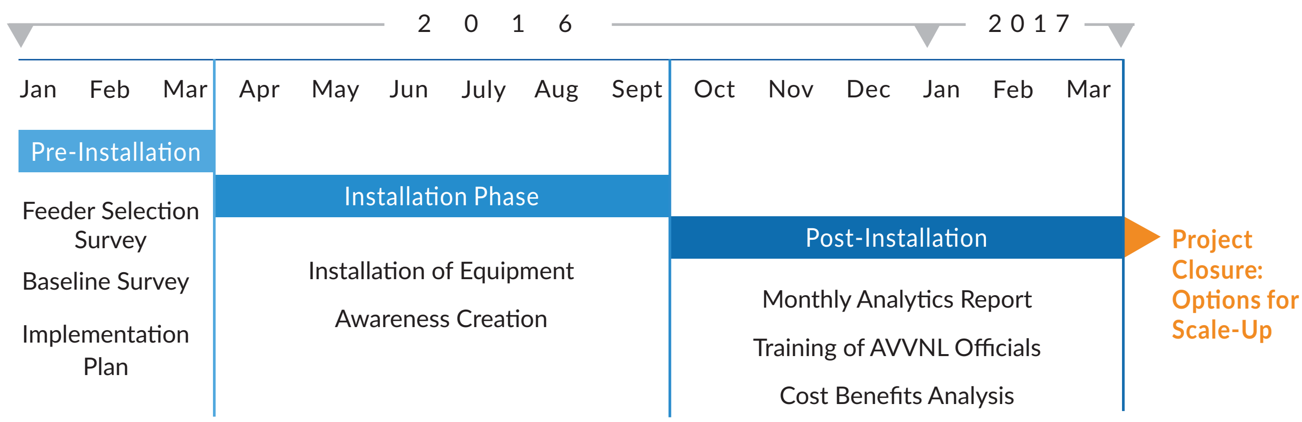


Figure 1: Journey of AVVNL Pilot Project

Pilot Benefits

The pilot was operational for six months starting October 1, 2016. Basis the intervention undertaken, total annual savings of ~INR 13 Lakh has been estimated for ~1000 consumers and considering total capex cost of the pilot project of INR 67 Lakh, a payback period of ~ 5-6 years is expected for the investments made. Since the scale of the pilot project was small, the costs incurred were relatively higher.

A summary of the benefits estimated from the pilot program is projected in Figure 2.

AT&C LOSS REDUCTION

- Automatic DT wise energy audit identified high loss area for reducing losses – loss on one DT reduced from 60% to less than 20%
- Auto remote disconnect to enable faster collection– 11 cases of uncollected due for 6 months identified – estimated to increase collection efficiency by 1.2%
- Reconciliation and consumption data analysis 20-25 cases of slow traditional meters – 2.2% of energy billed unaccounted
- Consumption on Inactive Meter (CIM) – Remote disconnect to eliminate such cases– One case of disconnected consumer actively consuming 60 units/month identified

METERING & BILLING IMPROVEMENT

- Automation of meter reading and meter punching with smart meter- removes cost of manual reading and punching
- Quicker bill generation with smart meters – interest cost saving on working capital
- Feasibility of monthly billing instead of present bi-monthly billing- Interest savings on Working Capital

OPTIMIZED ASSET MANAGEMENT

- Condition based asset maintenance (with monitoring of power quality and load parameters)– Reduced equipment failure and faster fault detection – 4 cases of meter failures (hang cases) identified by smart system reducing potential of unaccounted energy loss

IMPROVED SERVICE & RELIABILITY

- Improved customer satisfaction level with accurate billing, real time consumption information, outage notification (with mobile app) – Savings on customer care centers with reduction in consumer complaints
- Real-time detection and recording of outages without customer intervention – faster fault identification and restoration

PILOT BENEFIT ESTIMATES

AT&C Loss Reduction	Metering & Billing Improvement	Optimized Asset Management	Improved Service & Reliability
AT&C Loss Reduction **20% to 13.5%**	Bill Generation Cycle Reduction **14 Days to 5 Days**	Reduction in failure rate of meters by **50%**	Outage time reduction by **20%**
	Meter Reading and Punching Cost reduced to **0**	Reduction in failure rate of transformers by **30%**	Reduction in time spent on handling consumer queries by **80%**

PILOT BENEFIT ESTIMATES

AT&C Loss Reduction	Metering & Billing Improvement	Optimized Asset Management	Improved Service & Reliability
~₹ 12 lakh/annum	~₹ 1 lakh/annum	~₹ 12, 000/annum	~₹ 11,000/annum
~₹ 1,170/annum/ consumer	~₹ 98/annum/ consumer	~₹ 12/annum/ consumer	~₹ 11/annum/ consumer

Figure 2: Summary of estimated benefits to AVVNL

**Estimated benefits on asset optimization and improved service & reliability are estimated based on understanding and discussion with field staff. Although, considering the scale of pilot, these do not materially add to the overall quantum of savings. In case of larger deployments, especially where consumption per customer is high, these could be of significance. Refer Section 5 for detailed calculation.*

Pilot Learnings

Some key learnings from the pilot program that can be incorporated by utilities during scale-up of their Smart Grid projects are summarized in Figure 3.

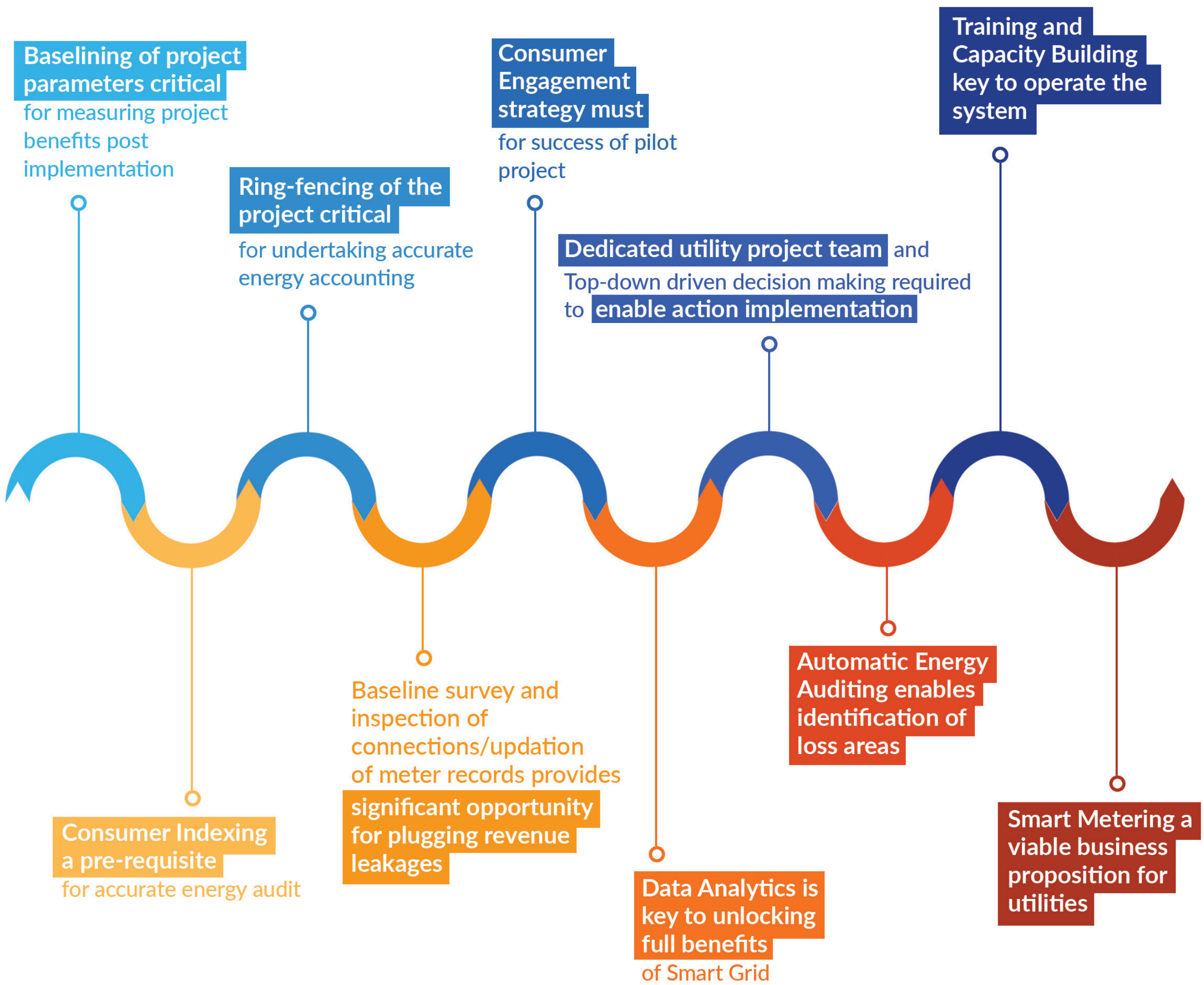


Figure 3: Key Learnings for Utilities

Through the pilot project in Ajmer, it is clear the installed Smart Grid infrastructure has demonstrated significant opportunities for the utility to unlock operational and financial efficiency improvement even when undertaken on a small scale.

SECTION 1
INTRODUCTION

Project Background

Smart Grid development is a key priority for the GOI – not only to curb power transmission and distribution losses but, also to improve reliability and quality of power supply, while, ensuring power to all. Over the years, the central government undertook several foundational policy, institutional and regulatory measures to support smart grid development in India.

Some of the key initiatives are presented in the Figure 4.

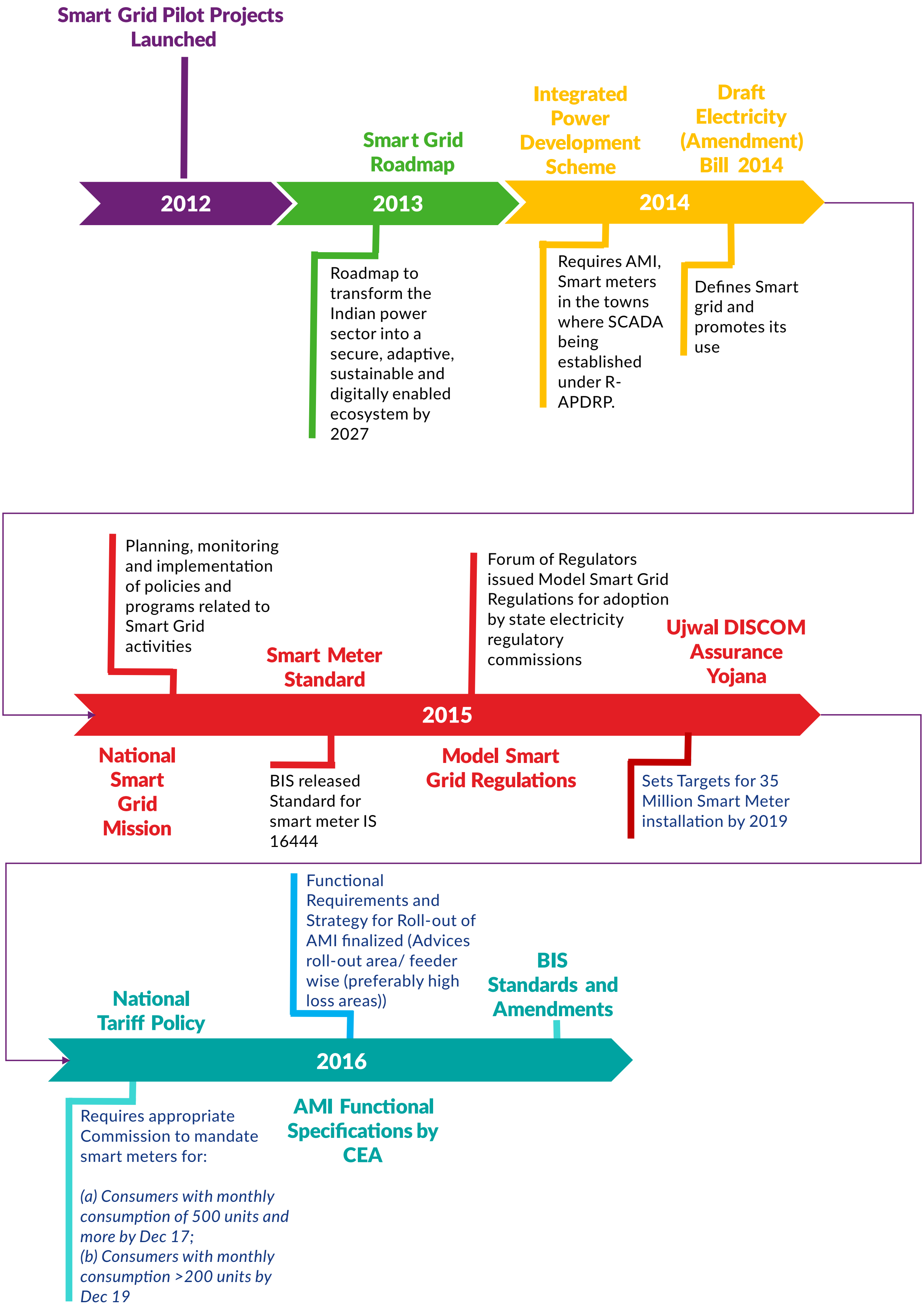


Figure 4: Key GOI Initiatives on Smart Grid

In this regard, the U.S.-India Bilateral PACE-D TA Program had been supporting the NSGM, MOP on various Smart Grid initiatives. One such intervention included the design and implementation of a small scale pilot in collaboration with the NSGM, MOP aimed to demonstrate the benefits of select Smart Grid functionalities and an innovative business model.

It was decided in consultation with MOP to undertake this pilot in Ajmer area, particularly in view of Ajmer being a part of the Smart City initiative. The Program worked on this with AVVNL, the utility responsible for electricity distribution and supply in that area.

AVVNL serves nearly four million consumers is responsible for electricity distribution and supply in 11 districts of Rajasthan, namely Ajmer, Bhilwara, Nagaur, Sikar, Jhunjhunu, Udaipur, Banswara, Chittorgarh, Rajsamand, Doongarpur and Pratapgarh. The utility posted distribution losses of around 26 percent in 2015[1] . The overall distribution loss profile of Ajmer, combined with the fact that it was covered under the Restructured Accelerated Power Development and Reforms Programme, Supervisory Control and Data Acquisition, and IT scheme, made it one of the ideal areas for demonstrating benefits of Smart Grid functionalities.

