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SHAKTI SUSTAINABLE ENERGY FOUNDATION

ISGF India Smart Grid Forum

DESIGN OF ROBUST TIME OF USE FRAMEWORK FOR ELECTRICITY TARIFF IN GUJARAT

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Knowledge Partner

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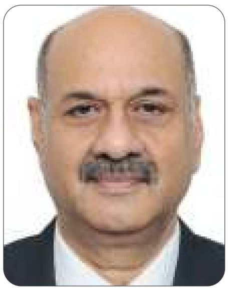

Mr. Anand Kumar
Chairman, GERC

Date: 24.02.2021

Message

I am pleased to note that India Smart Grid Forum (ISGF) supported by Shakti Sustainable Energy Foundation has developed a Robust Time of Use Framework for Electricity Tariff in Gujarat. In the present scenario of high penetration of renewable energy, knowledge about the demand-price relationship, consumers' willingness-to-pay for electricity, and demand forecasts shall become necessary to plan the supply and design of tariff structures. Increasing share of distributed energy resources (DER) such as solar photovoltaic (PV) and wind power which are intermittent as well as use of electric vehicles (EVs) will result in unanticipated peaks in demand-generation curve leading to huge stress on the power system equipment and networks. The real-time dynamic tariff enables demand flexibility in response to real-time price signals and helps flatten the load curve and improve the asset utilization while reducing emissions. The Analytical Tool developed by ISGF will help regulators and utilities to analyze different scenarios of peak load shifting and its impact on the utility revenue and customer's bills.

This study will help DISCOMs and Regulators to fine-tune their billing system for ToU regime for optimum use of their resources.

I congratulate ISGF for this important initiative and wish them success in their future endeavors.

Anand Kumar

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Chief Exective Officer
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To,

Mr. Reji Kumar Pillai
President
India Smart Grid Forum
CBIP Building, Malcha Marg
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The Indian power sector is on the cusp of new development and reforms. India has taken significant strides toward achieving universal energy access and has set ambitious renewable targets of 175 GW by 2022 and 450 GW by 2030. The Government of India is working towards addressing systemic issues and challenges in the power sector through proposed amendments to the Electricity Act, 2003, Electricity (Right of Consumers) Rules, 2020 and others measures. Concurrently, efforts are being made towards providing “24X7 Power for All” with newer developments on the front of storage and round the clock (RTC) power supply from renewable. Power markets are also being transformed with the launch of new products and platforms such as Green Term Ahead Market (GTAM).

The pricing of electricity become the fulcrum of these developments, and it is essential to implement a dynamic tariff structure to optimize capacity additions and power supply positions. The introduction of dynamic tariff structures is critical at the juncture to balance the demand and shave the ever-increasing demand peaks from the economic growth predicted for India.

We are pleased to support India Smart Grid Forum (ISGF) to develop this critical implementation roadmap for adopting the ToU tariff regime. We hope it will encourage distribution utilities across India to explore the implementation of the Time of Use tariff framework in their respective geographies.

Regards,

Dr. Anshu Bhardwaj
Chief Executive Officer
Shakti Sustainable Energy Foundation

Preface

Reji Kumar Pillai
President, India Smart Grid Forum
Chairman, Global Smart Energy Federation

Pricing of electricity is one of the key challenges in the efficient functioning of the power sector. Electricity tariffs typically do not reflect the true costs of generation, transmission and distribution in India. Knowledge about the demand-price relationship, consumers' willingness-to-pay for electricity, and demand forecasts are necessary to plan the supply and design of tariff structures. Typically, in most cities, the last 100 MW of the peak demand is experienced for about 100 hours or less in a year; and creating an entire infrastructure to meet this load makes the whole system uneconomical. As the share of distributed energy resources (DER) increases, the power system require flexibility both on the supply and demand sides to manage the peak demand and also the intermittency of the DERs. With flat tariffs, which are in place today, customers do not have incentives to shift loads to non-peak hours. And the Time of the Day (ToD) tariff applicable to commercial and industrial customers in certain states are also not very effective in managing demand from the standpoint of higher share of intermittent VRE and actual timing of peak demand owing to changes in weather pattern and life style. So, there is a need for real-time or dynamic tariff for electricity which will be beneficial to all stakeholders.

ISGF with support from Shakti Sustainable Energy Foundation embarked on the project “Design of Robust Time of Use Framework for Electricity Tariff in Gujarat”, a first of its kind study in India. This study examined the detailed feasibility on the possible impacts of the Time of Use (ToU) tariff policy in the state of Gujarat. As part of this project, ISGF developed a ToU Tool that utilities and regulators can use for analyzing different “what-if” scenarios on how much peak load can be shifted and what impact it would have on the utility revenue, reduction in peak power purchase cost and impact on the customer's bills. An implementation framework and practical roadmap is also given in the ToU report. The study also assessed the use and the impact of the policy on peaking power plants and reduction in the use of DG sets that are used to meet peak loads. It is recommended that the ToU tariff may be implemented on pilot basis in Naroda area in UGVCL in 2021. In the initial phase (6 months to 1 year) there should not be any financial implications of ToU – the customers opting for ToU may be presented two bills: one regular bill that they will pay; and another bill which will show the charges if they had opted for ToU scheme and shifted part of their load. This Shadow Bills should show how much they would have saved if they shifted their load by 10%, 15%, 20%, 25% etc during peak hours during the billing cycle. This experiment will give enough time for distribution utilities and regulators to fine-tune their billing system for actual implementation of the ToU regime.

ToU has the potential to flatten demand profiles and thus help power suppliers to reduce expenditure on capacity addition and efficiently plan electricity generation and distribution. This real-time dynamic tariff enables demand flexibility in response to real-time price signals that will help flatten the load curve and improve the asset utilization while reducing emissions. Although the report is for Gujarat, the ToU Tool is relevant for other states as well. We hope this report will herald the era of ToU tariff in the country.

Reji Kumar Pillai

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Our appreciation to **Mr. Yesh Vardhan Agarwal** for his analysis of load consumption patterns and development of the ToU Tool.

We also like to extend our sincere gratitude to all the stakeholders for their cooperation during the course of this study.

Shakti Sustainable Energy Foundation seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following areas: clean power, energy efficiency, sustainable urban transport, climate change mitigation and clean energy finance.

India Smart Grid Forum is a Public-Private Partnership initiative of Ministry of Power (MoP), Government of India for accelerated development of smart grid technologies in the Indian power sector. The mandate of ISGF is to advise Government on policies and programs for the promotion of Smart Grids in India, work with national and international agencies in standards development, and help utilities, regulators and the Industry in technology selection, training and capacity building.

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Abbreviations

ABT	Availability Based Tariff
ARR	Annual Revenue Requirement
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CPP	Critical Peak Price
CSO	Civil Society Organizations
DDUJY	Deen Dayal Upadhyaya Gram Jyoti Yojana
DISCOM	Distribution Company
DSM	Demand Side Management
DSO	Distribution System Operator
ERC	Electricity Regulatory Commission
ESS	Energy Storage System
EV	Electric Vehicle
FOR	Forum of Regulators
GS	Generating Station
ICT	Information and Communication Technology
LAC	Large Area Coverage
MYT	Multi-Year Tariff
NERSA	National Energy Regulator of South Africa
PGCIL	Power Grid Corporation of India Limited
RES	Renewable Energy Source
RLDC	Regional Load Dispatch Centre
RTSS	Roof Top Solar System
SAUB HAGYA	Pradhan Mantri Sahaj Bijli Har Ghar Yojana
SEB	State Electricity Board
SERC	State Electricity Regulatory Commission
ToD	Time of Day
ToU	Time of Use
UGVCL	Uttar Gujarat Vij Company Limited
UI	Unscheduled Interchange
VPP	Variable Peak Price

1. INTRODUCTION

Rapid growth and urbanization have delivered modern challenges that affect the fundamental elements of survival of humanity and the surrounding life. From the most powerful and influential economies to the developing ones, the problem of climate change is affecting everyone in ways like never before. Fighting the ever-growing consequences of climate change is not a choice today, but a necessity which we must accept and work towards mitigating it. The electricity sector is one of the biggest emitters of greenhouse gases. All countries are promoting renewable energy to decarbonize the power sector. The electricity demand varies throughout the day depending on the customer's consumption pattern. During the summer months, the demand is maximum in the afternoon because of the cooling requirements of various industrial, commercial and residential users. Two most popular methods of managing such peak loads in India are load shedding and the use of peaking power plants.

- **Load shedding or rolling blackouts** is the intentional interruption of power at pre-scheduled hours at select locations/regions. This is the most common method practiced in India for managing peaks. However, this might lead to interruption of power to important services and amenities in the region thereby reflecting the poor quality of power supply. When load shedding happens, most customers use their small size diesel generators or Inverters/UPS systems.

- **Peaking Power Plants** are provisioned in different regions that run on gas or diesel. Power generated from these peaking plants is expensive as they use imported fuels that are costly and also the plants run less than optimal hours in a year. The peaking plants are high on emissions as well.

Demand-side management (DSM) techniques are being leveraged to reduce and manage energy consumption at the consumer end. Time of Use (ToU) tariffs or real-time pricing is one such strategy employed under DSM to manage electricity consumption to avoid or limit peak hour demands.

1.1 Background

Traditionally, Gujarat never practiced load shedding to manage peak demand. However, when required, peaking power plants are run and/or power purchased from the power exchange. Peaking power plants are used in combination with base load power plants, which supply a reliable and consistent amount of electricity to meet the minimum demand requirements. Peak load plants are power plants that can be switched ON or OFF almost instantaneously rendering them as a viable solution to supply electricity during peak hours. However, petroleum based peaking power plants pollute the environment more than the conventional power plants, and hence, their operation and use need to be limited by innovative policies and tariff schemes. Also, owing to the low utilization factor (few hundred hours/year), the cost of power from peaking plants is very high. To counter such challenges, DSM can play a pivotal role in helping the electricity distribution companies (DISCOM's) manage their energy requirements during the peak hours efficiently.

Electricity retail market is undergoing rapid transformation. Pricing is one of the key components characterizing the level of customer service. Electricity tariffs typically do not reflect the true costs of generation, transmission, and distribution in India. Knowledge about the demand-price relationship, consumers' willingness-to-pay for electricity, and demand forecasts are necessary to plan the supply and design of tariff structures.

Increase in distributed energy resources (DER) such as solar photovoltaics (PV), wind turbines and electric vehicles (EVs) will result in unanticipated peaks in demand/generation curve, thereby stressing the generation, transmission, and distribution assets. Huge capacity addition is required to meet such unanticipated peaks. This peak capacity stays idle during off-peak periods resulting in a loss of opportunity cost and system efficiency. Typically, in most cities, the last 100 MW of the peak is experienced for about 100 hours or less in a year; and creating an entire infrastructure to meet this load makes the whole system uneconomical.