Parameter	Unit	Value[2] (FY15)
Sales	MU	18,647
Revenue	Rs. Cr	7,701
AT&C losses	%	26
No. of consumers	Nos.	3,885,628
No. of substations	Nos.	1,487
No. of 11kV feeders	Nos.	6,602
No. of Distribution Transformers	Nos.	3,90,088
Collection Efficiency	%	100

Project Objectives

The pilot project envisaged the following objectives:

Demonstrate Innovative Business Model

Two Different Solutions Tested:
1. Over the top 2. Smart Meter

Demonstrate Benefits through Analytics-based Applications for Smart Meter Data

The aim of the pilot project was to demonstrate benefits of the Smart systems and subsequently prepare a base for a larger roll-out. AMI functionalities selected for demonstration included automatic energy audit; loss reduction analytics including energy theft monitoring and tamper alerts.

[1] Audited losses as per order on approval of true-up of ARR for FY 2014-15 and FY 2015-16 (http://rerc.rajasthan.gov.in/TariffOrders/Order271.pdf)
[2] Source: AVVNL MYT FY 15,
http://www.avvnl.com/ and order on approval of true-up of ARR for FY 2014-15 and FY 2015-16 (http://rerc.rajasthan.gov.in/TariffOrders/Order271.pdf)

Purpose of Case Study

The purpose of this case study report is to document the entire lifecycle of this pilot project, key learnings and good practices emerging from the project. It is expected that this case study would provide useful lessons for up-scaling future Smart Grid projects in India.

Given this background, the case study has been organized into four key pilot project phases, with each phase including details about the various activities undertaken.

The structure of the report is as per Figure 5.

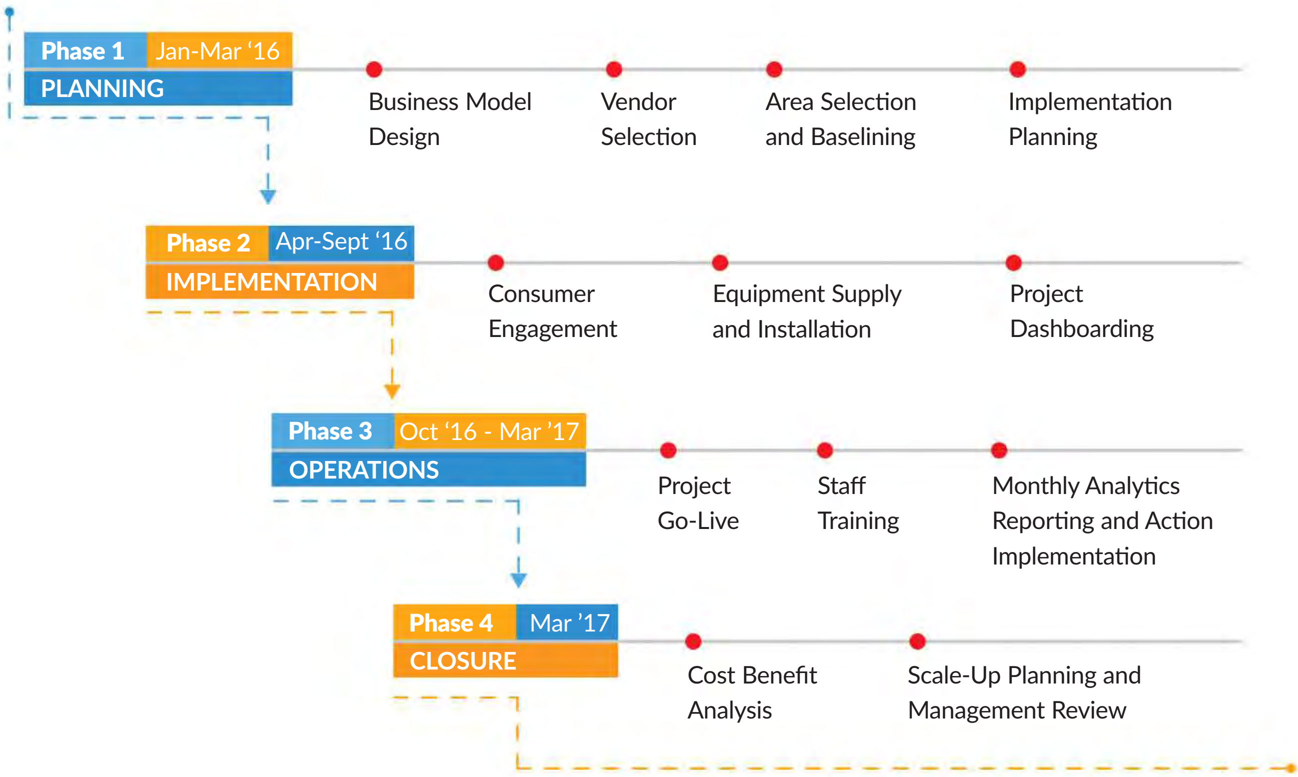
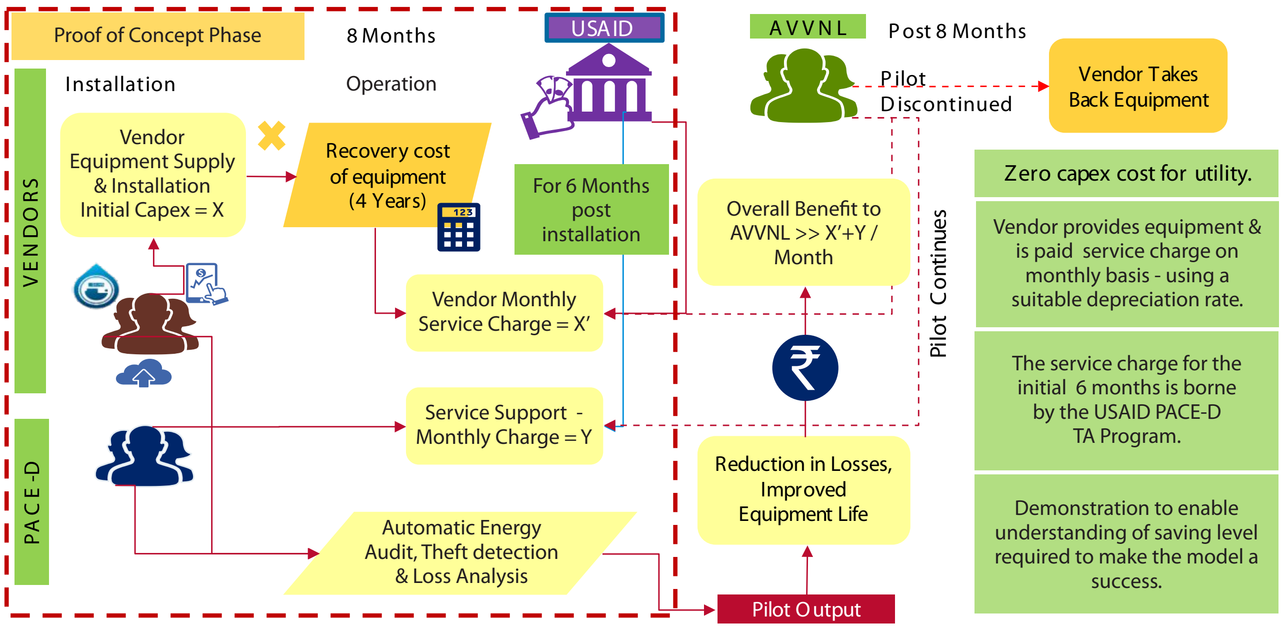


Figure 5: Phases of AVVNL Pilot Project Life-cycle

SECTION 2
PHASE-1 PROJECT PLANNING

Project Business Model : Pay for Service/Rental Mode

The project was implemented via an innovative Pay for Service ("or rental") model. The benefit of this model is that the utility is not required to invest upfront and at the same time vendor becomes a project partner to ensure the success of the project. The contours of the business model are as described in illustration below.



2.1 Vendor Selection

To implement the project, two vendors (with two different solutions) were selected to demonstrate their respective solutions for ~500 consumers on the selected feeders. The selected vendors were Radius Synergies International Pvt. Ltd. (RSIPL) and JnJ Powercom Systems Ltd (JnJ). RSIPL solution was based on Machine-to-Machine (M2M) communication which made the existing metering infrastructure smart by installing their proprietary adaptors on the Common Meter Reading Instrument port of the existing meters. The second solution of JnJ involved installation of AMI including smart meters, which was installed in electrical series with the existing meters. The list of equipment for the respective vendor is listed in Annexure-1.

Please Note: This pilot was undertaken with specific purpose of demonstrating pay for service model and savings through loss reduction for a period of six months. Accordingly, the meters were installed in electrical series without disturbing the existing metering infrastructure. The discretion to continue the pilot beyond the initial study period is that of the utility.

JnJ Smart Meter

Radius OTT Solution

The broad roles and responsibilities for each of the stakeholders are highlighted below.

Role of Utility

- Nomination of nodal officers for coordination of the pilot
- Access and Installation support at both utility and consumer end
- Provision of required data for carrying out the project:
- Support in technical analysis of the project area
- Support in consumer interaction/awareness of pilot functionality
- Metering of DT's to ring fence the project
- Implementation of field actions basis recommendation/ suggestion from Smart Meter data analysis

USAID PACE-D

- Baselining/Planning and Pre-implementation Analysis for different functionalities.
- Coordination with the vendors throughout the project duration.
- Defining of various analytical reports and provide actionable insights for implementation for a period of 6 months
- Consumer engagement-Assisting AVVNL in designing appropriate messaging for reaching out to consumers in the pilot area
- Cost- Benefit Analysis for the project
- Documenting benefits and lessons learnt for further scale up of the utility
- Training of utility personnel

Role of Vendor

- Site survey, planning, design, engineering, manufacturing, supply, transportation & insurance of equipment, delivery at site, unloading, handling, storage, installation, integration, testing, commissioning, demonstration for acceptance, maintenance of equipment's identified for demonstration of identified functionality.
- Providing cloud storage for secure collection of requisite data
- Providing analytics software / mobile application for generating periodic reports and alerts related to energy audit, energy theft, load violation, etc.
- Generate periodic reports as agreed
- Training of the Utility's personnel with respect to the installed systems/sub-systems

2.2 Area Selection

In order to demonstrate the pilot functionalities, a single feeder for 1000 consumers was selected. The feeder for the pilot was selected in a manner wherein:

a. The benefits of the proposed functionality (loss reduction) could be demonstrated;
b. AVVNL, based on their experience, suspect losses in the area;
c. Project could be ring fenced and manageable;
d. Feeder is compatible with the requirement of vendors; and
e. The actions/suggestions for loss reduction could be easily implemented

The team also held detailed interactions will the AVVNL officials and analysed the following information: (i) Number of customers; (ii) Customer Mix; (iii) Area/circle losses; (iv) No. of Transformers for various feeders. Based on the above, **Satguru feeder** (which supplied to 1912 consumers with around 17 percent reported aggregate technical and commercial (AT&C) Losses[3] was selected.

Since the project size was limited to 1000 consumers, a detailed feeder survey was undertaken to ring-fence the project and map consumers to each pole and Distribution Transformer (DT).

2.3 Baselining

The USAID PACE-D TA Program, along with the two vendors, carried out a detailed baseline survey on the selected feeder with support from AVVNL officials to map consumers to each pole and DT and to identify cut-off point for both vendors. During the field survey, a copy of the latest electricity bill was also collected from every individual consumer for the purpose of indexing consumer data with their corresponding K-Numbers. Once the meters were mapped, rest of the details with respect to historical (last two years) consumption, billing and collection were obtained from the utility's IT system. This exercise helped in validating the customer data, ring-fencing, defining baseline, understanding gaps in field infrastructure and also crucial observations were made in terms of the consumer behaviour. Figure 6 represents the key parameters recorded as part of the consumer mapping survey. Similarly, Figure 7 represents the SLD of the area post ring-fencing of the project area; and Figure 8 represents the baseline summary of pilot area basis survey conducted and billing data collected[4].

[3]Details of the identified feeder in terms of the number of consumers and DTs and losses were based on records provided by AVVNL. It is important to mention that these were reported numbers based on the existing infrastructure. The numbers were refined based on baseline data derived post AMI installation.

[4]At the time of establishing the project baseline, utility had no mechanism to account for energy input from feeder in case of switching. Therefore, the project could not accurately calculate area losses and relied on the estimation of 17% as AT&C losses as provided by AVVNL.