Dynamic tariff structures have the potential to flatten demand profiles and thus help power suppliers to reduce expenditure on capacity addition and efficiently plan electricity generation and distribution. Dynamic tariff enables demand response which can be defined as the capacity of end-use customers to change their electricity usage from their normal or current consumption patterns in response to market signals. In contrast to energy efficiency, which aims at reducing the overall energy consumption, demand response is mainly about shifting consumption to a different point in time.

Benefits of ToU Tariff Scheme

The successful implementation of the ToU tariff scheme can reduce peak demand by 5 to 25 percent by shifting interruptible loads to non-peak hours. This will reduce the carbon footprint and lead to a cleaner environment in the following ways:

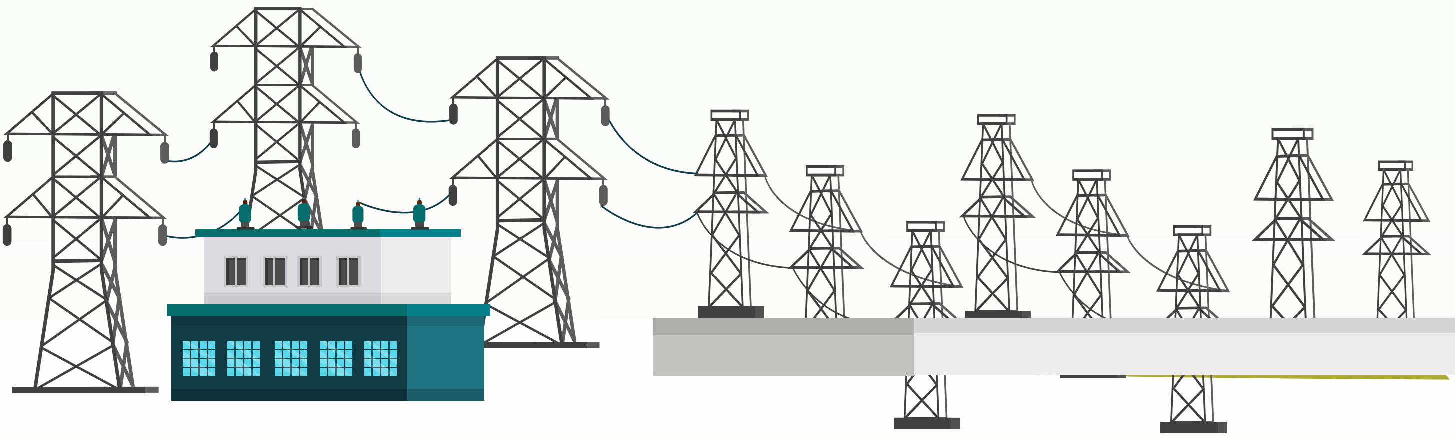
- Mitigation of peak demand
- Reduction in AT&C losses
- Avoidance of diesel generator (DG) sets
- Avoidance of peaking power plants
- Avoidance of inverters (mostly run-on lead-acid batteries)
- Integration of renewable energy as a base-load
- Control EV charging pattern
- New market opportunities
- Cost savings to customers
- Reduction in power purchase cost
- Deferral of generation, transmission and distribution infrastructure upgrades

1.2 Purpose of the Project

Gujarat has a Time of Day (ToD) tariff in place and the adoption of Time of Use (ToU) or real-time pricing is proposed as a test case to review the effect of real-time pricing of electricity on consumer's behaviour and the subsequent impact on generation, transmission and distribution utilities, their assets and revenues. Further, Gujarat is also planning to upgrade its renewable portfolio by several thousand megawatts in line with the Government of India's ambitious target of 175 GW of renewable power by 2022 and 450 GW of renewable power by 2030. The ToU tariff will be relevant to play a pivotal role in integrating and adopting renewable energy into the energy mix efficiently and also contribute towards reducing the carbon emissions' footprint.

The elements of an economically efficient tariff fit for addressing the current and expected network challenges can be derived from long-established principles of good tariff design. Those principles dictate that tariffs should:

- Be simple, predictable, and understandable
- Reflect long-run marginal costs
- Focus on usage-driven components
- Provide consumers the information, the opportunity, and the incentive to consume in a manner that optimizes the utilization of grid infrastructure
- Where possible and appropriate, provide for the recovery of system costs based on how much a customer uses, when they use it, and where they are located



A brief about the Gujarat power system is presented below:

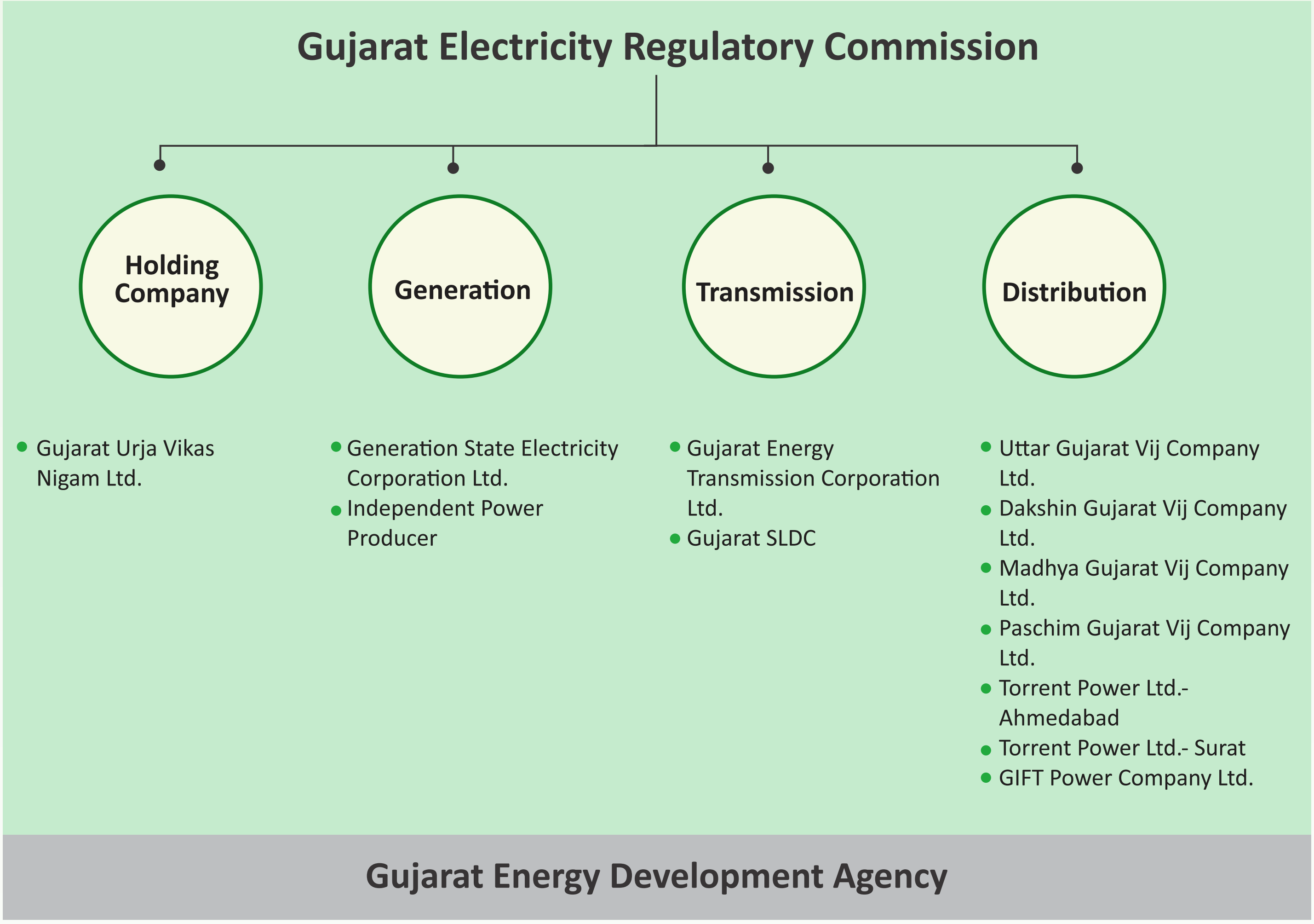


Figure 1-1: Power System Structure of Gujarat State

1.2.1 Increasing Electricity Requirement and Peak Demand

GERC estimated the Discom-wise electricity requirement in FY 2019-20 and FY 2020-21 as follows:

Year	Electricity Requirement Projections (MUs)						
	UGVCL	DGVCL	MGVCL	PGVCL	TPL (Ahmedabad)	TPL (Surat)	Total Requirment For Gujarat
2019-2020	22968	19297	10446	29668	8,145.79	3,451.83	93,976.62
2020-2021	24584	20304	11076	31859	8,480.99	3,503.83	99,807.82

Table 1-1: Electricity Requirement Projections

According to estimates provided by the Western Regional Power Committee (WRPC), the peak electricity demand for Gujarat has followed the trend given below:

Month	Peak Demand (MW)	Peak Deficit (MW)	Peak Deficit (%)
March 2018	14,801	38	0.26
April 2018	15,053	11	0.07
May 2018	17,016	1198	7.04
June 2018	16,392	77	0.47
July 2018	14,590	21	0.14
August 2018	15,591	11.7	0.08
September 2018	16,963	0	0
October 2018	16,624	19	0
November 2018	14,632	22.17	0.15
December 2018	14,304	32.23	0.23
January 2019	14,897	5.6	0.04
February 2019	15,409	0	0

Table 1-2: Gujarat Peak Electricity Demand Scenario

As observed from the table above, the electricity requirement in Gujarat is expected to accelerate in the coming years. This is mostly due to the increase in the connected load on account of significant progress of SAUBHAGYA and DDUGJY schemes along with industrialization within the state.

The peak demand scenario for the past year indicates that Gujarat failed to meet peak demand requirements for nine months. Particularly in May 2018, a significant peak deficit of 7.04% was observed. ToU tariff can be applied as a DSM tool to encourage domestic and industrial consumers to shift their electricity usage to non-peak hours. This would help flatten the electricity load curve and minimize peak deficit.

These estimates were made before the Covid-19 pandemic. Post Covid-19, the demand has come down significantly. By 2022-23, it is expected that the demand will resume to pre-Covid days.