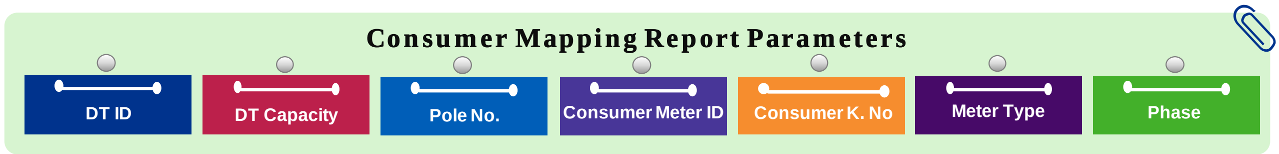


Figure 6: Consumer Mapping Report Parameters

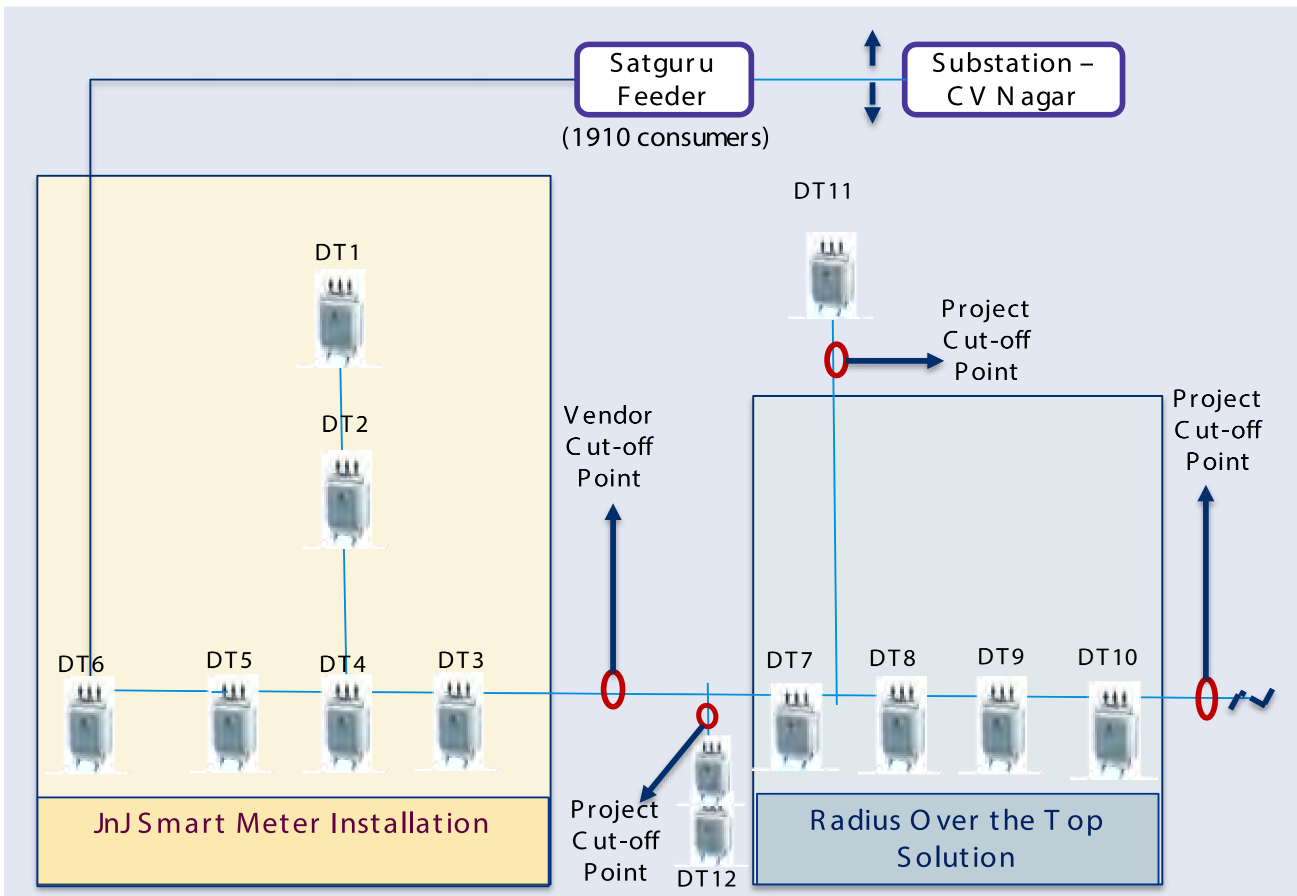


Figure 7: SLD of the area post ring-fencing of the pilot

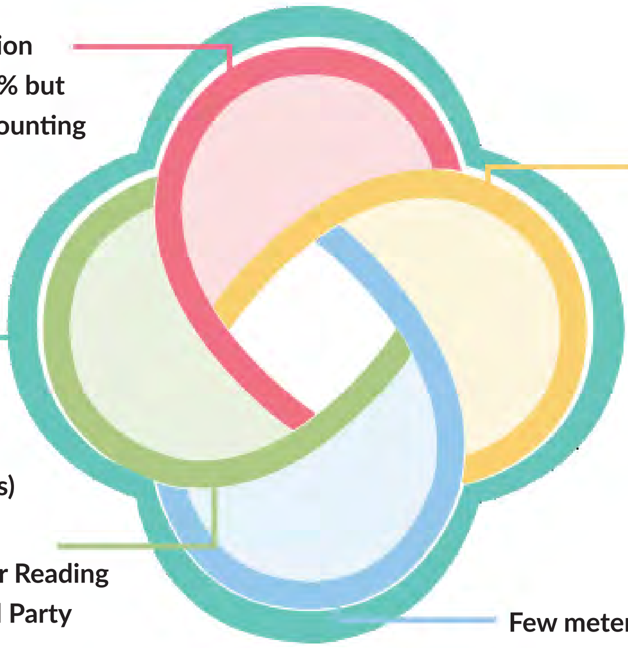


Figure 8: Baseline Summary of Pilot Area Basis Survey Conducted and Billing Data Collected

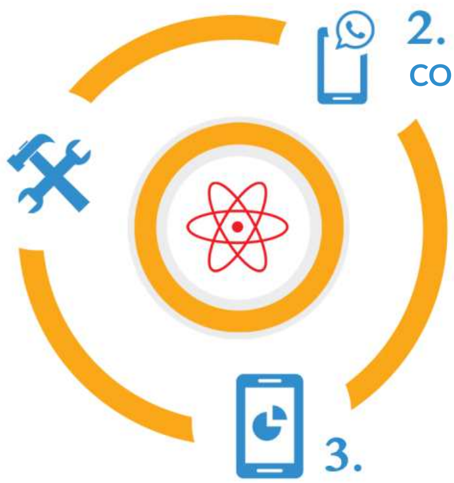
2.4 Implementation Plan

Post the baseline survey, a detailed installation plan of equipment was prepared, clearly documenting the weekly timelines for supply and installation, outage schedule. The implementation also included defining installation report format, defining of analytics report and development of analytics dashboard. Consumer-Utility contact points were also identified. It was observed that meter readers are very well versed with the local areas and consumers. Therefore, it was decided that meter readers would accompany the team during installation of equipment. Details of the implementation stage are explained in the following section.

SECTION 3

PHASE-2 PROJECT IMPLEMENTATION

The installation phase started in April 2016. The overall implementation period for installation, testing and commissioning of all equipments, including development of customized dashboard took six months. Major activities included:



1. EQUIPMENT SUPPLY AND INSTALLATION

Equipment Testing by AVVNL

Supply of Equipment

Installation and Documentation

2. CONSUMER ENGAGEMENT

Engagement Strategy Design

Door-to-Door Awareness Campaign

Consumer Participation through Mobile App

3. PROJECT DASHBOARDING AND REPORTING

Date Report Definition

Customization of Web-based Dashboard

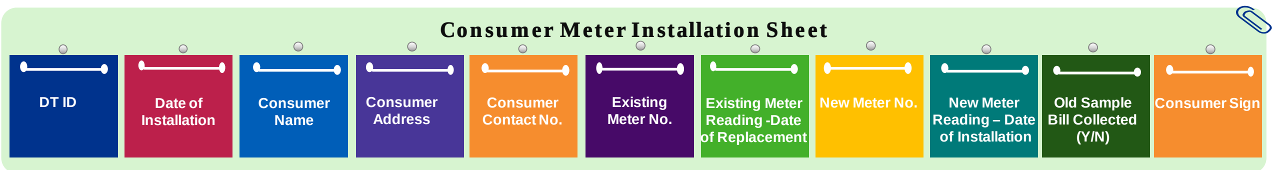
3.1 Installation of Equipment

In order to streamline the process of deployment, an installation strategy was chalked out to ensure smooth deployment, enhance consumer experience and increase the likelihood of success of the smart grid program. Some of the key aspects included:

- Consumers were segregated DT wise/area wise to ensure targeted approach, minimize distance and time in installations and improve productivity.
- Consumers were informed in advance (15-20 minutes before the installation) to ensure customer convenience.
- Arrangements were made for easy and fast installation so as to avoid consumer complaints/agitation.
- Installers carried portable tool set to ramp up the installation time.
- Senior experts from the vendor team supervised initial installations.
- A communication network was set up simultaneously for real time tracking of data captured by the smart meters/adaptors; and to identify any possible meter/adaptor faults to ensure minimal customer interface

and disturbance.

- Installations were not carried out during afternoon to ensure that the consumers are not disturbed during their rest period.
- Installers were equipped with handheld cameras to document the site prior to and after installation.
- Installers carried a consumer meter installation sheet/ check-list to validate consumer and meter details, and improve recordkeeping of the consumer database.



3.2 Consumer Engagement

To create a positive consumer experience at all stages of smart grid technology deployment, the phase wise consumer engagement strategy adopted as part of the pilot project included the following:

- **Pre-Installation Phase:** Field visit was undertaken by the USAID PACE-D team along with the vendors and utility officials, in different parts of Ajmer city. The purpose of this visit was to undertake a broad survey of the utility infrastructure and identify feeders where the proposed vendor solutions were compatible with the existing infrastructure. Upon selection of the feeder in consultation with AVVNL officials, a consumer mapping exercise was undertaken on the selected feeder. Consumer details and historical operational data such as energy consumption, AT&C losses, average billing, collection efficiency, etc. were collected during the baseline survey. Along with this, consumer understanding and their concerns towards Smart Grid technology were also documented.

- **Installation Phase:** In order to improve focus on consumer experience and increase the likelihood of Smart Grid program success, a number of consumer engagement initiatives were undertaken to create awareness and understanding about the Smart Grid technology, and facilitate active consumer participation.

- **Feedback and Redressal:** Smart Grid deployment and operation may involve situations like customers dissent to smart meter/adapter installation, unsatisfactory service, concerns on privacy and information access, poor complaint resolution and response, increase in bills, etc. It is important to resolve customer concerns especially during the early stages of project, as this could negatively affect the credibility of Smart Grid efforts. Since the project was implemented on small set of consumers and billing was done on the basis of utility meters, no pro-active action was undertaken to get consumer feedback and redressal related to this pilot project. Nevertheless, it is essential to take such initiatives while scaling up the pilot project.

Snapshot of Consumer Engagement strategy adopted during the pilot project is provided in Figure 9.

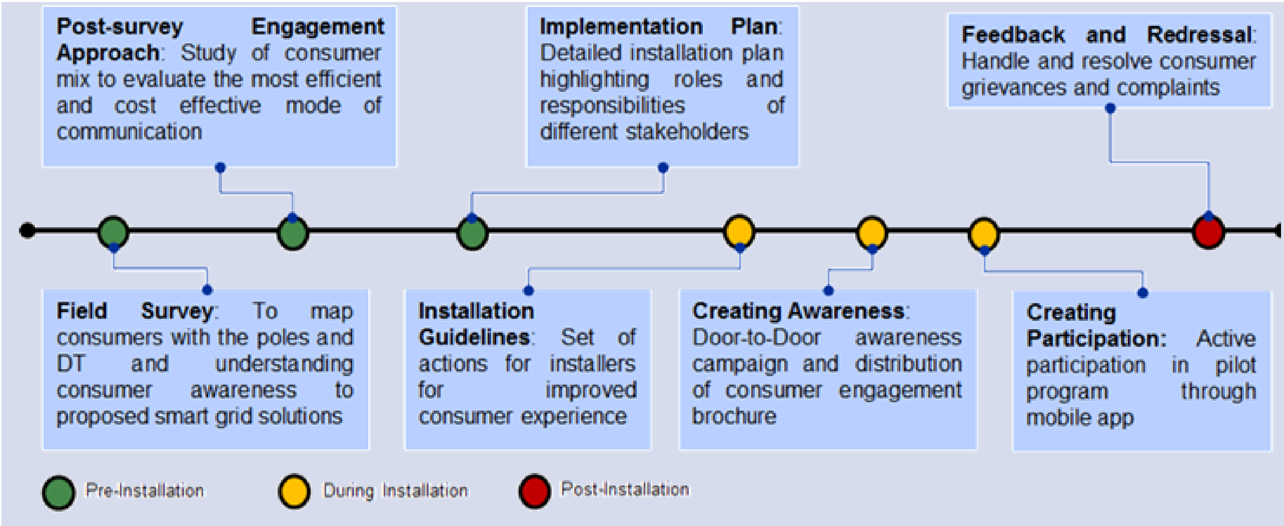


Figure 9: AVVNL Consumer Engagement

1. Field Survey

During the initial field survey undertaken, following crucial observations were noted in terms of consumer behaviour and area readiness towards smart meter installation:

- **Lack of technology awareness-**Consumers were generally unaware of the concept of smart meter and how it would impact them. However, with the advent of the concept of a Smart City in Ajmer, consumers were receptive and curious to understand the benefits of a Smart Grid and how it could benefit them going forward.
- **Initial doubts raised-** Most consumers were cooperative but, few shared their apprehensions on whether a smart meter would lead to an increase in their electricity bills.
- **Timely and accurate meter reading and billing were the top most concerns** of the consumers and any solution to address these aspects were considered broadly acceptable to consumers.

2. Post Survey Engagement Approach

Assessment of pre-installation field survey and qualitative assessment of consumer specific parameters revealed that the target group mostly constituted residential consumers (ranging from lower to upper middle class of consumers) and small commercial shops.

Table 1: Ajmer Pilot- Consumer Attributes

S.No.	Parameter	Attributes		
1	**Area**	**Lohar Basti Region**	**Satguru Colony Households**	**Shop Owners (Kirana Stores)**
2	Income group	Low	Middle	Middle
3	Energy consumption	Low	Average	High
4	Understanding of Smart Meter	Low	Low	Low
5	Likely commitment towards Smart Grid activity	Low (less likely to participate- a number of unmetered connections found)	Average (Overall positive, but some doubts on new meter resulting in higher bills)	Average (Overall positive, but some doubts on new meter resulting in higher bills)
6	Type of consumer	Residential	Residential	Commercial

These observations helped in devising an appropriate communication strategy for consumer engagement initiatives. Basis the above and in discussion with AVVNL, use of print medium in form of multi-lingual flyer (English and Hindi) was selected as the most efficient and cost-effective communication medium for sensitizing consumers on the Smart Grid pilot project and technologies. Since the project was implemented on a small set of consumers on a pilot basis, it was also decided to provide three LED bulbs free of cost to the consumers as a token of appreciation for their support and to incentivize them to actively seek interest in the project.

To implement the awareness activity, a door-to-door awareness campaign was initiated along with the installation process. In the door-to-door campaign, the concept and benefit of Smart Grid technologies were explained to the customers and the consumer engagement brochure was also shared alongside[5] (Figure 10). Sharing of the relevant information with the customers also led to increased customer cooperation during the installation process.

[5] In order to articulate the value proposition of the smart grid to the consumers, the messaging of the brochure was parameterized. This is detailed out in Annexure-2

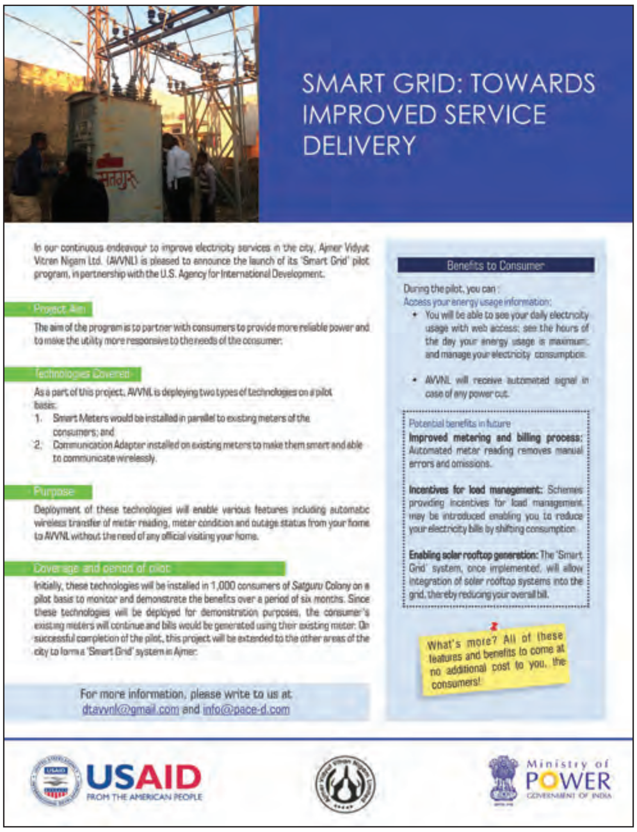


Figure 10: Consumer Engagement Brochures

3. Enhancing Participation

A mobile application was developed to involve consumers as active participants in the Smart Grid deployment (Figure 11). The key features of mobile application are as follows:

- Access to near-real time monitoring of their own electricity usage.
- Graphical displays for hourly, daily and monthly consumption.
- Details of current meter reading, instantaneous load, voltage, current and power factor.
- Option to receive push notifications and advisories through this application.