1.2.2 Smart Metering Status in Gujarat

UGVCL has commissioned the smart grid pilot project funded through a grant from the Ministry of Power (MoP) on 27th February 2019. The project has deployed AMI for both residential and industrial consumers along with outage management systems. The number of consumers covered in the smart metering systems are 22,230. Besides this pilot project in UGVCL, there are no major smart metering projects undertaken in Gujarat so far.

1.2.3 Installed Renewable Energy Capacity

Small Hydro (MW)	Wind Power (MW)	Bio Power	Solar Power			Total RE Capacity (MW)
		BM Power/Bagasse Cogen. (Grid Interactive) BM Cogen. (Non-Bagasse/Captive Power) Waste to Energy (MW)	Ground Mounted (MW)	Roof Top (MW)	Total (MW)	
61.3	6073.07	77.3	2113.46	326.67	2440.13	8651.8

Table 1-3: Renewable Energy Installed Capacity

The MNRE estimates that Gujarat has an estimated RE potential of 72.726 GW. Solar energy potential for the state is estimated at 35.77 GW. The RE target set for Gujarat for 2022, was 16,963 MW. Gujarat has managed to achieve an installed RE capacity of 8,651.8 MW as of 2019. Renewable energy capacity can be leveraged to both base load as well as peak load needs through ToU tariff implementation.

1.2.4 Existing ToD Tariff Structure in Gujarat

According to the recent retail supply tariff orders of Gujarat, ToD surcharge/rebate is currently applicable only to a few consumers. The scheme is applicable for different periods of the day, i.e., normal period, peak load and off-peak load period. The surcharge/rebate on energy charges according to the period of consumption are given below:

State DISCOM's:

Time of Day tariff applicable to all the waterworks consumers having connected load of 50 HP and above for the energy consumption during the Off-Peak Load Hours of the Day	
Off-peak period, viz., 1100 Hrs to 1800 Hrs	40 Paise per kWh
Night period, viz., 2200 Hrs to 0600 Hrs next day	85 Paise per kWh
Time of Day Tariff for the supply of electricity at High Tension (3.3 kV and above, 3-Phase 50 Hertz), Extra High Tension and Seasonal Consumers taking HT Supply (For the two peak periods, viz., 0700 Hrs to 1100 Hrs and 1800 Hrs to 2200 Hrs)	
For Billing Demand up to 500 kVA	45 Paise per kWh
For Billing Demand above 500 kVA	85 Paise per kWh

Table 1-4: ToD tariff applicable to all the waterworks consumers having connected load of 50 HP and above

Torrent Power:

For the consumption during specified hours, as mentioned here below:

- For April to October period: 12:00 Hrs. to 17:00 Hrs. And 18:30 Hrs. To 21:30 Hrs.
- For November to March period: 08:00 Hrs. To 12:00 Hrs. And 18:00 Hrs. To 22:00 Hrs.

Applicable for the supply of energy to High Tension consumers contracting for a maximum demand of 100 kW and above for purposes other than pumping stations run by local authorities	
For Billing Demand up to 300 kW	80 Paise per kWh
For Billing Demand above 300 kW	100 Paise per kWh
Time of Day Tariff applicable for: • Supply of energy to Water and Sewage Pumping Stations run by local authorities and contracting for a maximum of 100 kW and above. • Consumers take electricity at high voltage, contracting for not less than 100 kW for a temporary period. A consumer not taking supply regularly under a formal agreement shall be deemed to be taking supply for a temporary period. • Supply of energy to Metro traction, contracting for a maximum demand of 100 KW and above.	
60 Paise per kWh	

Table 1-5: High Tension consumers contracting for a maximum demand of 100 kW

1.3 Project Objectives

The objective of this project is to examine the existing regulatory framework in electricity retail tariff and develop a strategy for implementing ToU/dynamic tariff in the retail market within the present legal framework of the Electricity Act, 2003. ToU tariff is recognized globally across electricity industries as an important DSM measure used to incentivize consumers to shift a portion of their loads from peak times to off-peak times, thereby improving the system load factor by reducing the demand on the system during peak period.

1.4 Project Scope

This project includes a detailed feasibility study and recommendation on the possible impact of the ToU tariff policy in the state of Gujarat. An implementation framework and effective roadmap will be created for the utilities to understand the procedure and required infrastructure to implement ToU. The study will also assess the use and the impact of the policy on peaking power plants and reduction in the use of DG sets that are used as peaking power plants. The impact of policy on the reduction of carbon emissions in the state would be estimated. The policy and regulatory issues will also be prescribed. The main outcomes of the project are as follows:

- Buy-in of the stakeholders for the project
- Understanding of customer responses to different tariff structures and their concerns on ToU implementation challenges
- Key stakeholders will be consulted
- Pros and Cons of different ToU structure in the state and its analysis and consultations with different stakeholders
- ToU Implementation in the state with the cooperation of all stakeholders
- Forum of Regulators (FoR) buy-in on ToU for other states

1.5 Methodology

A well-designed research methodology is instrumental in carrying out a detailed study and analysis. Our proposed research methodology is outlined below:

Step 1:

Conducting the literature review and kick-off meeting with key stakeholders

Tariff orders, regulations, and state and central level policies have been studied to understand the potential and impact of the existing ToD tariff of utilities in Gujarat. International best practices and peer-reviewed research work was reviewed and analyzed. The challenges faced in the implementation of ToU tariffs in different utilities in selected countries were studied. A stakeholder consultation meeting with Regulators, Government, Utilities, large industrial and commercial customers, industry associations, power generation companies, state load dispatch center, NGOs, etc. was held to present the objectives, and outcomes of the project. The detailed feedback/suggestions were received which has been incorporated in the report.

Step 2:

Sampling methodology design and data collection

ISGF will design and develop various data collection methods such as questionnaires for industry responses. These will be used as an actual field survey to carry out data gathering from customer responses to gauge consumer behavior, willingness, and their ability to respond to ToU price signals.

Step 3:

Analysis of load consumption patterns, ToU options and consultation with state regulators.

Daily peak and daily average power consumption patterns across months, load patterns for weekdays and weekends and changes in consumption pattern over the years will be analyzed to understand the fluctuations between the highest and lowest consumption days. This analysis will be performed using a custom-built analytical tool which will allow us to input details such as the customer category, month of the year, time of the day, ToU tariff scenarios and the power procurement cost etc. This analytical tool will automatically generate the recommendations for the ToU tariff structure and suggest revised load patterns. The ToU options generated with the help of the analytical tool would be presented to the state regulators and their views will be collected for designing the final ToU recommendations.

Step 4:

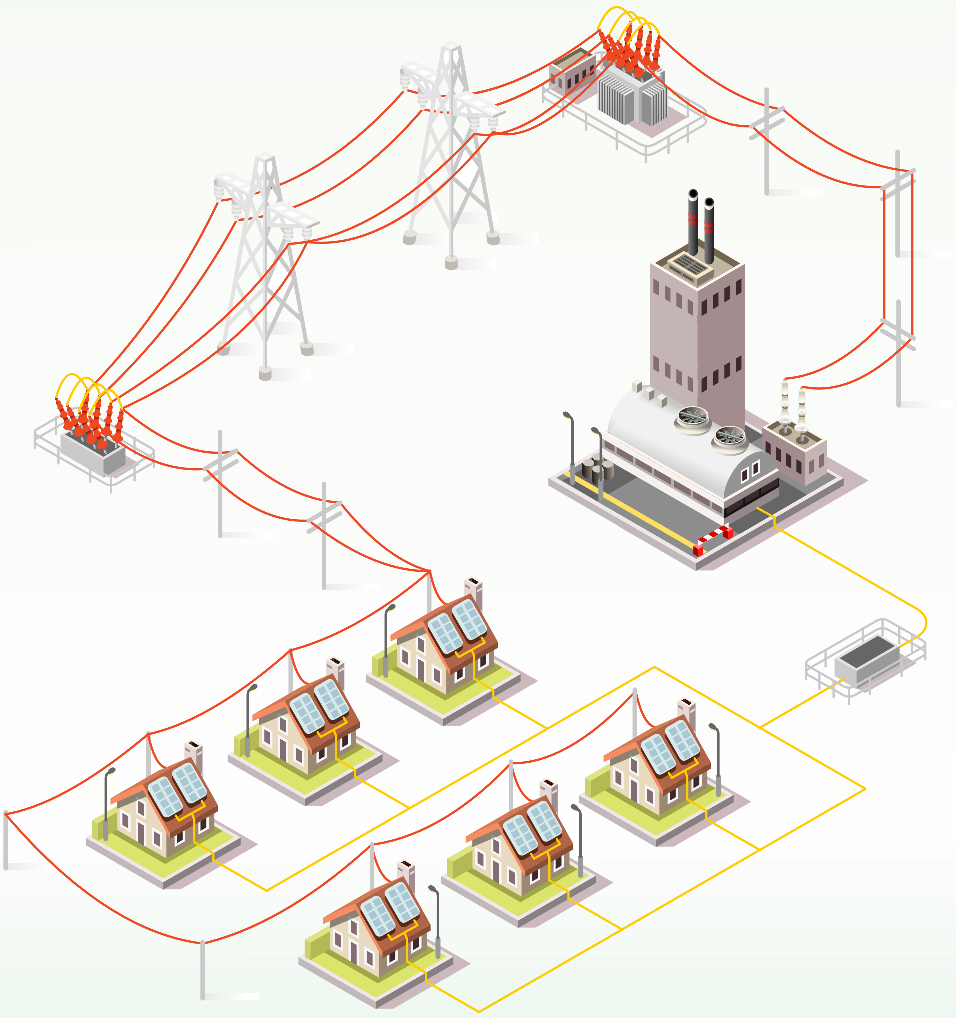
ToU implementation Roadmap

Infrastructure requirements would be assessed to implement the ToU tariff regime such as smart metering and demand response deployment. Stakeholder meetings and workshops to be held with the regulators, Government, utilities, customers, and NGOs. Recommendations will be made accordingly for implementation of the final ToU tariff structure and a Roadmap for ToU Implementation in Gujarat will be prepared.

Step 5:

Recommendations for ToU framework for other States in India

The ToU framework and Roadmap designed for Gujarat and its expected benefits will be presented to FOR and recommendations will be made advising other states in India to adopt ToU Tariffs.



2. TARIFF POLICIES AND REGULATORY FRAMEWORK IN INDIA

The opening up of the electricity sector as part of economic liberalization and the establishment of Central and State Regulatory Commissions have made the sector transparent. Apart from making available essential information to the public, these regulatory bodies have created ample opportunities for the consumers and civil society organizations (CSO) to participate in the regulatory process. Determination of electricity tariff is an important function of the regulatory commissions. Unlike in the past, tariff now is determined through a transparent process with the involvement of all stakeholders, including consumers. The regulator follows a set procedure and hears the views of the public and the utilities before the tariff is determined. Consumers must understand these procedures so that their intervention is effective.