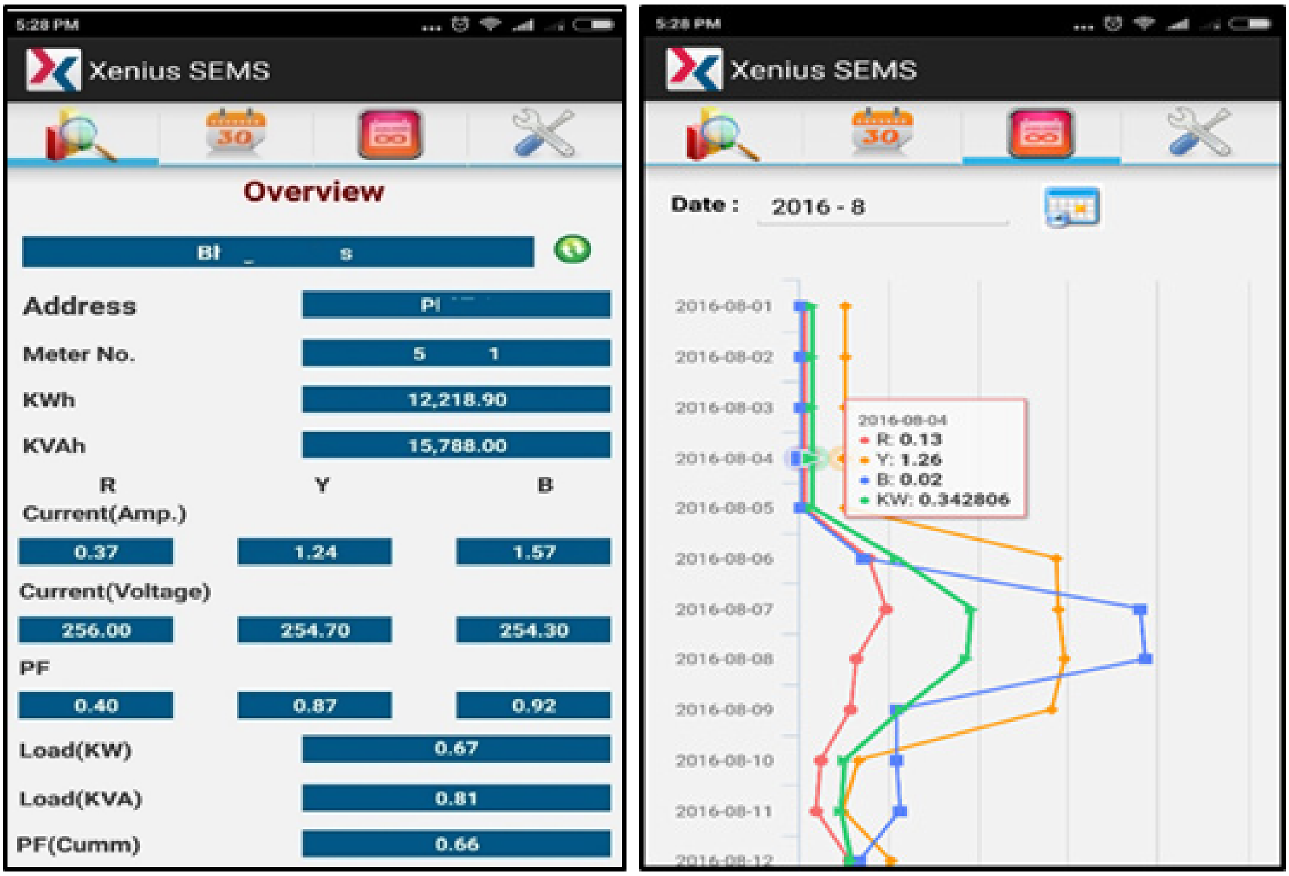


Figure11: Screenshot of Consumer Mobile Application

3.3 Project Data Report and Dashboard

In order to provide real-time data and exception reporting on a user friendly interface, an online web-based dashboard (Figure 12) and set of standardized smart meter data report formats were prepared. The dashboard was designed to monitor critical parameters like low power factor, phase imbalance, load exceeding by consumers and provide instant health check of the entire distribution system for optimizing, improving and near future planning. The key considerations while designing dashboard for fetching details from smart meters/adapter included:

- DT-wise consumer mapping.
- Near real-time DT audit on daily and monthly basis. This includes tabular view of kWh reading, current, voltage, power factor, and maximum demand.
- Understanding consumption patterns on instantaneous, hourly, daily and monthly basis.
- Identify power outages and load violations precisely for each DT.
- Print graphs or download in various standard formats.
- Highlight consumers whose data is not being read.

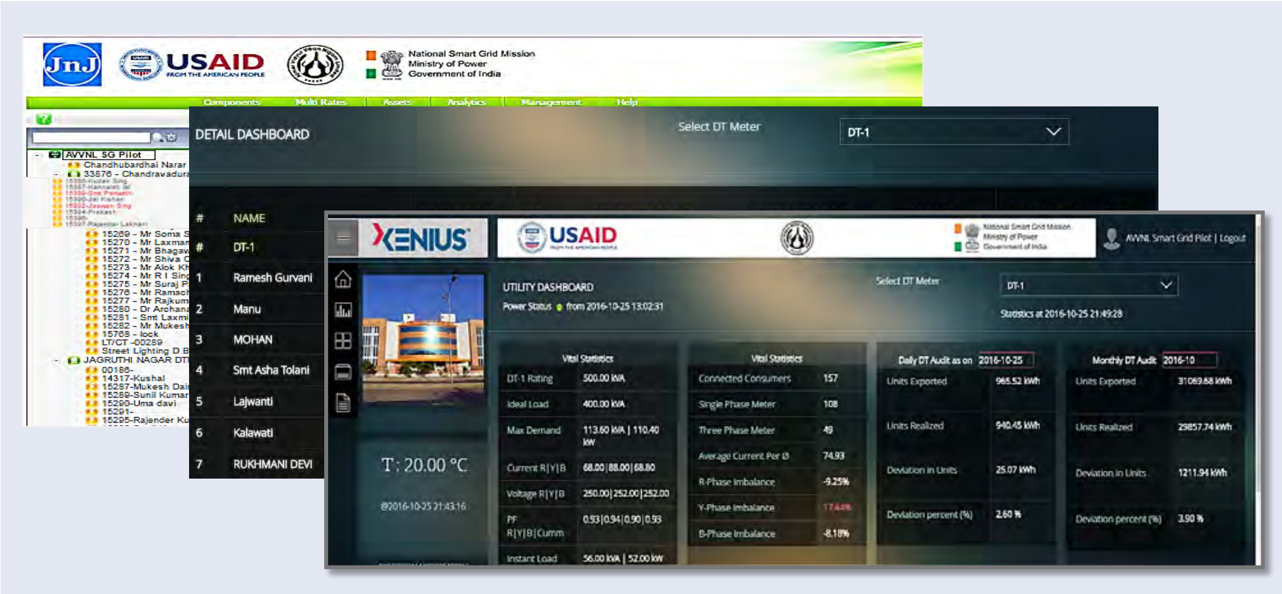


Figure 12: Online Web-based Dashboard

In addition to the dashboard, the standard analytical report and alert formats prepared were also enabled to be generated automatically by the system and were scheduled to provide information on different frequencies (days/month/user selected time period). These reports were integrated with the dashboard for easy download by the utility. Some of the key reports developed as part of the project were:

Loss Management

- DT Loss Report
- Feeder Loss Report
- Loss Summary Report (Feeder level)
- Loss Reconciliation Report (Feeder level)
- Consumer Meter Abnormality Report (Tamper/Theft)
- Consumption Exception Report for Theft Alert
- Communication Failure Report

Load Management

- DT Load Status Report (DT utilization and Load Violations)
- Consumer Load Violation Report

Power Quality and Reliability Monitoring

- Power Quality Exception Report (DT Level)
- Power Outage Report (Feeder level)
- Power Quality Exception Report (Consumer Level)

Apart from these reports, real time alerts on DT outages were also configured to be sent to designated utility personnel via SMS (Figure 13).

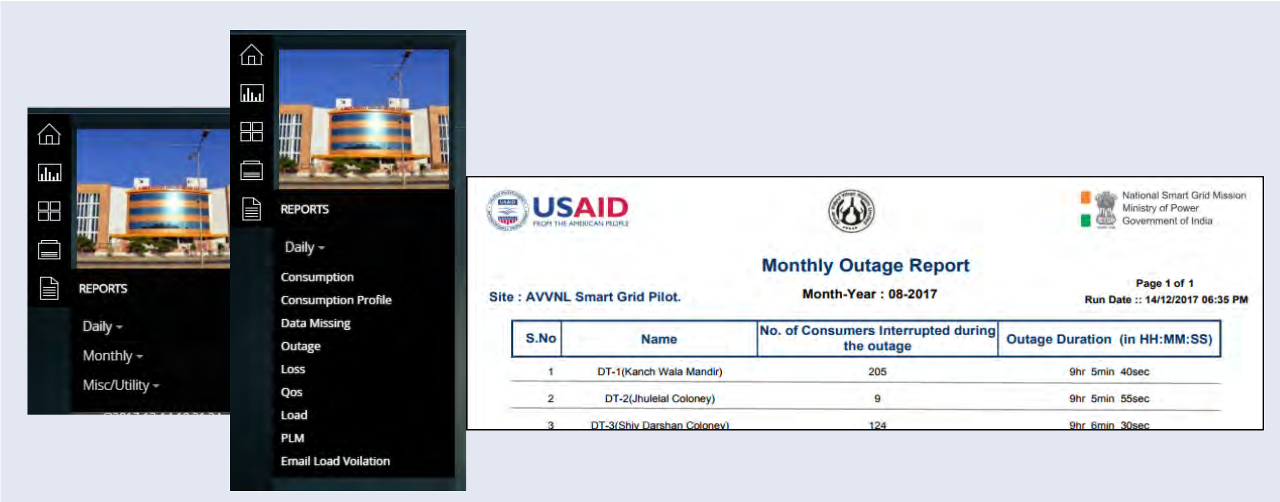
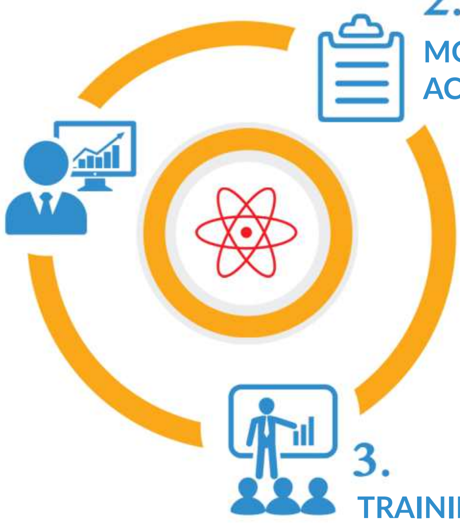


Figure 13: Illustrative Smart Meter/Adapter Data Report Integrated with Utility Dashboard

SECTION 4

PHASE-3 PROJECT OPERATIONS

Project commenced operational phase from October 1, 2016 and involved the following activities:



1. BASELINE CALIBRATION

No Prior accurate loss figures available

Baseline losses re-calculated basis initial month Smart Meter datato provide accurate loss figures

2. MONTHLY ANALYTICS ACTIONABLE INSIGHTS REPORT

Monthly Smart Meter analytic reports provided insight's to enable utilities to reduce losses and improve consumer service

3. TRAINING OF UTILITY OFFICIALS

Trained utility officials on various technical and operational aspects of the pilot project

4.1 Baselining Based on Smart Meter/ Adapter Data

During installation of a smart system, detailed consumer data was collected to map all consumers with DT and with their billing data to update the previous baseline to include all consumers (1023).

Table 2 provides key parameters of the pilot project once smart systems became operational.

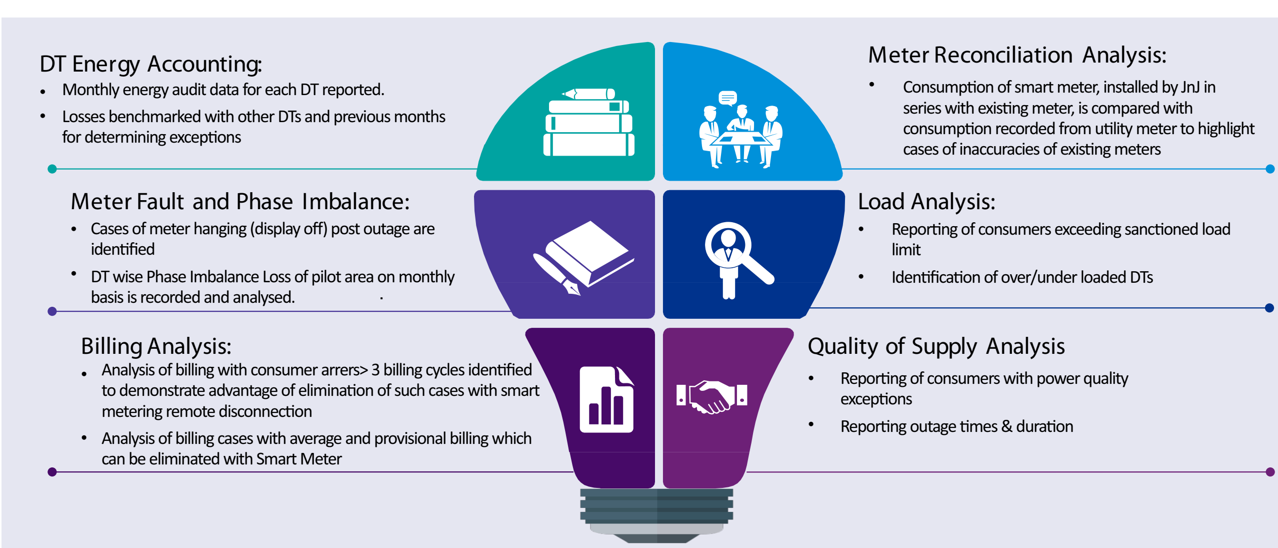
Table 2: Baseline Scenario of Project Area based on Smart Meter/ Adapter Data

Parameter	Units	Frequency	Baseline data	Source
Number of consumer meters in the pilot area	No.		1,023	Field Survey
Consumer Meters-Radius Area	No.		515	Field Survey
Consumer Meters-JnJ Area	No.		508	Field Survey
Energy Units Billed	MU	Annual	2.21	AVVNL Billing Data
Energy Revenue Billed	Rs Cr.	Annual	1.5	AVVNL Billing Data
Billing Inefficiency	%	Annual	17.52%	Losses calculated basis Smart Meter/ Adapter Data during baseline month of December, 2016
Amount Collected	Rs Cr.	Annual	1.4	AVVNL billing data – FY16
Collection Efficiency	%	Annual	96.6%	AVVNL billing data – FY16
Total Outage in project area	Hours	Annual	180	Average outage data from Oct 2016-Feb 2017 from Smart Meter/ Adapter Data projected for the entire year

4.2 Monthly Analytics- Actionable Insights Reporting

In order to realise the benefits of the smart systems, monthly reporting system was institutionalised to provide actionable insights to the utility.

The major components of monthly report were:



Basis the monthly analytics reports a number of loss reduction strategies were identified. These analysis and strategies were presented to AVVNL management at the end of each month. Basis this, relevant field actions were undertaken to reduce area losses. Some of the key findings and results basis the monthly analysis and actions undertaken by utility officials are presented in Figure 14.

High loss DT areas identified and field action initiated

Loss reduction in one of the DT Area - 60% to 25%

Smart Meter Energy Audit findings

- Losses of 60% at one DT
- DT level visibility on losses enables Utility officials to undertake targeted field visits on high loss area

Field survey findings

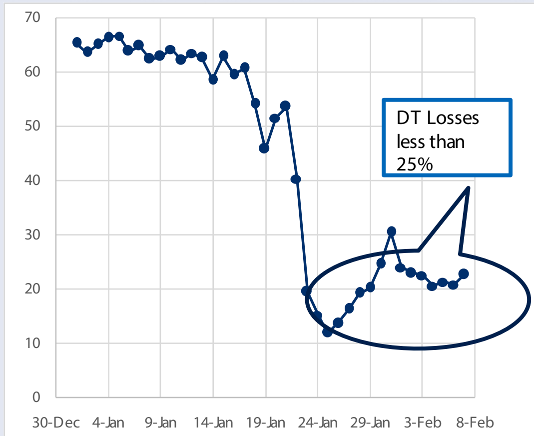
- Unmetered consumption
- Unauthorized tapping of power from poles of street lights

Action Taken

- LT supply altered to remove unauthorized access by unmetered households

Impact

- Reduction of DT losses 60% → 25%
- New connections to unmetered connections



13 slow meters identified and replaced

1 case of Consumption on Inactive Meter (CIM)

Case ID	Consumption As per AVVNL for the Billing Period (kWh)	Smart Meter Consumption for the Billing Period (kWh)	Un-accounted energy (kWh)	Extra Consumption recorded due to increased accuracy (in kWh)
Case-1	65	191	126	126
Case-2	120	272	152	152
Case-3	209	361	152	152
Case-4	404	659	255	255
Case-5	46	164	118	118
Case-6	139	241	102	102
Case-7	63	140.32	77	77
Case-8	45	261	216	216
Case-9	71	409	338	338
Case-10	5	68.14	63	63
Case-11	92	171	79	79
Case-12	8	129	121	121
Case-13	0	388	388	388
Total				2187

~2% of monthly consumption recorded

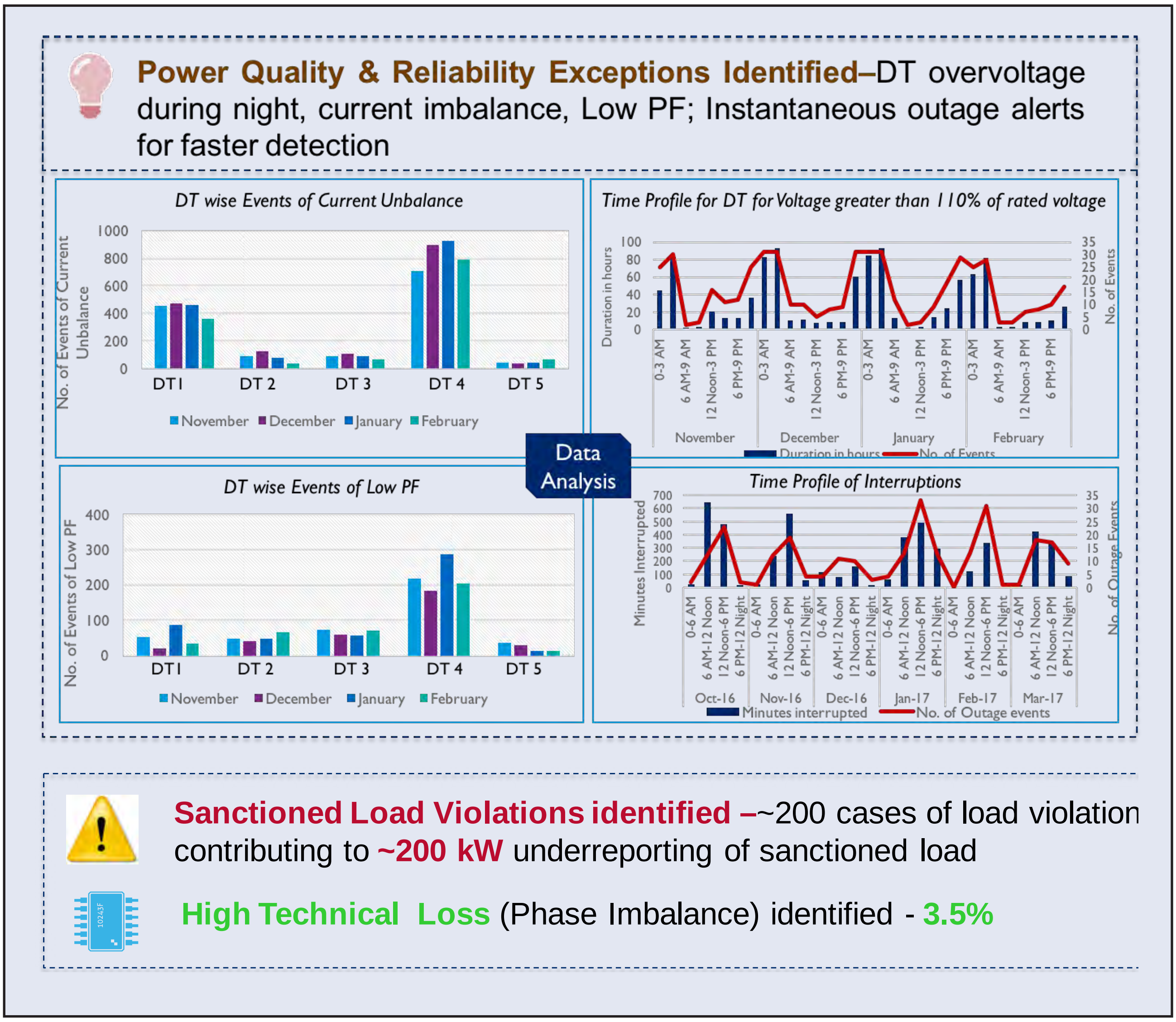


Figure 14: Key Findings of Monthly Analysis

4.3 Training of Utility Officer

It is essential to impart training to utility personnel for operating the automated systems to derive maximum benefits. In this context, a training session was held at Ajmer to sensitize utility officials on the objective and key benefits of the Smart Grid Pilot project[6] as well as build their capacity with respect to various technical and operational aspects of the pilot project .

Apart from dedicated training sessions, continuous operations support to the concerned Assistant Engineer and its field staff was also provided to enable them to effectively use the system dashboard and interpret smart meter/adapter data to generate actionable insights and actions for day-to-day operations.

[6]Details on https://www.pace-d.com/november-22-2016-ajmer-smart-grid-training-for-avvnl-utility-professionals/

S E C T I O N 5

PHASE-4 PROJECT CLOSURE

This phase involved cost-benefit analysis of the project and preparation of options for scaling up of AVVNL Smart Grid Pilot Project.

5.1 Cost Benefit Analysis

The cost benefit analysis of the pilot project is provided below. Following were the general assumptions and baseline used for calculations in cost-benefit analysis.

Table 3: Assumptions and Baseline for Cost-Benefit Analysis

DATA	UNITS	VALUE	SOURCE
Annual Interest rate for working capital loan	%	9.70	www.uday.gov.in/MOU/Rajasthan/MoU_Ajmer.pdf
Daily interest rate for working capital loan	%	0.03	Calculated based on Annual rate
Inflation rate	%	3.40	www.mospi.gov.in/sites/default/files/press_release/CPI_PR12jan17th.pdf
CAGR in electricity demand	%	3.80	AVVNL historical billing data
CAGR in Power Tariff	%	3.90	AVVNL historical billing data
Debt	%	70	Standard Assumption
Equity	%	30	Standard Assumption
Cost of Equity	%	16	Standard Assumption
WACC	%	11.6	Calculated
Average retail tariff (in pilot area)	Rs./kWh	6.91	AVVNL project area billing data – FY 16
Annual Energy Billed	MU	2.21	AVVNL project area billing data – FY 16
Annual Energy Revenue Billed	Rs Cr.	1.5	AVVNL project area billing data – FY 16
Annual DT to ConsumerEnergy Losses	%	14.62	Losses calculated basis Smart Meter Data during baseline month of December, 2016
Annual Transformation Losses	%	3.4	Losses calculated basis Smart Meter Data during baseline month of December, 2016
Annual DT Output (= Energy Billed/ (1- DT to Consumer Energy Losses)	MU	2.59	Assumption basis billing inefficiency calculated from Smart Meter during baseline month
Annual DT Input(= DT Energy Output/ Transformation Losses)	MU	2.68	Assumption basis technical loss calculated from Smart Meter during baseline month
Amount Collected	Rs Cr.	1.4	AVVNL project area billing data – FY 16
Annual Collection Efficiency	%	96.6	AVVNL project area billing data – FY 16
Annual Outage in project area	Hours	180	Average outage data from Oct 2016-Feb 2017 from Smart Meter Data annualized
Average Cost of Power Purchase	Rs./ kWh	5.81	www.uday.gov.in/MOU/Rajasthan/MoU_Ajmer.pdf

Project Cost

Based on smart solution capabilities and cost estimates from vendors, cost per node was in the range INR 6,000 – INR 7,000. The total project capital expenditure for the smart system infrastructure was estimated to be INR 66.9 Lakh with average cost per node of INR ~6,500. The details of the cost per node are provided below.

Table 4: Project Cost

Item Description	Unit Price Per Consumer (in Rs.)
Total Capital Expenditure for Pilot Project – Includes cost of all hardware and software installed (including Smart Meters, OTT)	**6,538**
Total OPEX - besides Annual Maintenance Costs, it entails cost for MDMS on cloud including data processing & storage, backend platform support, communication cost, dashboards & mobile app	**422/ per annum[7]**

Project Benefits

The benefits of the AVVNL Smart Grid pilot project can be categorized into four broad categories viz. Reduced AT&C losses, Metering and Billing Improvement, Optimized Asset Management, and Improved Service and Reliability. The objective of the pilot was to demonstrate functionality related to reduction in AT&C losses. It must be noted that once base infrastructure (smart systems) are installed the incremental cost of adding new functionalities are minimal. However, for the purpose of analysis, direct benefits were only considered.

The detailed quantification for each of the aforementioned categories is provided below:

1. Reduced AT&C losses

Annual savings from improved billing efficiency

Smart solution installations in pilot area improved billing efficiency through:

i. Reduced theft and improved meter accuracy and
ii. Reduced technical losses

Pre smart installations (includes both smart meters and OTT), it was not possible to undertake energy audit at DT/feeder level. Losses were estimated/calculated only at the substation level; therefore visibility into high loss pockets within the substation area was not available. With smart installations, consumption data can be monitored continuously and in real time at feeder, DT and consumer level, thus allowing for detailed energy audit.

Energy Audit functionality provided vital information on high loss pockets. Losses to the tune of 60 percent were observed at one of the DTs. This information enabled utility officials to undertake targeted field visits to identify and address causes of high energy losses. Such action led to reduction of DT losses from 60 percent in December 2016 to less than 25 per cent by end of February 2017. It is expected that losses would be lower than that recorded by the smart system as somenew connections were provided by the utility to the previously unmetered customers, for which smart system installation were impending.

[7] Operating Expenditure entails cost for Meter Data Management Services on cloud including data processing and storage on cloud, backend platform support, communication cost, dashboards and mobile app for end-consumers besides Annual Maintenance Costs (AMC). Operating Expenditure is assumed to be incurred from Year 1 till end of the project and does not include IT infrastructure like dedicated control center and related operating expenses

Further, consumption of smart meter, installed by JnJ in series with existing meter, was also compared with consumption recorded from utility meter for ~500 consumer connections. Meter reconciliation analysis showed that an overall 2.2% of billed energy which was un-accounted in pre-Smart Meter baseline scenario compared to post-roll out Smart Meter baseline scenario[8].

Overall, it was estimated that based on loss reduction in this DT and improved accuracy of replaced meter (identified basis reconciliation analysis) the billing efficiency of the area would increase from 82.35 percent (as identified in baseline) to 88.95 percent in post roll-out scenario.

The figure below compares the actual DT losses recorded by Smart Systems at baseline month versus DT loss recorded by Smart Systems at end of February[9].