An efficient tariff design should have certain features such as:

- Tariffs must be cost-reflective and made transparent for retail consumers through simplification of tariff categories and slab structures
- Tariffs should provide appropriate economic signals to the consumers as well as the market participants such as developers, investors etc. and subsidies need to be well-targeted
- Tariff structures must facilitate smoothening of demand curve through ToU metering or tariffs to optimize power purchase cost

The regulated tariffs should be such that they encourage and not stifle competition which is the underlying objective of the Electricity Act of GoI, 2003. However, most of these are currently absent in the sector because of various socio economic / political considerations.

2.1 Existing Legal and Policy Framework

This project examines the prevailing tariff policies and the overall regulatory treatment on the subject of making tariffs economically efficient for all classes of consumers. Various legislative and legal frameworks existing in the country which promote the implementation of ToD as an important DSM tool are:

Electricity Act

According to section 61 of the Electricity Act 2003:

"The appropriate commission shall, subject to the provisions of this Act, specify the terms and conditions for determination of tariff and in doing so, shall be guided by the following namely:

- The principles and methodologies specified by the central commission for determination of tariff applicable to generating companies and transmission licensees
- The generation, transmission and distribution supply of electricity are determined on commercial principles
- The factors, which would encourage competition, efficiency, economical use of the resources, good performance and optimum investments
- Safeguarding of consumers' interest and at the same time, recovery of the cost of electricity in a reasonable manner
- The principles of rewarding efficiency in performance

- Multi Year Tariff principles
- That the tariff progressively reflects the cost of supply of electricity, and also, reduces and eliminates cross-subsidies within the period to be specified by the appropriate commission
- The promotion of co-generation and generation of electricity from renewable sources of energy
- The National electricity policy and tariff policy

Further, under section 166(2) of the Electricity Act, 2003, the FOR was constituted vide Notification dated 16th February, 2005, which is responsible for harmonization, coordination and ensuring uniformity of approach amongst the electricity regulatory commissions across the country, in order to achieve greater regulatory certainty in the electricity sector.

The relevant provision of section 62(3) of the Act which guides the State Electricity Regulatory Commissions (SERC) to incorporate ToD tariff is:

"The appropriate commission shall not, while determining the tariff under this Act, show undue preference to any consumer of electricity but may differentiate according to the consumer's load factor, power factor, voltage and total consumption of electricity during any specified period or the time at which the supply is required or the geographical position of any area, the nature of supply and the purpose for which the supply is required."

Besides, the commission may prescribe certain rules, regulations in this regard. Tariff differentiation may be made in the following cases:

- Consumer's load factor, power factor, voltage and total consumption
- Time of supply
- Geographical location of any area
- Nature of supply and the purpose for which the supply is required

As per Section 62(4)

"No tariff or part of any tariff may ordinarily be amended, more frequently than once in any financial year, except in respect of any changes expressly permitted under the terms of any fuel surcharge formula as may be specified."

National Tariff Policy

The relevant provisions no. (5.4.9) of the National Electricity Policy, defines the tariff components, design principles and its impact are as under:

"The Act requires all consumers to be metered within two years. The SERCs may obtain from the Distribution Licensees their metering plans, approve these, and monitor the same. The SERCs should encourage use of prepaid meters. In the first instance, ToD meters for large consumers with a minimum load of one MVA are also to be encouraged. The SERCs should also put in place independent third-party meter testing arrangements."

NTP 8.4 definition of tariff components and their applicability

Two-part tariffs featuring separate fixed and variable charges and time differentiated tariff shall be introduced on priority for large consumers (say, consumers with demand exceeding 1 MW) within one year. This would also help in flattening the peak and implementing various energy conservation measures."

Draft Amendments to Tariff Policy (January 2016.)

The relevant excerpts from the amendments to tariff policy are mentioned below:

"For consumers who are having suitable meters, the ToD and two-part tariffs shall be introduced before 1st April 2019. This scheme should automatically be extended to other consumers as, or when they get meters suitable for ToD and two-part tariff."

Objectives of the Tariff policy:

- Ensure the availability of electricity to consumers at reasonable and competitive rates
- Ensure the financial viability of the sector and attract investments
- Promote transparency, consistency and predictability in regulatory approaches across jurisdictions and minimize perceptions of regulatory risks
- Promote competition, efficiency in operations and improvement in the quality of supply
- Promote the generation of electricity from Renewable sources
- Promote hydroelectric power generation including Pumped Storage Projects (PSP) to provide adequate peaking reserves, reliable grid operation and integration of variable renewable energy sources
- Evolve a dynamic and robust electricity infrastructure for better consumer services
- Facilitate the supply of adequate and uninterrupted power to all categories of consumers
- Ensure creation of adequate capacity including reserves in generation, transmission and distribution in advance, for the reliability of supply of electricity to consumers

National Electricity Policy

The relevant provision of the National Electricity Policy to encourage metering for ToD is:

"The Act requires all consumers to be metered within two years starting from August 2017. The SERCs may obtain from the distribution licenses their metering plans, approve these, and monitor the same. The SERCs should encourage the use of pre-paid meters. In the first instance, ToD meters for large consumers with a minimum load of 1 MVA are also to be encouraged. The SERCs should also put in place independent third-party meter testing arrangements".

Forum of Regulators (FOR)

The FOR is a statutory body comprising the Chairperson of Central Electricity Regulatory Commission (CERC) and Chairpersons of State Electricity Regulatory Commissions (SERCs). The Chairperson of CERC is the Chairperson of the FOR.

"The Forum shall discharge the following functions, namely:

Analysis of the tariff orders and other orders of central commission and state commissions and compilation of data arising out of the said orders, highlighting, especially the efficiency improvements of the utilities

- Harmonization of regulation in the power sector
- Laying of standards of performance of licensees as required under the Act

- Sharing of information among the members of the Forum on various issues of common interest and also of a common approach
- Undertaking research work in-house or through outsourcing on issues relevant to power sector regulation
- Evolving measures for the protection of interest of consumers and the promotion of efficiency economy and competition in the power sector
- Such other functions as the Central Government may assign to it, from time to time

Based on the above functional mandates, FOR has given the following recommendations in its working group report on metering Issues:

"ToD metering is important while propagating and implementing DSM and achieving energy efficiency. Hence, ToD metering and automatic meter reading system should be introduced wherever it has not already been done."

Further, views of FOR on ToD in its working group on "DSM and Energy Efficiency" are:

ToD Tariffs

As a DSM measure, ToD initiatives aim to change customers' energy-usage behaviour, particularly to alter the times at which electricity is used. 'ToD tariff' is typically used to reduce the demand on the system during peak periods. Several regulatory commissions have recognized the importance of 'time of day' tariffs as a DSM measure and have determined the charges for certain consumer categories under their jurisdiction. Generally, these charges have been introduced for large industrial and commercial category consumers. While it is noted that several states have implemented 'ToD' tariffs, no significant information is available on the impact of these tariffs on the consumption pattern or load curve of the utilities. In many cases, 'ToD' tariffs determined do not factor load profiling to find out the loads which contribute to the peak requirement.

Central Electricity Authority (CEA) Regulations

CEA (installation and operation of meters) regulations, 2006 have stated the following concerning ToD metering:

"Adoption of new technologies - The distribution licensee shall make out a plan for introduction and adoption of new technologies such as pre-paid meters, time of the day meters, automatic remote meter reading system through appropriate communication system with the approval of the appropriate commission or as per the regulations or directions of the appropriate commission or pursuant to the reforms program of the appropriate government."

From the above excerpts, it is understood that as per the Electricity Act, 2003, SERCs have the power of tariff fixation, licensing etc. ToD tariff is already implemented in most states. However, the objective behind ToD implementation is not fully achieved till date and there is a need to take a step forward and move from ToD to ToU tariff regime, which is self-adaptive to meet the desired objectives. ToU tariff shall enable, both the DISCOMs and the consumers, to optimize their power procurement cost without affecting/stressing the grid network.

2.2 Role of Regulatory Commission

According to section 66(178) of the Indian Electricity Act 2003, the development of an electricity market is the responsibility of the regulators. For the same, CERC took an initiative to develop a common platform for electricity trading with its staff paper on July 20, 2006. The CERC also suggested a function diagram of a power exchange. By opening up energy markets, unbundling the electricity services and opening access to electrical networks, the Indian electric sector is in the process of becoming an industry marketplace. In order to achieve lower power prices, improvement of system efficiency and incentives towards innovation, it is deemed that more options and freedom is given to market participants to allow stimulating competition in power trading.

CERC is a statutory body constituted under the provision of the former Electricity Regulatory Commissions Act, 1998(ERC) and continued under Electricity Act, 2003 which has since repealed inter alia the ERC Act, 1998. The main functions of the CERC are to regulate the tariff of generating companies owned or controlled by the Central Government, to regulate the tariff of generating companies other than those owned or controlled by the Central Government, if such generating companies enter into or otherwise have a composite scheme for generation and sale of electricity in more than one state, to regulate the inter-State transmission of energy including tariff of the transmission utilities, to grant licenses for inter-State transmission and trading and to advise the Central Government in the formulation of National Electricity Policy and Tariff Policy.

2.3 Approach for Tariff Determination

The FOR prepares draft regulations and guidelines on tariff methodology and defines implementation parameters which are only guiding in nature. SERCs, however, notify state specific methodologies, regulations, and guidelines, and conduct tariff-filing activities and tariff hearings. Tariff determinations are conducted after public hearings. Tariff orders are issued typically every year, although some states covered in the study such as Assam, Madhya Pradesh and Tamil Nadu follow a policy of conducting tariff filings and determinations once in 3 years, following MYT principles. The distribution annual revenue requirement is calculated considering the forecast cost of energy (as determined by the respective generation tariff orders) and wheeling charges to be paid to transmission (both the national grid and the state grid, as determined by the respective tariff orders). This, along with the allowed losses (which are determined based on the loss targets issued by each SERC), yields the annual revenue requirement (ARR) and the average tariff. Thereafter, retail tariffs for each customer category are determined based on a mix of historic structure of tariffs, government policies, state policies, and the public hearing results.

At the end of each tariff period, an evaluation is conducted (a true-up exercise) to consider changes in the costs of each generation, transmission and distribution utility as well as the market structure and the sales during the tariff period, and certain revisions to costs are allowed and included in the subsequent determination of ARR. Accordingly, the transmission and distribution utilities are allowed to claim additional costs and subsequent customer tariffs. These utilities and regulators get an opportunity to claw back any unspent allowances in the previous ARR and return such credits to customers through the subsequent determination of the ARR. The entire process is depicted below:

Figure 2-1: Approach for Tariff Determination

The distribution entities in states operate independently with limited autonomy while privatization of DISCOM's is still in progress. It may be concluded that tariff determination in Indian states follows a methodology that enables the costs of supply to be evaluated transparently based on regulations and methodologies.

2.4 Tariff Structures in India

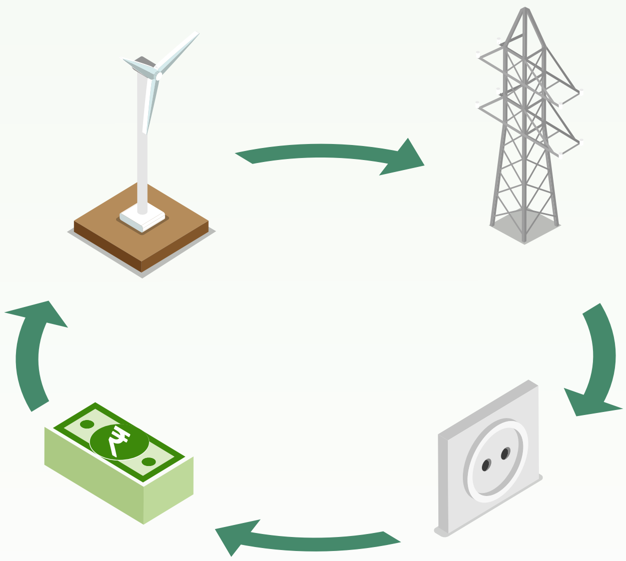
Tariff refers to the amount of money the consumer has to pay for making the power available to them at their homes. Tariff system takes into account various factors to calculate the total cost of the electricity. The electrical power system mainly consists of generation, transmission and distribution.

For the generation of electrical power, India has many PSUs and private-owned generating stations. The inter-state transmission of electricity is mainly carried out by the central government body, Power Grid Corporation of India Limited (PGCIL) while intra-state transmission is handled by state owned transmission corporations in each state. To facilitate this process, India is divided into five regions: Northern, Southern, Eastern, Western and North-Eastern regions. Further within every state, a State Load Dispatch Centre (SLDC) is formed. The distribution system is carried out by distribution companies (DISCOM's), which are both private and public owned.

The terms and conditions for tariff setting in India are generally guided by the principles contained in the Electricity Act 2003. Though the legislation under the act provides for the differentiation of tariffs, even among the same category of consumers (according to, e.g., basis of the load factor, power factor, and even the time at which supply is required), the tariff currently set by State Commissions is mostly at fixed rates (barring a few instances where ToD tariff is being implemented for bulk consumers). The main reason for this is a lack of information and communication technology in the Indian distribution network for capturing consumption data in near real-time. All this is set to change with the implementation of smart grid technologies in the Indian distribution sector.

The GoI formulated the tariff policy in January 2006 under Section 3 (1) of the Electricity Act 2003 with the following objectives:

- Ensure the availability of electricity to consumers at reasonable and competitive rates
- Ensure the financial viability of the sector and attract investments
- Promote transparency, consistency, and predictability in regulatory approaches across jurisdictions and minimize perceptions of regulatory risks
- Promote competition, efficiency in operations, and improvement in the quality of supply



Balancing these conflicting cost/viability objectives, while implementing dynamic rates to increase power quality is the key challenge. With the present distribution system operating with average AT&C losses of around 28%, there is ample scope for the DISCOM's to balance the conflicting objectives of providing electricity at competitive rates while ensuring the financial viability of the sector making operations more efficient. With the introduction of dynamic pricing, the DISCOM's can avert costly peak power purchases and reduce their power purchase costs.

Under the provisions of the Electricity Act, the Central Government established the FOR which would, inter alia, facilitate interstate consistency in approach, especially in the area of distribution.

The distribution tariff provides for recovery of prudent cost incurred in licensed wheeling (i.e., the creation, maintenance, upkeep, renewal, and development, including replacement and expansion of the wire network and supply of the distribution licensee plus Return on Equity (RoE) at the prescribed level of performance).

SERCs determine the allowable tariffs and operating and cost parameter norms for a tariff period after considering past operational and financial performance (Tariff order).

The ARR for the generating companies, transmission companies, and the distribution companies forms the primary basis for recovery of charges from consumers through retail tariffs. The ARR for a DISCOM is broadly comprised of an assessment of power purchase cost (fixed and variable cost) for existing stations and future capacities, power purchase requirements, inter-state and inter-regional transmission charges to be paid for transmission system usage, Load Despatch Centre charges, Operation and Maintenance expenses, cost for depreciation of assets of the distribution system, interest and finance charges on project loans, return on equity, interest on working capital, interest on the consumer security deposit, bad and doubtful debts, regulatory commission fees, miscellaneous income on account of rent or charges imposed on consumers, etc. which are determined by the DISCOM following the prevailing tariff regulations of the SERC.

2.5 Tariff Structures in Gujarat

In order to simplify the tariff structure for residential customers, on 24th April 2019, GERC has reduced the number of slabs from 5 to 4 by merging 100-200 units and 200-250 units' slabs into one slab of 100-250 units. Due to this, there is a reduction of 10 Paise/unit in energy charge for consumption falling under early slab 200 to 250 units. This charge is applicable to consumers of both states run DISCOMs and the private DISCOM in Surat distribution area. In Ahmedabad and Gandhinagar service areas, 3 slabs have already been rationalized. Further, the energy charges for agricultural customers using electricity for lift irrigation purposes have been reduced by 30 Paise/unit. For the for Government owned DISCOMs, the base Power Purchase Cost (PPC) has been hiked from Rs. 4.22 per unit for 2018-19 to Rs. 4.32/ unit for 2019-20, while base Fuel Price & Power Purchase Adjustment (FPPPA) has been revised from Rs. 1.49 per unit to Rs. 1.61 per unit. In case of Torrent Power Ltd. (TPL), base PPC is hiked from rupees 4.66 per unit to rupees 4.80 per unit and FPPPA from Rs. 1.23 to Rs. 1.38.

2.6 Tariff Cost Components

A DISCOM's power purchase cost (PPC) constitutes 70-80% of the total tariff chargeable to consumers. The bulk of this PPC is contracted through long-term contracts (PPA's) based on two-part tariffs, whereby capacity (fixed) charges are a utility's fixed obligations and need to be serviced irrespective of purchase of power by the utility, which is largely dependent on the demand of consumers.

In addition to the above, the utilities also have their own fixed costs relating to retail supply and wheeling costs. Currently, distribution tariffs are largely skewed towards the recovery of a utility's Aggregate Revenue Requirement (comprising of both fixed and variable charges), through a levy of per unit consumption-based energy charges, with a small component being recovered through a fixed or demand charge (based on Rs per Kilowatt per month) irrespective of consumption.

As a major part of the utility's fixed cost is recovered through variable energy charges dependent on sales, which could vary to the extent of 50% due to seasonal or weather conditions (sales are maximum in summer season and minimum in winter season), there is always a mismatch between the real fixed cost liability versus the amount collected thereof through tariff.

Consumer Tariff

Let us now discuss the tariff of electricity for the consumer i.e., the cost a consumer pays to the DISCOM's.
The total cost levied on the consumer is divided into three parts usually referred to as a three-part tariff system.

Total cost of electrical energy

Fixed Cost
Fixed cost independent of the maximum demand and energy consumed. This cost considers the cost of land, labour, interest on capital cost, depreciation, etc.

+

Semi Fixed Cost
Constant which when multiplied by maximum K.W. demand gives the semi-fixed cost. This considers the size of the power plant as maximum demand determines the size of the power plant.

+

Variable Cost
Constant which when multiplied by actual energy consumed KW-h gives the running cost, which considers the cost of fuel consumed in producing power.

Fuel cost, PPA charges and other applicable charges, if any, shall be in accordance with the formula approved by the ERC from time to time.

Thus, the total amount paid by the consumer depends on its maximum demand, actual energy consumed plus some constant sum of money.

Major tariff-related issues in this country are the recovery mismatch between variable and fixed costs of the DISCOM's through retail tariffs. In order to ensure that fixed costs are largely recovered through the fixed component of the tariff, it is important that the energy charges and fixed or contract demand charges are progressively adjusted with the fixed component being increased with a corresponding reduction in energy charges. Also, an increase in fixed charges shall act as a deterrent to theft of electricity as the incentive to manipulate consumption will progressively lower down with reducing variable energy charges.

There are four components that make up an electricity bill and their influences are as follows:

01

Power Procurement Costs

The cost to generate the power which is driven by the overall mix of generation, the cost of fuel for each generation source, the efficiency of those generators, and the capital and operational cost of each generator. In addition, this component also accounts for (technical) losses incurred in transmission and distribution.

02

Transmission charges

The cost of moving high-voltage power from the generators over the inter-state and intra-state lines to the DISCOMs infrastructure, is driven by the cost of building and maintaining these lines as India's need for electricity grows.

03 Distribution charges

The cost to distribute and transform to lower voltages, the power from the transmission lines to individual customers which is driven by the cost to build and maintain the infrastructure to deliver power and comply with renewable procurement obligations from each state.

04 Cross-subsidy charges

Cost for commercial and industrial customers to offset the total delivered cost of electricity to domestic customers which are driven by political matters in each state.