Figure 15: Comparison of DT wise Losses for October 2016 to February 2017

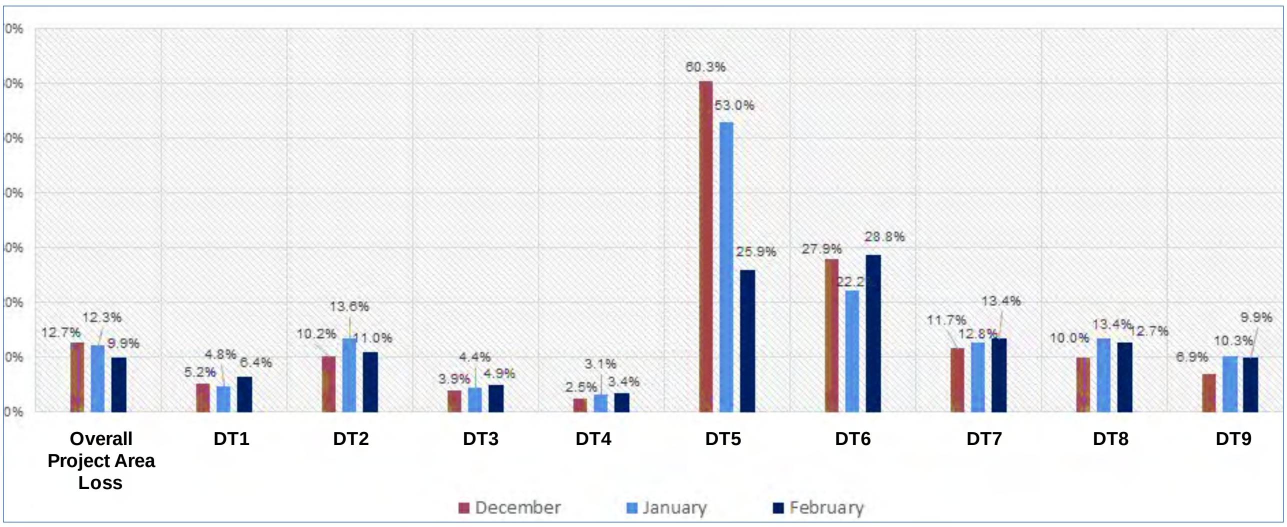


Table 5 highlights assumptions for post-roll out scenario and comparison of commercial losses in baseline and post-roll out scenarios. Post roll-out data has been estimated on annual basis for Cost Benefit Analysis (CBA)[10] For estimating the overall project benefit, it is conservatively assumed that for DTs other than DT5 and DT6 (where field action was undertaken or was impending), the level of losses over the 10-year project life will at least be equal to the baseline level of losses recorded in December.

[8]The cases of slow meter identified with Smart Meter reconciliation analysis accounted for 2.2% of energy billed in JnJ area. It is assumed that such cases can be identified in the Radius area as well as profile of both the areas are similar

[9]For estimating the overall project benefit, it is conservatively assumed that for DTs (with lower loss levels) other than DT5 and DT6 (where field action was undertaken or was in progress), shall at least maintain the baseline level of losses recorded in December, if Smart Systems continue to be used by the utility.

[10]This does not capture the reduction due to technical losses from phase imbalance. This is captured separately in the next section

Table 5: Assumptions for Post Roll-out Scenario and Comparison of Commercial Losses

DT Name	Baseline Losses – December 2016				Estimated % Energy Loses (Post roll-out of Smart Systems)
	Energy Input ('000 kWh)	Energy Realized ('000 kWh)	Energy Lost ('000 kWh)	% Loss	
DT1	27.9	26.45	1.45	5.20%	5.20%
DT2	9.75	8.76	0.99	10.16%	10.16%
DT3	17.6	16.92	0.69	3.90%	3.90%
DT4	26.11	25.46	0.65	2.50%	2.50%
DT5	14.28	5.66	8.62	60.34%	20%
DT6	6.3	4.54	1.76	27.87%	20%[11]
DT7	8.75	7.72	1.02	11.69%	11.69%
DT8	17.93	16.13	1.8	10.04%	10.04%
DT9	10.05	9.36	0.7	6.92%	6.92%
Overall DT Losses	138.67	121	17.67	12.74%	8.23%
Additional Losses Estimated in Baseline month due to unaccounted energy with slow traditional meters (2.2% of energy realized)			2.60		
Overall Losses Baseline (Excluding Phase Imbalance Losses)			20.27	14.62%	
Decrease in Loss Reduction from Pilot Program				6.40%	

Improved billing efficiency through reduced theft and improved meter accuracy was estimated to generate **annual savings of ~INR 114,000[12].**

One-Time Recovery from consumers with slow meters

Automated Metering Infrastructure involves automatic energy audit at the feeder, LT level, and customer level. This enabled AVVNL to regularly track the system losses and initiate measures to control losses. Bi-Monthly Consumer Reconciliation reports helped in identifying losses due to faulty meter or incorrect meter reading of existing meters. Basis discussion with field officials, it was understood that for such cases identified,a charge on previous years billed amount can be levied based on percentage of slow consumption recorded during that period. Assuming this data, **an estimated one-time amount of ~INR 336,000 can be recovered from consumers with slow meters[13].**

Reduced Technical losses (Phase-balancing)

The connection of single-phase loads of different characteristics and power consumption to the three-phase power supply system will result in unequal currents flowing in the three-phase power circuits and unbalanced phase voltages at the power supply point, i.e. unbalanced distortion. Unbalance current tends to increase copper losses. A 10 percent unbalanced phase current would increase the total copper loss by about 1 percent.

[11] Measures were identified for bringing down losses (metering of unmetered temporary connections). For the analysis, conservative loss reduction estimates have been taken

[12] **Formula:** ((Billing Efficiency Percentage [DT outgoing to Consumer at end of project]) – (Billing Efficiency Percentage (DT outgoing to Consumer at baseline) x Average retail tariff x Annual DT Energy Output to the Project Area.
Calculation: (14.66%-8.22%)* (Rs 6.91/ kWh) *(2.59*10^6 kWh) = 11.4 Lakh per annum

[13] **Formula:** (Per cent of Annual consumption recorded as slow from traditional meters) x Annual Energy Billed in Previous Year x Average retail tariff
Calculation: 2.2% * (Rs 6.91/ kWh) *(2.21*10^6 kWh) = 3.36 lakh

Technical losses in pilot area prior to smart solution installation were 3.40 percent in baseline month (December 2016)[14]. DT wise Phase Imbalance loss analysis for baseline period showed that 2 DTs had a loss of ~4.5 percent and ~5.25 percent. Taking a conservative estimate that the transformation losses can be reduced to at least the average area losses of 3.4 percent for these two DTs (by re-arranging the phase wise loads), the overall transformation losses post balancing was expected to reduce to 3.08 percent. Table 6 compares phase imbalance losses in base case and post rollout scenario.

Table 6: Comparison between Phase Imbalance Losses in Base Case and Post Rollout Scenario

DT Name	December 2016			Estimated Transformation Loss % Post Smart Systems Roll-out [15]
	Phase Imbalance Loss for the Month ('000 kVAh)	DT energy export for the month ('000 kVAh)	Transformation Loss %	
DT1	0.82	28.7	2.78%	2.78%
DT2	0.45	10.08	4.27%	3.4%
DT3	0.95	18.03	5.01%	3.4%
DT4	0.68	27.17	2.44%	2.44%
DT5	0.54	14.28	3.64%	3.4%
DT6	0.38	10.05	3.64%	3.4%
Total	3.81	108.32	3.40%	3.03%

Reduced technical losses through phase balancing were estimated to generate annual ***savings of ~INR 59,000[16].***

Annual savings from improved collection efficiency

In the post rollout scenario, implementation of remote disconnect for defaulting customers would allow the utility to reduce the overall amount owed by consumers as well as the number of consumers defaulting on bill payments. This would help to improve cash flows for the utility and reduce working capital requirements leading to savings in interest expense.

Remote connect/disconnect feature aids in faster recovery of uncollected arrears in each billing cycle and hence, a saving on interest on working capital for the utility. In the current pilot, 11 cases of uncollected arrears were identified contributing to 1.2 percent of total amount which could have been recovered one bill cycle early through remote disconnect/connect feature. Accordingly, beyond the 96.6 percent collection efficiency in baseline scenario, 1.2 percent more of energy billed can be collected earlier leading to increase in collection efficiency to 97.8 per cent. Improved collection efficiency through remote connect/disconnect was estimated to generate annual ~***interest savings of INR 3,000[17] .***

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[14] Refer Annexure-4 for calculation methodology

[15] The losses and savings calculated are as per vendor estimates, for few DTs the technical loss data for pilot period was unavailable. These technical loss estimates could not be verified due to lack of feeder metering for the pilot area. The technical losses are transformation losses between DT Input and DT Output and does not include losses from DT Output to Consumers (Which is calculated separately in billing efficiency above)

[16]Formula:((1/1-Transformation Loss %)$_{\text{post roll-out}}$ - (1/1-Transformation Loss %)$_{\text{baseline)}}$ x Average Cost of Power Purchase X Annual Energy Input to Project Area$_{\text{baseline}}$
Calculation:(((1/(1-3.4%)) –(1/(1- 3.03%))) * (2.58*10^6 kWh)*(Rs. 5.81/ kWh)

[17] Please note in the context of AVVNL pilot, smart installations were not enabled with remote connect/ disconnect and hence the savings provided are on estimated basis. Formula: Annual Energy Revenue Billedpost roll-out * Bi-monthly rate of interest rate for utility working capital loan * (Collection efficiency % post roll-out – Collection efficiency % baseline)* Average Retail Tariff per unit
Calculation:(2.37*10^6)*(1.55%)*(97.8%-96.6%)*6.91

2. Metering and Billing Improvement

Reduced Meter Reading and Punching Costs

In the baseline scenario, meters are read by meter readers who visit each consumer premise. Further, once read, manual punching of data into the billing system is required to be undertaken by dedicated staff.

In the post rollout scenario, meter reading would have been automated improving operational efficiency for the utility. Table 7 shows the cost to be saved on for manual meter reading and punching[18].

Table 7: Cost to be saved on Manual Meter Reading and Punching[19]

Data	Units	Value
Cost per meter reading	Rs./meter/billing cycle	3.84
Annual Cost to Company (salary + perks + pension etc.) for personnel involved in meter data punching[20]	Rs./ Year	225,000.0
Annual Cost per Consumer for meter reading and punching	Rs./ Year/consumer	242.77

Source: Discussion with AVVNL Field Officials

Reduced meter reading and meter punching personnel related costs is estimated to generate annual ***savings of ~INR 53,000[21]*** .

Reduced Float between Meter Reading and Customer Billing

In baseline scenario, due to manual operations, there is a significant delay between readings of meter data to generation of bill for consumers.

In the post roll-out scenario, the entire duration of billing process can be significantly reduced. This would mean improvement in cash flows and reduction in working capital requirements for the utility leading to savings in interest expense. Bill generation is expected to decrease from 14 days in baseline scenario to five days in post rollout scenario which is estimated to generate ***annual savings on interest expense of ~INR 37,000[22].***

[18] Please note in the context of AVVNL pilot, smart installations were not integrated with the billing system and hence the savings provided below are estimated basis.
[19] Please note in the context of AVVNL pilot, smart installations were not integrated with the billing system and hence the savings provided below are estimated basis.
[20] Monthly CTC of each employee is INR 18,750. 3% of time spent by 4 employees. Officials involved in meter data punching can now be effectively utilized in other utility functions/ other areas.
[21] **Formula:** ((Meter Reading cost per meter for external contract) x (No. of Meters in the area) x (Frequency of meter reading)) + ((Number of personnel engaged for meter punching) x (Average percentage time dedicated by personnel for meter punching work in project area) x (Average personnel cost to company per annum))
Calculation: (Rs 3.83/ meter * 1023 *6) +(4*3.28%*225000)
[22] Please note in the context of AVVNL pilot, smart installations were not integrated with the billing system and hence the savings provided are estimated ones. Formula:(Annual energy revenue billedpost roll-out) x ((1+daily rate of interest rate for utility working capital loan)^(Days saved for bill generation)-1)
Calculation:(1.64 * 10^7/)*((1+0.025 %)^(9)-1)

Interest Cost Saving on Billing Monthly Instead of Bi-Monthly

With automated meter readings, it would be possible for the utility to now move towards monthly billing cycle in place of bi-monthly, leading to reduction in working capital and hence interest cost. Changing the billing cycle from bi-monthly in baseline scenario to monthly in post-roll out scenario is estimated to generate **annual interest savings on working capital of ~INR 10,000**[23]**.**

3. Optimized Asset Management

Data from smart installations can be analyzed for determining the asset condition and utilization for assets across the network (e.g. transformer loading, over and under voltage, current imbalance, etc.). Real-time monitoring thus enables utility to take pro-active actions leading to lower equipment failure, faster fault detection and improved equipment life. It was estimated that with condition-based monitoring a greater than 30 percent (conservative estimated) reduction in transformers failures and a greater than 50 percent reduction in meter failures[24] (and additional benefit of reduced unaccounted energy loss by faster failure detection) and can be achieved as compared to the baseline scenario.

Optimized Asset Management was estimated to generate ***annual savings of ~INR 12,000***[25] **.**

Table 8: Transformer and Meter Replacement Cost

Data	Units	Value
Conventional Meter Replacement Cost		
Cost of meter	Rs./meter	1,000.0
Cost of Labor	Rs./meter	200.0
Cost of Transport and other consumables	Rs./meter	50.0
Transformer Replacement Cost		
Cost of Transformer	Rs./transformer	60,000.0
Cost of Labor	Rs./transformer	1,000.0
Cost of Transport and other consumables	Rs./transformer	50.0

Source: Discussion with AVVNL Field Officials

Data	Baseline Scenario	Post roll-out Scenario	Source for Baseline Scenario
No. of defective meters changed per year (on an average) in the project area	72	>50% reduction	Based on past 2 year billing data
No. of transformer failures per year (on an average) in the project area	1	>30% reduction	10% failure based on AVVNL SOP data

[23]Please note in the context of AVVNL pilot, smart installations were not integrated with the billing system and hence the savings provided are estimated ones.Formula: :(Monthly energy revenue billedpost roll-out) x (monthly rate of interest rate for utility working capital loan)
Calculation :(0.137 * 10^7) * (0.76%)

[24]Early detection of high load, poor power quality and tamper would prevent meter failure on account of burnout and tampering. Further, faster detection of fault would also eliminate cases of average billing and therefore reduce unaccounted energy for such cases. This benefit has not been quantified separately and is implicitly assumed by taking a high range (80%) of failure reduction assumed in post roll-out scenario. 4 Cases of meter fault (hang cases) were identified by the smart systems during the pilot program.