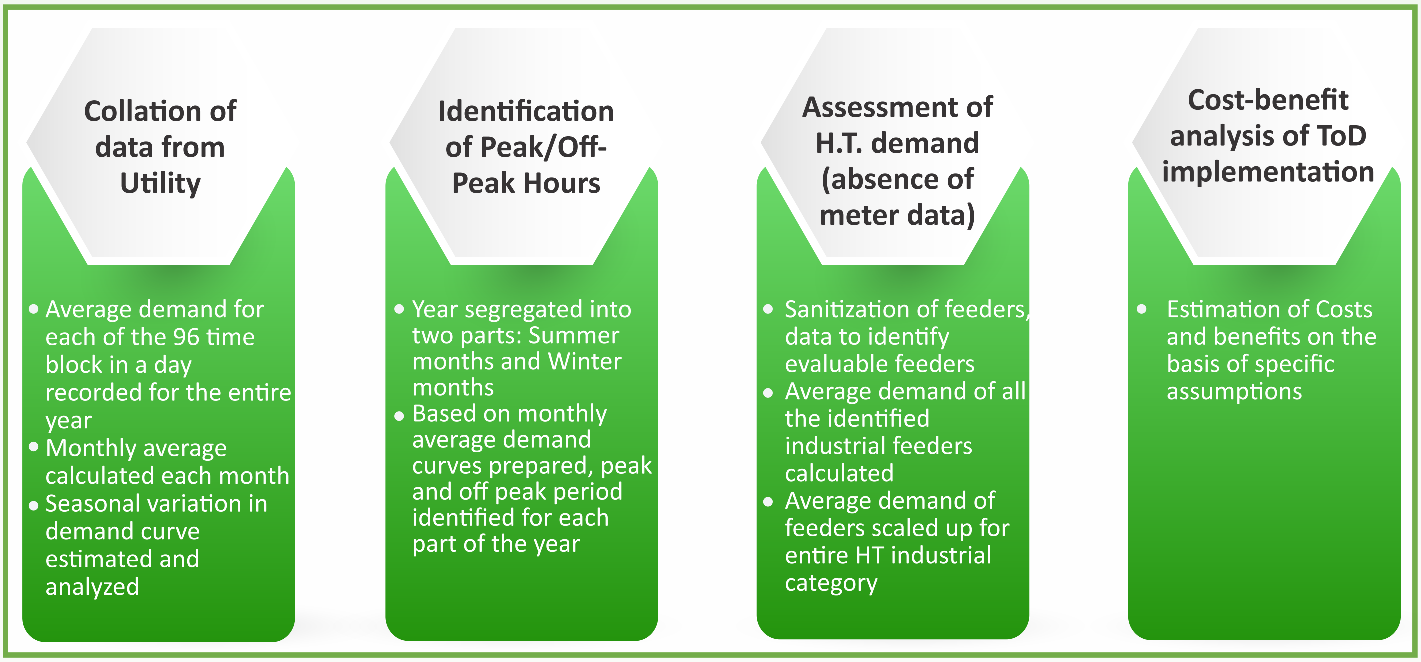


Figure 2-2: Estimation of tariff

2.7 Existing Time of Day (ToD) Tariff Scenarios

Usually, during the day, the power demand is very high, and the supply remains the same. Consumers are discouraged to use excess energy during peak demand periods by making the cost high. Contrary to that during night time, demand is less compared to supply, and hence consumers are encouraged to consume power by providing it at a cheaper rate. All these are done to make/keep the power system stable. The ToD tariff serves as a DSM tool in the context of peak demand deficit scenario in India.

The SERCs could follow a systematic approach towards setting the ToD tariff outlined as under:

- Identification of system peak period and off-peak period, through the analysis of the system load curve to devise the ToD structure (time bands)
- Proper load profiling of the consumer categories for which ToD is slated to be introduced, through the installation of proper meters
- Estimation of the load shifting through the use of different tariff differentials through a study on sample consumers
- Introducing an initial ToD tariff which could be set described as an under computation/initial ToD tariff level that makes the revenue estimate the same for both i.e., under existing base tariffs and under ToD tariffs. Since the calculation of these tariffs is dependent upon the consumption during each of the time periods, an assumption shall have to be made to start with on the number of consumers who would likely opt for ToD tariff. In computing ToD tariff, off-peak charges are set as a certain percentage of the base tariff. The charge for consumption during peak period can then be set at a level that fully recovers the revenue from base tariffs.

- Analysis of the impact of the ToD tariff is to be done by the utility through the load research on the consumer categories for which ToD is introduced after one year of introduction of ToD tariff
- Modification of the ToD tariff/structure in terms of the following:

Time bands | Peak and off-peak tariff | Optional/compulsory

The above process is an iterative process which needs to be followed by the SERCs from time to time. During the entire process of setting up the ToD tariff, the utilities should be directed to make efforts to educate consumers about the benefits of ToD tariff and the potential savings resulting through the shifting of the load from peak to off-peak period.

Introduction of ToD tariff has helped in developing pricing mechanisms for setting up generation plants which could meet the system peaking power requirements. The ToD tariff as applicable for major consumer categories in various Indian States/Union Territories (UTs) is summarized in the below table:

S. No.	State	Time of Day (ToD) Tariff							
		Implementa-tion Status	Applicable Category	Months	Normal Hours	Peak Hours	Surcharge on Energy	Off-Peak Hours	Rebate on Energy
1.	Assam	Yes	Industries, Tea, Coffee and Rubber, Oil and Coal		0600 hrs to 1700 hrs	1700 hrs to 2200 hrs	(+)1.5 Rs per unit	2200 hrs to 0600 hrs	(-) 1.5 Rs per unit
2.	Bihar	Yes	All H.T. consumers		0500 hrs to 1700 hrs	1700 hrs to 2300 hrs	120% of the average rate of energy charges	2300 hrs to 0500 hrs	85% of the average rate of energy charges
3.	Chhattisgarh	Yes	HV-2 (Mines), HV-3 (Other Industrial and General Purpose Non-Industrial), and HV-4 (Steel Industries) tariff category		0500 hrs to 1800 hrs	1800 hrs to 2300 hrs	120% of the normal rate of Energy Charge	2300 hrs to 0500 hrs (next day)	75% of the normal rate of Energy Charge
4.	Gujarat	Yes	HTTP 1, 2 and 3		1100 hrs to 1800 hrs	0700 hrs to 1100 hrs and 1800 to 2200 hrs	Rs. 0.45-0.85/unit (based on contract demand)	2200 hrs - 0600 hrs (next day)	40 paise (only for HTP 1)
5.	Himachal Pradesh	No							
6.	Jharkhand	Yes	All the consumers drawing power at a voltage level at 6.6 kV and above except Domestic-HT consumers		1000 hrs to 1800 hrs	0600 hrs to 1000 hrs & 1800 hrs to 2200 hrs	120% of the average rate of energy charge	2200 hrs to 0600 hrs (next day)	85% of the average rate of energy charge.

S. No.	State	Time of Day (ToD) Tariff							
		Implementa-tion Status	Applicable Category	Months	Normal Hours	Peak Hours	Surcharge on Energy	Off-Peak Hours	Rebate on Energy
7.	Karnataka	Yes	areas under City Municipal Corporations, hospital and consumers with contract the demand of less than 500 KVA;		1000 hrs to 1800 hrs	0600 hrs to 1000 hrs and 1800 hrs to 2200 hrs	(+) 100 Paise/unit	2200 hrs to 0600 hrs	(-) 100 Paise/unit
8.	Kerala	Yes	All Industrial consumers have connected load above 20 kW, L.T. domestic consumers (3 Phase) having monthly consumption above 500 units and all EHT consumers (except Railway Traction) and all H.T. consumers.		0600 hrs to 1800 hrs	1800 hrs to 2200 hrs	150%	2200 to 0600 hrs	75%
9.	Madhya Pradesh	Yes			0600 hrs to 1800 hrs	1800 hrs to 2200 hrs	No surcharge	2200 hrs to 0600 hrs	20 % of Normal rate of Energy Charge as Rebate
10.	Maharashtra	Yes	L.T. - 2 (Commercial), L.T. - 3 (Industry), L.T. - 4 (Public Water Works), LT IX (A) - Public Services - Govt Hospitals and Educational Institutions, LT IX (B) - Public Services - Others, LT XI- Electric Vehicle Charging Stations, HT I (Industry), HT II (Commercial), HT IV - Public Water Works (PWW) and Sewage Treatment Plants, HT VIII - Electric Vehicle Charging Stations			0900 hrs to 1200 hrs	Energy Charge + Rs. 0.5	2200 hrs to 0600 hrs (next day)	Energy Charge - Rs 0.75
						1800 hrs to 2200 hrs	Energy Charge + Rs 1		

S. No.	State	Time of Day (ToD) Tariff							
		Implementation Status	Applicable Category	Months	Normal Hours	Peak Hours	Surcharge on Energy	Off-Peak Hours	Rebate on Energy
11.	Orissa	Yes	Three-phase consumers with static meters are allowed to avail ToD rebate excluding Public. Lighting and emergency supply to Captive Generating Plants (CGP)					0000 hrs to 0600 hours (Next day)	20 paise/unit
12.	Tamil Nadu	Yes	H.T. Consumers			0600 - 0900 hrs and 1800 hrs to 2100 hrs	20%	2200 hrs to 0500 hrs (next day)	5%
13.	Tripura	Yes							
14.	Uttarkhand	Yes	L.T. industry with a load of more than 25 kW and H.T. industry	Winters 01.10 to 31.03	0900 hrs to 1800 hrs	0600 hrs to 0900 hrs and 1800 hrs to 2200 hrs	1.5x for LT, 1.65x for HT (up to 40% load factor) and 1.5x for HT (above 40% load factor)	2200 hrs to 0600 hrs	0.85x for L.T. and HT
				Summers 01.04 to 30.09	0700 hrs to 1800 hrs	1800 hrs to 2300 hrs		2300 hrs to 0700 hrs	
15.	Uttar Pradesh	Yes	LMV-3 (Public Lamps)			0600-1800 hrs	20%		
			LMV-6 (Small and Medium Power)	Summers 01.04 to 30.09	1100 hrs to 1700 hrs and 2300 hrs to 0500 hrs (next day)	1700 hrs to 2300 hrs	15% of energy charges	0500 hrs to 1100 hrs	15% of energy charges
				Winters 01.10 to 31.03	0500 hrs to 1700 hrs	1700 hrs to 2300 hrs	15% of energy charges	2300 hrs to 0500 hrs	15% of energy charges
			LMV - 11 (E.V. Charging)	Summers 01.04 to 30.09	1100 hrs to 1700 hrs and 2300 hrs to 0500 hrs (next day)	1700 hrs to 2300 hrs	15% of energy charges	0500 hrs to 1100 hrs	15% of energy charges
				Winters 01.10 to 31.03	0500 hrs to 1700 hrs	1700 hrs to 2300 hrs	15% of energy charges	2300 hrs to 0500 hrs	15% of energy charges