[25]Formula :((Annual % of equipment breakdown baseline * Average cost of unit replacement baseline) – (Annual % of equipment breakdown post roll-out * Average cost of unit replacement post roll-out)) * Total No of Equipment
Calculation: ((7% meter failure in baseline * Rs 1250/ Meter) – (1.4% meter failure post-roll out* Rs 6538/ meter))*1023 + ((10% transformer failure in baseline – 7% transformer failure rate post roll-out)* INR 61050/ transformer * 9 transformer)

4. Improved Service and Reliability

Reduced call-centre and customer care centre costs

Customer care centres are specialized centres which are established to address customer concerns, queries, complaints, etc. A satisfied customer is less likely to use this feature than an unsatisfied customer. AMI functionalities improve customer satisfaction level for diverse functions like accurate billing due to automation, real time consumption information through consumer mobile applications, outage detection through automatic monitoring, etc., thus, reducing call-inflow of customer care centre. As a result, customer care centres can function with lower capacity to accommodate the reduced call-inflow.

Besides customer care centres, sub-divisional offces also spend time in attending customer related issues especially realted to billing, meter defects, etc. Grievance and Revenue department employees in sub-divisional offices spend 50 percent of their time in handling customer complaints. In the pilot area, it is assumed that smart solution can lead to an 80 percent reduction in percentage of time spent by sub-division employees on handling consumer queries. However, this benefit realization requires smart meter/ adapter data integration with Customer Information System (CIS) or provision for a consumer application with real time access to consumption information and outage information. Table 9 details the cost of attending to consumer complaints in sub-divisional offices. Similarly, Table 10 details the change in percent time spent on consumer complaints by sub-division employees for pre and post-roll out scenarios.

Table 9: Cost of Attending to Consumer Complaints in Sub-divisional Offices

Data	Units	Value
Number of sub-division employees attending to consumer complaints	Number	4
Average cost to the company for sub-division employees attending to consumer complaints	Rs./annum	144,000.0

Source: Discussion with AVVNL Field Officials

Table 10: Change in percent time spent on consumer complaints by sub-division employees

Data	Units	Baseline Scenario	Post roll-out Scenario
No. of transformer failures per year (on an average) in the project area	%	1.64%[26]	0.33%

Reduced customer care cost was estimated to generate **annual savings of ~INR 7,500**[27]**.**

[26]As per AVVNL, a sub divisional employee spends 50% time on resolving consumer complaints. A subdivision covers 31185 consumers, therefore for 1023 project area consumers, time spent on complaints is (50%*1023/31185) = 1.64%

[27]**Formula:** (Percentage of annual call duration on billing, meter, outage and reconnection queries) $_{baseline}$ – (Percentage of annual call duration on billing, meter, outage and reconnection queries) $_{post\ roll\text{-}out}$ x Annual cost of complaint handling per employee x No of Employee

Calculation: (1.64%-0.33%)*(144000*4)

Annual savings due to reduced outage

Smart solutions will enable advanced monitoring and real-time visibility on outages. Therefore, any outages at the customer side is duly detected and recorded without need of customers informing utility.

Based on this insight, AVVNL can get real-time alerts on outage location and take prompt repair actions which would decrease the outage time and thereby improve revenue for the utility. A conservative estimate of 20 percent reduction in outage time is assumed from an annual 180 hours in base case scenario. However, for full realization of the benefit and further reduction in outage time, this requires integration of Smart Meter/ Adapter data with Outage Management System (OMS) and FLISR (Fault Location Isolation and Service Restoration) application.

Reduced outage was estimated to generate annual savings of ~INR 3,700[28] .

Basis the CBA, annual benefit of INR 13 lakh/year was expected from the pilot project. Since, project was in the operational phase for only six months, all the benefits were not realised during the time period. It was expected that full realisation of benefits could be obtained if project was continued beyond the six months' time period with full integration with AVVNL existing applications. A summary of benefits realized and expected is provided in Table 11[29].

Table 11: Breakup of Annual Benefit Realized and Expected

Benefit Assumed in CBA	Benefit Realized	Benefit Value Realized (INR/ Annum)	Benefit Expected (Unrealized till date)	Further Benefit Value Expected (INR/ Annum)
AT&C LOSS REDUCTION				
Reduction in DT5 losses from 60% to 20% *(Contributing to 4.1% improvementin billing efficiency)*	Realized reduction-in DT5 losses from 60% to 25% during pilot period *(Contributing to 3.5% improvement in billing efficiency)*	630,000	With Smart Metering of new connection points identified in the area (~20), losses for DT 5 are expected to reduce to less than 20 per cent *(Contributing to additional 0.6% improvement in billing efficiency)*	*110,000*
Reduction in DT6 losses from 28% to 20% *(Contributing to 0.4% improvement in billing efficiency)*			Based on findings of unmetered temporary connections (new construction sites), losses are expected to come down to below 20%	*70,000*
Reduction in 2.2% billed energy unrealized due to slow/ defective meters	Realized 2.2% increase in billed energy in JNJ Smart Meter Area (500 consumers) due to	160,000	Based on Radius area consumption data analysis, a similar increase in billed energy is estimated in radius area	*160,000*

28 **Formula:** (Annual energy non-supplied hours baseline x Percentage decrease in outage $_{\text{post roll-out}}$) x((Average Retail Tariff (INR/kWh) x (Total energy billed annually $_{\text{post roll-out}}$ (INR)) – (Average Cost of Purchase (INR/kWh) X (Total energy purchased annually post roll-out (INR))/ Hours per year
Calculation: (180*20%)*((Rs 6.91/ kWh*2.37 MU) – (Rs 5.81x2.67MU))/ (365*24)
29 This does not include one-time INR 3.3 Lakh benefit accrued on account of recovery of charges of slow meters

Benefit Assumed in CBA	Benefit Realized (INR/ Annum)	Benefit Value Realized	Benefit Expected (Unrealized till date)	Further Benefit Value Expected (INR/ Annum)
(Contributing to 1.8% improvement in billing efficiency)	Electrical series *(Contributing to 0.9% improvement in billing efficiency)*		*(Contributing to 0.9% improvement in billing efficiency)*	
Faster collection – 1.2% of uncol-lected dues			With enablement of remote disconnect/ connect – unpaid dues are expected to be collected faster, thereby creating savings on interest cost	*3,000*
Reduction in DT6 losses from 28% to 20%			With phase balancing exercise, it is expected that DTs with high technical losses (4.5-5.5% loss) would reduce to at least 3.5% to 3%	*59,000*
METERING AND BILLING IMPROVEMENT				
Reduced meter reading costs			Expected to be realized on integration of smart solution meter data with AVVNL billing application	*23,500*
Reduced meter punching costs				*29,500*
Reduced float be-tween meter read-ing and customer billing				*37,500*
Interest cost saving on billing monthly instead of bi-monthly				*10,500*
OPTIMIZED ASSET MANAGEMENT				
Reduction in meter and transformer failure			Expected to be realized with analysis of load and power quality parameters	*12,000*
IMPROVED SERVICE AND RELIABILITY				
Savings on customer care operations cost (reduce consumer queries)			Expected to be realized on integration with AVVNL CIS application and on full-deployment of consumer application	*7,500*
Savings on reduced outages (faster detection)			Expected to be realized on configuration of outage alerts for the maintenance officials of AVVNL	*3,700*
		790,000		**526,200**

Net Benefit

Basis the intervention undertaken, total annual savings of ~INR 13 Lakh was estimated for ~1000 consumers and considering total capex cost of the pilot project as INR 67 Lakh, a payback period of about five-six years was estimated for the investments made. Since the scale of pilot project was small, the costs incurred were relatively higher. Figure 15 highlights the project financial results[30]

[30]Note: The annual benefit of around 13 lakh does not include one-time INR 3.3 Lakh benefit accrued on account of recovery of charges of slow meters. Further the benefit will increase each year due to expected demand/ tariff growth (Assumed as 3.8% and 3.9% annually based on historical AVVNL billing data). The total cumulative 10-year benefit considering tariff and demand growth is 19,300, 000 which is around 19.3 lakh per annum

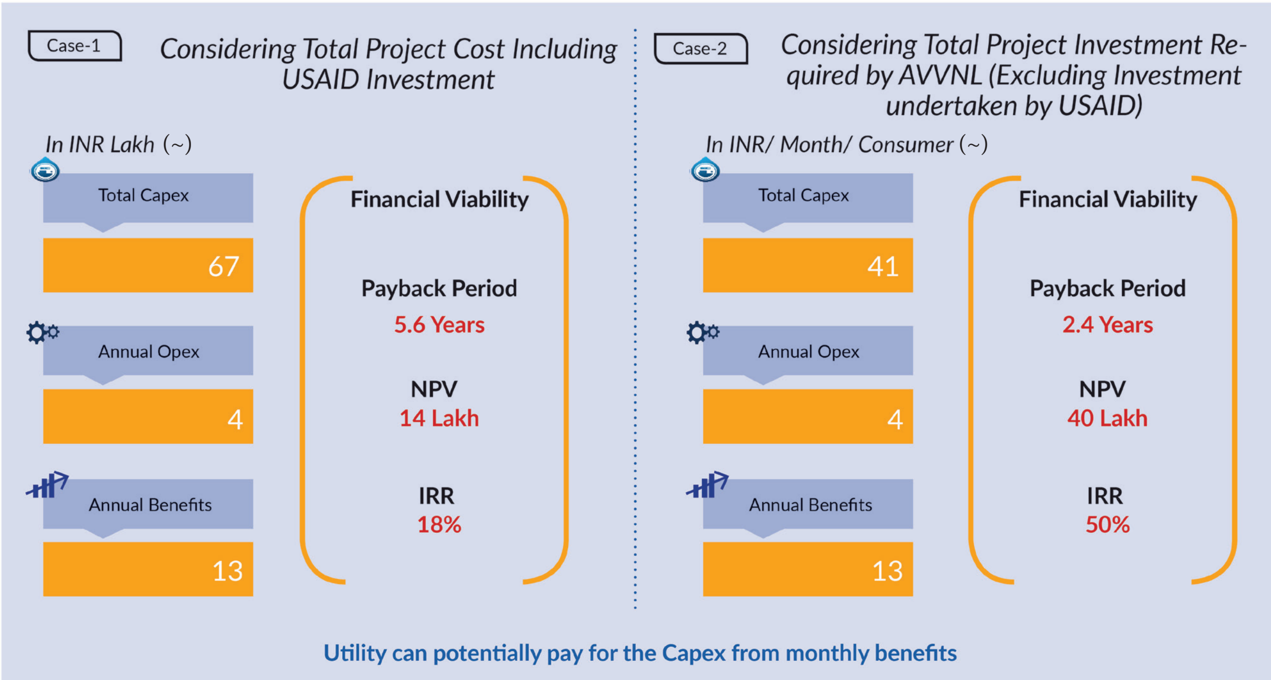


Figure 16: Financial Results

The remaining capex (~41 Lakh), if paid back as per the pay-for-rental model in equal monthly capex instalment payment over four years, would have resulted in payment of INR 85,295 per month, equivalent to ~INR 83 per month per consumer with a corresponding benefit of ~INR 108 per month per consumer. Hence, AVVNL, as per the pay-for-rental model, would have been able to payback the monthly capex from the monthly project benefits. Further, capex for the project is to be paid per month for four years, whereas, benefits would continue to accrue for the project life considered as 10 years. For the pay-for-rental model, the monthly costs and benefits for the project would be as per Table 12.

Table 12: Monthly Costs and Benefits for the Project

Particular	Units	Value
Total Cost to be paid by AVVNL (4 years)	INR/ Month	85,294
Total Cost to be paid by AVVNL (4 years)	INR/ Month/ Consumer	83.4
Total Opex to be paid by AVVNL	INR/ Month	36,008
Total Opex to be paid by AVVNL	INR/ Month/ Consumer	35.2
Total Benefit to AVVNL	INR/Month	110,896[30]
Total Benefit to AVVNL	INR/ Month/ Consumer	108

Note: As this was a small scale pilot implemented on a short time frame, the full benefit potential of the technology could not be realized due to limitations such as:

- *For all cut-off points and feeder meter, smart meter/OTT solution were installed; however, due to some field issues data from these meters was not available for analysis. Due to this, reconciliation of feeder level losses and other feeder level reports could not be generated for the pilot period. Energy auditing was therefore limited to DT level.*
- *Remote connect/disconnect though available was not utilized/ demonstrated in the pilot area as regulatory approval would have been required.*
- *There was no integration of Smart Meters/ OTT solution with utility existing billing system.*

5.2 Scale up Plan

The larger objective of the pilot was to demonstrate benefits of select functionalities to AVVNL by implementing a proof of concept (POC) on single selected feeder and subsequently suggest strategies for a larger roll-out basis the results of the POC. Post successful completion of the pilot, a broad conceptual framework for scale up to a larger area was prepared and presented to AVVNL.

For scale-up, a consumer engagement strategy was also designed (refer Annexure-3) basis consumer engagement initiative undertaken at the pilot stages.

Scale up plan envisaged to reap all benefits delivered in the pilot project viz. reduced AT&C losses and metering and billing improvement, while also delivering additional benefits in terms of peak load reduction, optimized asset management, improved service and reliability, etc.

5.3 Management Review

Apart from the benefits estimated by the USAID PACE-D TA Program, AVVNL team also presented its findings to MOP and observed the following benefits:

- Growth of sale in project area after installation of smart meters by 11 percent.
- Reduction in T&D losses by ~2.5 percent (from 14.74 percent to 12.18 percent) which is equivalent to ~100,000 kWh.
- Accuracy level of reading capacity was now 100 percent.
- No man inference in energy consumption capturing and reduction in billing time.
- Load balancing of distribution transformer can be undertaken according to the loading pattern of the connected consumer.
- Failure/Burning rate of transformer can be reduced to zero.
- Accurate data for power supply is available to both consumer and utility.
- Real time energy audit can now be provided.
- Consumer sanctioned load demand violation can now be monitored.
- The distribution transformer capacity can be designed according to actual load demand.

In conclusion, AVVNL stated that the smart systems were able to demonstrate the aforementioned benefits and continuance and up-scaling of the project was under management review. However, in the meantime the project area become part of distribution franchisee domain of M/S Tata Power Ltd. Delhi. Following this, the project was successfully concluded as it was positively able to demonstrate the various benefits of Smart Grid technology for utilities.

SECTION 6

KEY LEARNINGS

The key lessons learnt from the AVVNL pilot project include:-

- **Baselining of project parameters critical for measuring project benefits post implementation:** For accurate estimation of benefits from the project, it is essential that proper baseline is created before start of the project. In the present case, due to lack of consumer-feeder mapping in AVVNL database, it was not pos sible to determine pre-installation AT&C losses for the project. The accurate baseline for the project was thus improvised basis the inputs recorded from smart solutionduring the first month post installation.
- **Consumer indexing is a pre-requisite for accurate energy audit:** For enabling correct energy auditing down to the DT level, there is a need for accurate consumer indexing (mapping consumer to the DT and Feeder). Also, it is important, to attune utility business processes to capture load growth, removal of old and faulty meters, etc. in the project area on a timely basis.
- **Ring-fencing of the project:** It is important to ring fence the smart grid project for undertaking accurate energy accounting. Sometimes, same set of consumers are supplied electricity from multiple feeders/DTs and hence ring-fencing of the project becomes essential.
- **Baseline survey and inspection of connections and updation of meter records also provides significant op portunity for plugging revenue leakages.**
- **Consumer engagement strategy must for success of pilot project:** Smart Grid technologies and applica tions have direct beneficial impact on customers. The success of any Smart Grid deployment lies in the active participation of the consumers. Therefore, it is imperative to educate consumers on the benefits of Smart Grid technologies and address their concerns, if any
- **Automatic energy auditing enables identification of loss areas:** Smart meter captures feeder and DT losses on a real time basis, providing sufficient visibility to the utility for identification and correction of loss pock ets/areas.
- **Data analytics is key to unlocking full benefits of Smart Grid:** True value of Smart metering/adapter lies in analyzing the real time data to produce actionable insights for loss reduction, improved load management and improved power quality and reliability, etc. Data analytics is not only crucial for utilities, but is equally beneficial to consumers, who can utilize actionable insights on its consumption patternto drive down its overall bill value by optimizing their daily electricity consumption.

  For example, analysis of past billing data combined with real time data from smart meters/ adapters were utilized for analyzing consumers with unusual energy usage pattern, large consumption drops, near zero consumption and consistent meter failure cases in the pilot areas. Such analysis aided with field investigation of suspect cases and helped to detect cases of faulty traditional meters.
- **Regular Monitoring is required to derive maximum benefits:** The system once installed provide capability to the utility personnel to undertake accurate energy accounting and identify deviations as they occur. However, the system and data needs to be continuously checked by utility personnel for new installations, load growth, changes in field, system topology considerations, etc. to maintain the efficiency and accuracy of the system and derive maximum benefits.

- **Dedicated utility project team and top-down driven decision making required to enable action Implementation:** Smart meter/OTT and analytics can only provide recommendations on improvement areas. However, to realize the benefits, a dedicated utility project team is required that monitors the KPIs on a regular basis and makes use of analytics to take action on the improvement areas identified. Further, with smart meter/adapters, top management can now have greater visibility through management dashboards/reports which enables them to monitor situations at various divisions/ substations and give directions if KPIs are not being met.

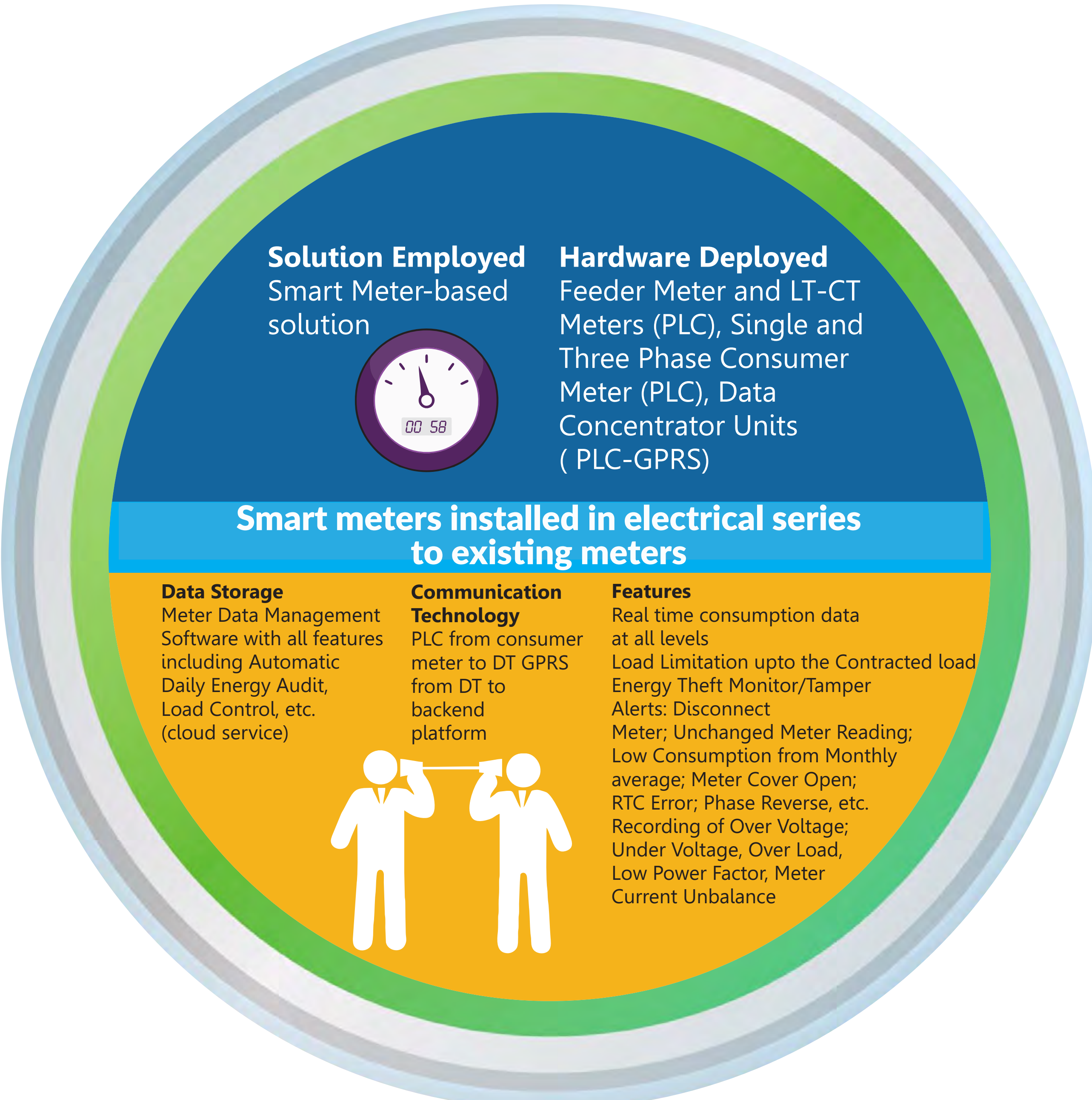
- **Training and capacity building key to operate the system:** It is essential to impart training to utility personnel for operating the automated systems to derive maximum benefits.

The project provides a proof of concept of smart metering/ adapters providing a viable business case for utilities even on a small scale, as it improves operational efficiency (elimination of manual meter reading, condition based asset maintenance) and financial performance (reduction in losses, improved service and reliability of supply) of the utility.

ANNEXURE – 1

JNJ AND RADIUS SOLUTION DESCRIPTION

JnJ Solution:
Smart Meters



Radius Solution: OTT Module

Hardware Deployed
Proprietary Adaptor, Bridges and Gateway

Description
Mix Mode Deployment – same module for single phase, three phase, LT-CT. Gives flexibility to pick and choose based on needs

Operates with all makes of meter as per existing IS13779 specs versus one make of smart meter

OTT module attached on existing CMRI port of Meter

Data Storage
Backend platform for storage, analysis and visualization of data (Cloud based)

Communication Technology
RF network from consumer adapter to DT Gateway GPRS from DT Gateway to backend platform

Features
Real time consumption and power quality data at all levels
Power Outage Reports
Send out alarms/alerts for: Contracted (sanctioned) load exceed; Probe remove/malfunction; Pole level theft; Low / High voltage; Phase imbalance; Phase missing

Mobile Application
Consumer application (Android based) to view near real time consumption information

ANNEXURE - 2
CONSUMER ENGAGEMENT MESSAGING

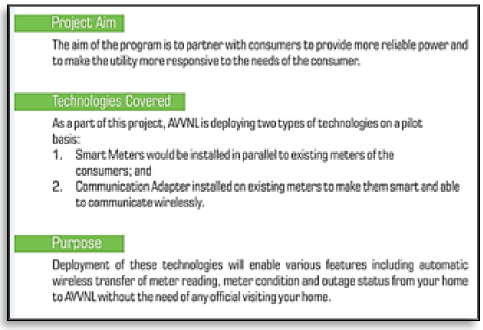
Ajmer Pilot- Formulating the Messaging

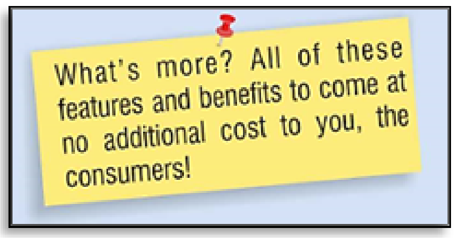
- **Keep it short and simple:**
  Clear and simple messages help in maximizing con sumer impact. In case of Ajmer, it was about relating to the day-day problem/issues faced by the consumers and how Smart Grid can help to resolve them.

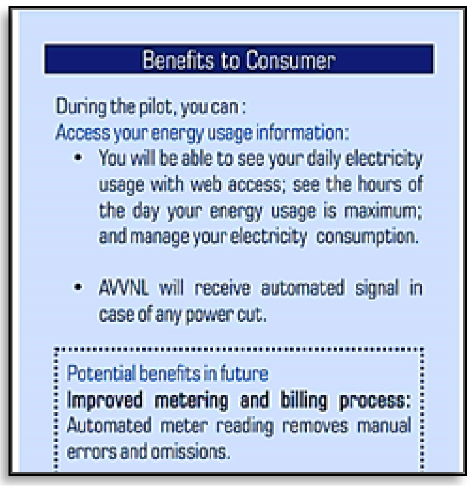
- **Clear messaging on the cost of technologies:**
  Consumers are cost conscious. Hence, it was critical to convey this to them that in case of our pilot project, there would not be any cost impact.

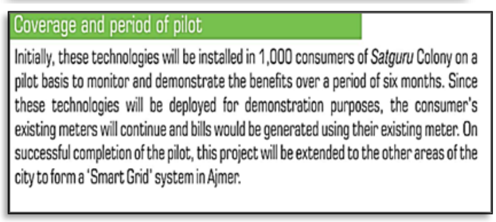
- **Clear focus on the benefits and setting the right expectations:** Message focussed more on actual and immediate benefits that would accrue to consumers and if successful what more potential benefits could accrue. Messages related to broader vision of Smart Grid, detailing out type of technology use should be avoided. Along with communicating benefits, address any fears/ concerns that consumers may have. In context of Ajmer, it was about communicating that the billing is still based on existing meters so that there is no misrepre sentation in consumer's mind about their billing post pilot installation phase.

- **Develop messages and communication materials in local languges:** For Ajmer it meant developing brochures in both English and Hindi languages.









ANNEXURE – 3
CONSUMER ENGAGEMENT STRATEGY FOR SMART GRID SCALE-UP

By incorporating the lessons learnt from the consumer engagement activity during the AVVNL pilot program, the overall consumer engagement implementation strategy for AVVNL was designed to follow a focused phase wise approach as summarized in Figure 17.

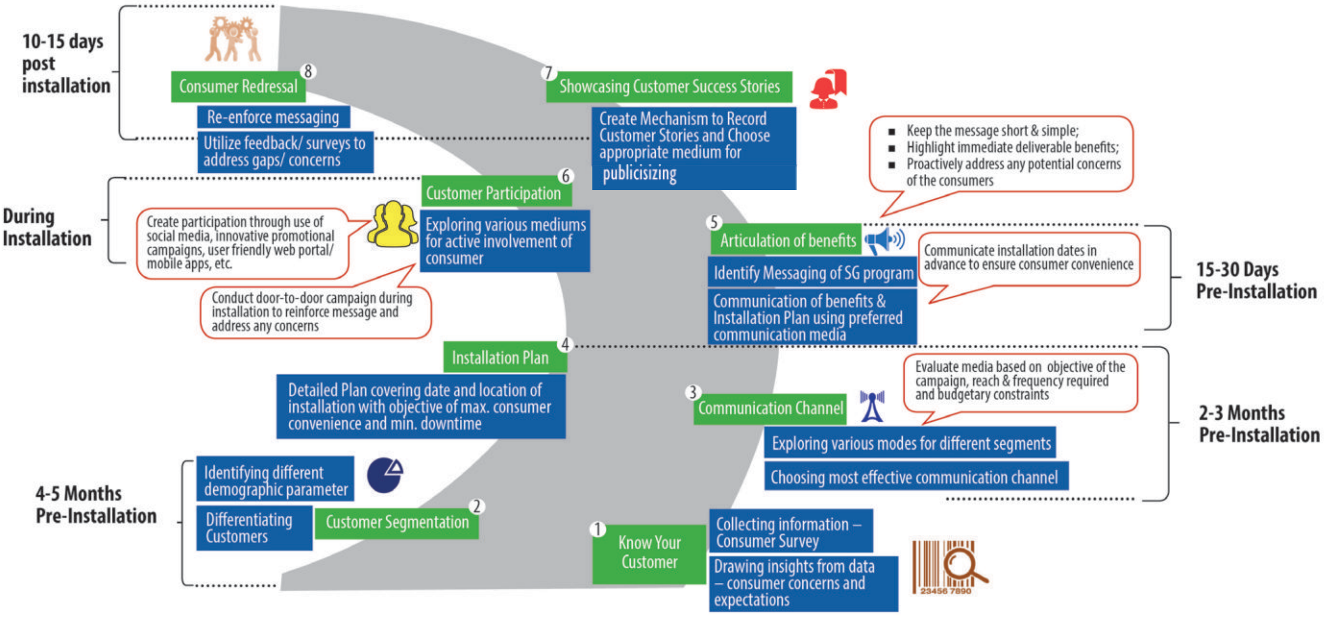


Figure 17: Consumer Engagement Implementation Strategy for Scale-up

A N N E X U R E - 4

PHASE IMBALANCE LOSS CALCULATION METHODOLOGY

Step 1:

Based on the current from individual phases, the average current and the imbalance is derived based on the following formula:

Iu= (Id × 100) / Ia

Where,

- Iu – percentage current unbalance
- Id -maximum current deviation from the average current
- Ia – average current among three phases

Step 2:

Each positive imbalance is converted to kVAh for each phase and added up for total loss at that point. The assumption for converting imbalance to kVAh losses is that a 10% unbalanced phase current would increase the total copper loss by about 1%.

Step 3:

The average loss per hour is calculated. This gives 24 values for a day and when these are added they give the daily loss figure from phase imbalance.

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