S. No.	State	Time of Day (ToD) Tariff							
		Implementa-tion Status	Applicable Category	Months	Normal Hours	Peak Hours	Surcharge on Energy	Off-Peak Hours	Rebate on Energy
			HV-2 (Large and Heavy Power)	Summers 01.04 to 30.09	1100 - 1700 hrs and 2300 - 0500 hrs (next day)	1700 hrs to 2300 hrs	15% of energy charges	0500 hrs to 1100 hrs	15% of energy charges
				Winters 01.10 to 31.03	0500 hrs to 1700 hrs	1700 hrs to 2300 hrs	15% of energy charges	2300 hrs to 0500 hrs	15% of energy charges
16.	West Bengal	Yes/Optional	L.T. - CM 2 (Small Industries)	Prepaid	0600 hrs to 1700 hrs	1700 hrs to 2300 hrs	1.1x of normal tariff	2300 hrs to 0600 hrs (next day	0.9x of normal tariff
			L.T. - CMR (Commercial Rural)	Normal	0600 hrs to 1700 hrs	1700 hrs to 2300 hrs	1.2x of normal tariff	2300 hrs to 0600 hrs (next day	0.85x of normal tariff
			L.T. - CMU (Commercial Urban)						
			L.T. - Irrigation Pump		0600 hrs to 1700 hrs	1700 hrs to 2300 hrs	2x of normal tariff	2300 hrs to 0600 hrs (next day	0.65x of normal tariff
			L.T. - Commercial Plantation	Prepaid	0600 hrs to 1700 hrs	1700 hrs to 2300 hrs	1.2x of normal tariff	2300 hrs to 0600 hrs (next day)	0.95x of normal tariff
		Optional	L.T. - Industry (Rural)		0600 hrs to 1700 hrs	1700 hrs to 2300 hrs	1.2x of normal tariff	2300 hrs to 0600 hrs (next day)	0.75x of normal tariff
			L.T. - Industry (Urban)		0600 hrs to 1700 hrs	1700 hrs to 2300 hrs	1.2x of normal tariff	2300 hrs to 0600 hrs (next day)	0.75x of normal tariff
			HT Industries (11 kV/33 kV/220 kV/400 kV)	Summer, Winter and Monsoon	0600 hrs to 1700 hrs	1700 hrs to 2300 hrs	1.18x of normal tariff	2300 hrs to 0600 hrs (next day)	0.73x of normal tariff
			Commercial		0600 hrs to 1700 hrs	1700 hrs to 2300 hrs	1.5x of normal tariff	2300 hrs to 0600 hrs (next day)	0.6x of normal tariff
17.	Andhra Pradesh	Yes	Applicable to all H.T. consumers			0600 hrs to 1000 hrs and 1800 hrs to 2200 hrs	1.16x of energy charge at respective kV level	2200 hrs to 0600 hrs	0.85x of energy charge at respective kV level
18.	Delhi	Yes	all consumers (other than Domestic) whose sanctioned load/MDI (whichever is higher) is 10kW/11kVA and above	May - September		1400 hrs to 1700 hrs and 2200 hrs to 0100 hrs	20%	0400 hrs to 1000 hrs	20%

S. No.	State	Time of Day (ToD) Tariff							
		Implementation Status	Applicable Category	Months	Normal Hours	Peak Hours	Surcharge on Energy	Off-Peak Hours	Rebate on Energy
19.	Haryana	Yes		Oct-March	0530 hrs to 1830 hrs	1830 hrs to 2200 hrs	19% premium	2200 hrs to 0530 hrs	15 % rebate
20.	Jammu & Kashmir	No							
21.	Punjab	Yes	Applicable to NRS/BS consumers with sanctioned Contract Demand exceeding 100 kVA, all LC/MS consumers (including Rural Water Supply Schemes & Compost/Solid Waste Management Plants) and E.V. charging stations	April 1 to May 31	0600 hrs to 1800 hrs			2200 hrs to 0600 hrs (next day	Normal Tariff* minus Rs.1.25/kVAh
					1800 hrs to 2200 hrs				
				June 1 to September 30 October 1 to March 31	0600 hrs to 1800 hrs	1800 hrs to 2200 hrs	Normal Tariff plus Rs. 2.00/kVAh	2200 hrs to 0530 hrs	15 % rebate
					2200 hrs to 0600 hrs (next day)0600 hrs to 1800 hrs			2200 hrs to 0600 hrs (next day)	Normal Tariff minus Rs. 1.25/kVAh
					1800 hrs to 2200 hrs				
22.	Rajasthan	No							
23.	Manipur	No							
24.	Meghalaya	Yes	HT/EHT Industrial		0600 hrs to 1700 hrs	1700 hrs to 2300 hrs	1.1x of normal tariff	2300 hrs to 0600 hrs (night off-peak)	0.75x of Normal tariff
25.	Arunachal Pradesh	No							
26.	Tamil Nadu	Yes	H.T. IA Industrial consumers			0600 hrs to 0900 hrs and from 1800 hrs to 2100 hrs	20% additional charge on energy charges	2200 hrs to 0500 hrs (next day)	5% rebate on energy charges
27.	Telangana	Yes	H.T. Consumers		0600 hrs to 1800 hrs	0600 hrs to 1000 hrs and 1800 hrs to 2200 hrs	1.15x of normal tariff	2200 hrs to 0600 hrs	0.85x of normal tariff
28.	Odisha	Yes	Three-phase consumers with static meters					0000 hrs to 0600 hrs	Rebate of 20 p per unit

S. No.	State	Time of Day (ToD) Tariff							
		Implementation Status	Applicable Category	Months	Normal Hours	Peak Hours	Surcharge on Energy	Off-Peak Hours	Rebate on Energy
29.	Ladakh	No							
30.	Daman and Diu	Yes			0600 hrs to 1800 hrs	Evening Peak - 1800 hrs to 2200 hrs	120% of the expected rate of energy charges	2200 hrs to 0600 hrs (next day)	90% of the average rate of energy charges
31.	Goa	Yes			0700 hrs to 1800 hrs	1800 hrs to 2300 hrs	120% of the average rate of energy charges	2300 hrs to 0700 hrs (next day)	90% of the average rate of energy charges
32.	Dadra and Nagar Haveli	No							
33.	Chandigarh	Yes	HT/EHT consumers		0600 hrs to 1800 hrs	1800 hrs to 2200 hrs	120% of the expected rate of energy charges	2200 hrs to 0600 hrs (next day)	90% of the average rate of energy charges
34.	Nagaland	No							
35.	Mizoram	No							
36.	Sikkim	No							
37.	Andaman & Nicobar Islands	Yes							
38.	Puducherry	Yes	HT/EHT consumers		0600 hrs to 1800 hrs	1800 hrs to 2200 hrs	120% of the average rate of energy charges	2200 hrs to 0600 hrs (next day)	90% of the average rate of energy charges

Table 2-1: State-wise ToD Tariff Summary

2.8 Framework for ToD Impact Analysis

The process of setting the ToD tariff is iterative, which requires periodic monitoring to ensure the effectiveness of its implementation. The following steps are suggested for monitoring the impact of ToD tariffs:

01 Prerequisites for the study, it is emphasized that the same set of consumers should be monitored before and after the implementation of ToD tariff for proper monitoring

02 The utilities should be directed to conduct load curve study for the consumer categories for which ToD has to be introduced, before the introduction of ToD tariff on a periodic basis and after the introduction of ToD Tariff

As seen above, most of the states have introduced ToD tariff as a means of DSM measures and load factor improvement. The SERCs have followed diverse mechanisms in designing the ToD tariff, with different tiers, different periods within a day, and different rates applicable to these periods. Hence it is pertinent to analyse the relationship between the ToD tariff and the load factor as a measure of the impact analysis for ToD as a DSM measure.

In this study, the state of Gujarat is being considered for analysing the impact of ToD and how the state DISCOMs should move in due course of time to be able to tackle the market interventions i.e. large-scale integration of the rooftop solar system, EV's and ESS. Existing ToD duration are as follows:

Peak hours

07:00 to 11:00 hours and
18:00 to 22:00 hours

Off-peak hours

22:00 to 06:00 hours
(next day)

To begin with, energy schedule data of UGVCL supply area, in Gujarat, for 1 year (January-December, 2019) is compiled and worked upon. Load deviation from the average load is calculated for each time slot. Seasonal average load deviation curves (slot wise) are plotted to better analyse the impact of ToD tariff on load pattern. The seasonal, slot wise, load deviation curves are discussed below:

2.8.1 Winter Season (Nov.-Feb., 2019)

From the above load deviation curve, it is observed that peak load duration is from 08:30 to 13:30 hours and from 16:00 to 19:00 hours. No major change in off-peak hours, as compared to existing duration, is observed during the winter season. However, peak duration can further be divided to have peak tariff (from 08:30 to 13:30 hours) and mid-peak tariff (16:00 to 19:00 hours). It is therefore recommended to shift the peak hours as per the above observation, to flatten the load curve and reduce stress on distribution assets.

Figure 2-3: Standard Deviation Curve – Winter Season

2.8.2 Summer Season (March – June 2019)

During the summer season, overall average consumption is high, thereby resulting in reduced peak deviation as compared with that in winters. Here, the peak is from 09:00 to 14:00 hours followed by mid-peak from 15:30 to 18:30 hours. Further, the off-peak duration is from 01:30 to 06:00 hours rather than from 22:00 to 06:00 hours. The reduction in off-peak hours during the summer season can mostly be attributed to high air conditioning load.

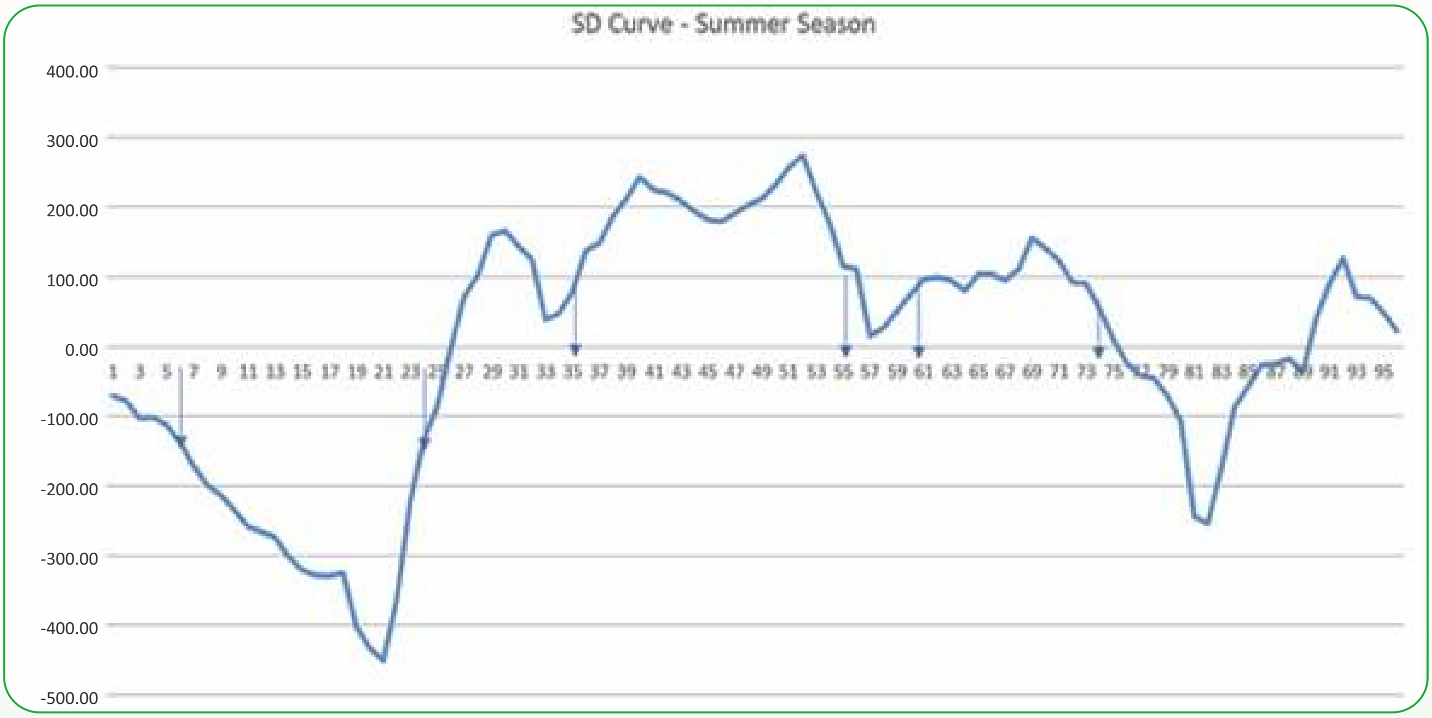


Figure 2-4: Standard Deviation Curve – Summer Season

2.8.3 Monsoon Season (July - October 2019)

During monsoon, the load deviation curve is mostly flat throughout the day time. Here, the peak could be considered to occur from 09:30 to 18:30 hours while off-peak duration is from 23:30 to 06:30 hours. The peak hours as per tariff order of UGVCL do not match the actual peak duration.

Figure 2-5: Standard Deviation Curve – Monsoon Season

From the above load deviation curves, it is seen that seasonal peak and off-peak hours vary from the existing tariff schedule, which does not take into account the variations in load pattern due to seasonal changes. Thus, to have efficient tariff and to better achieve the objective of load flattening, it is recommended to move from fixed ToD to seasonal ToD tariff as a first step. Gradually, the DISCOM's should then move to monthly ToD, that too separate for weekend/holiday and weekday. Before the implementation of the above recommendation, it is advisable to further analyse the load pattern of past 4-5 years for a better understanding of seasonal/monthly variations in peak and off-peak hours.

Once consumers start realising the benefits of ToU and begin to adopt this tariff regime on large scale, the tariff design can further be evolved to incorporate real-time parameters, such as wholesale market price, network congestion, consumer category contribution to peak/off-peak etc., and thereby making ToU tariff more robust and efficient.

3. INTERNATIONAL CASE STUDIES OF DYNAMIC TARIFFS

Different countries have varying regulations on dynamic tariffs. This section provides international case studies, concepts, learnings and analysis of the best practices from the implementation of dynamic tariffs in different parts of the world. The key drivers for the adoption of dynamic tariffs in the power sector are discussed along with an attempt to provide an understanding of the diverse dynamics of design and implementation of dynamic tariffs. Based on this assessment, the key design and implementation choices related to dynamic tariff design are identified and discussed to draw lessons for its application in the state of Gujarat. This section also identifies key lessons and implementation barriers that should be taken into account when introducing dynamic tariff implementation.

3.1 Tariff Structure in Selected Countries

There are two types of retail tariffs namely, static tariff and dynamic tariff. A static tariff is a flat rate that does not vary in time. That is, the consumer pays the same price per unit at all times of the day. In this type of tariff, no time-dependent economic signal is sent to the end consumer.

Unlike static tariff, a dynamic tariff varies in time to provide an economic signal that incentivizes consumers to change their consumption patterns to reach an optimal socio-economic use of electricity.

A tariff can incorporate a dynamic (time-varying) element by altering one or a combination of six different dimensions of the tariff: the number of pricing periods, the timing of pricing periods, price level, notification, incentive and combination. As a result, there are different types of dynamic tariff such as ToU, critical peak pricing, peak time rebate and real-time pricing.

In a ToD tariff, the day is broken into time blocks and a tariff is set for a period of time (e.g., revised annually or seasonally) for each block. A simple example is two blocks: peak hours (with higher prices) and off-peak hours (with lower prices).

A critical peak pricing (CPP) tariff is one in which the customer pays a higher price for specific days during the year when the wholesale energy prices are the highest or the grid is exceptionally constrained. There are three common variations of this approach:

- A static CPP is one where the critical days/hours are fixed
- In a variable CPP (CPP-V) the peak days/hours are not fixed, and the customers are notified of the application of critical peak price at a short notice (e.g., day ahead)
- If the price level during the critical days/hours also varies then it is called variable peak pricing (VPP)
- In the peak time rebate approach, instead of increasing the price at a peak, the customer is provided with an incentive in the form of a rebate to reduce their load during peak hours

The most sophisticated type of dynamic tariff is real-time pricing. In this approach, the price offered by the retail customer is linked with the hourly wholesale price. Therefore, the price varies every hour (or the time interval at which the wholesale market clears) for the customer. The Table below captures some key indicators of ToU tariffs and International case studies of country-specific adoption of ToU tariff structure.

Key parameters	Description
Countries where ToU tariffs are applied	17 European countries (including Sweden, Germany, Finland, France, Germany), USA
Types of ToU adopted	• **Static ToU tariffs:** Day/night ToU differentiation (this is very common in Europe; e.g., in Italy, all low-voltage consumers are mandatorily exposed to ToU pricing if they do not choose a supplier in the liberalised market). • **Dynamic real-time pricing:** Estonia, Romania, Spain Sweden and the U.K. applied such tariffs (e.g., between 25 % and 50 % of all households in Estonia and Spain incur their supply charges based on hourly pricing). • **Other dynamic pricing methods** apply in Denmark, Norway and Sweden, where electricity consumers incur spot-market-based pricing through the monthly average wholesale price. • **Critical peak pricing:** This is applied to a smaller extent in the U.K., Lithuania, Portugal, Romania and France (ACER, 2016).
Services provided	• Implicit demand response (participation of consumers in the energy transition). • Consumer's benefits, such as electricity bill savings. • Cost-reflective tariffs are benefiting suppliers. • Increased competition among suppliers in the retail market, as a driver for innovative business models.

Table 3-1: Key indicators of ToU tariffs and International case studies

3.1.1 Finnish Dynamic Pricing Structure

In Finland, consumers have the option of choosing a dynamic pricing tariff structure for electricity. Retail suppliers offer dynamic pricing to consumers who chose to do so in the liberalised market (as opposed to regulated markets). The price is determined based on the Nord pool spot price for the price area of Finland. The customer, who chooses a dynamic price tariff structure, pays the hourly price, retailer's premium and a monthly fixed fee to the retailer with which they opted to enter into a contract with the retailer.

By the end of 2017, approximately 9 % (about 3,40,000) of customers had opted for this tariff structure. The customer can check electricity prices for each hour of the succeeding day from the chosen retailer's website. The published prices are based on the spot market timetable. Therefore, the prices for the next day (24 hours), starting from midnight, are finalised at around 2 pm of D-1 (day ahead). The price that the customer pays for a particular time slot depends on the time of consumption. This customer requires hourly metering, which is the case for all consumers in Finland.

Customers can see their hourly consumption one day after delivery on their local distribution system operator's (DSO's) web portal or application.

Apart from the above pricing structure, some retailers offer price-optimised heating hours, depending on weather conditions and actual heating capacity. This enables the current heating system to operate efficiently and helps to save up to 15% on heating expenses.

3.1.2 New Market Design in the European Union

While there is significant variation in the penetration of ToU tariffs among electricity consumers in the European Union, the new draft electricity directive and electricity regulation (being part of the clean energy for all Europeans legislative package) sets new rules for consumers throughout the union. For example, via the new market design rules, every consumer in the European Union would be able to offer demand response and to receive remuneration, directly or through aggregators. Dynamic electricity price contracts reflecting the changing prices on the day-ahead or intraday markets would allow consumers to respond to price signals and actively manage their consumption. As such, consumers would be able to freely choose and change suppliers or aggregators, while also being entitled to a dynamic price contract. Additionally, the new framework foresees the entitlement of every consumer to request a smart meter equipped with a minimum set of functionalities, and it improves pre-existing rules on the consumers' ability to share their data with suppliers and service providers by clarifying the role of the parties responsible for data management and by setting a common European data format.

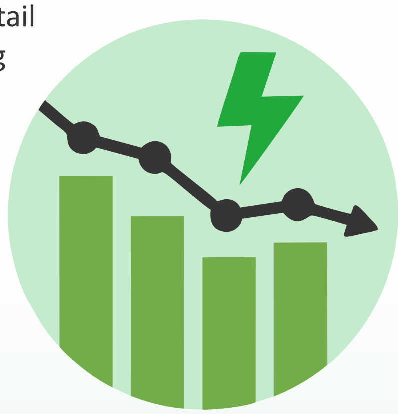
3.1.3 Real-Time Pricing in Illinois (U.S.)

In a demand response programme in Illinois, launched by Con Ed, the local utility in Illinois, consumers were given the opportunity to participate in an hourly pricing programme in which electricity prices were reflective of the electricity load (i.e., prices were low during the low demand period and prices were high during the high demand hours). An example of demand shifting by consumers includes pre-cooling the house in early morning hours, when prices are lower, and setting the cooling systems to an idle mode when prices are higher. The programme has allowed consumers to save about 15 % on their electricity bills (USD 15 million from 2007 to 2016).

3.1.4 Reducing Renewable Energy Curtailment in Arizona (U.S.)

The Arizona Public Service Company (APS), the utility in Arizona, experiences demand peaks in summer due to increased space cooling use. However, with more moderate temperatures during the remaining nine months of the year, the utility has excess renewable energy that is often curtailed. The electricity prices during some time intervals in the daytime turn negative on account of solar generation exceeding demand.

APS recently proposed a new programme that aims to reduce the need to curtail solar energy during the periods of negative pricing. Instead of curtailing renewable production, APS will pay customers to use energy to keep the renewables online and maintain the load curve flat to the extent feasible. This is similar to load shifting. However, since it is less predictable in terms of the on-peak/off-peak price arbitrage (due to the intermittency of the renewables), the APS programme will be specific to the dispatchable non-essential loads. For example, EVs with smart charging could offtake the free or negatively priced energy when the reverse demand response is activated, and smart appliances (e.g., dishwashers, washing machines, dryers, water pumps, water heaters etc.) could be set to run during these times as well.



3.2 International Best Practices on the Applications of Dynamic Tariffs

Different implementations of dynamic tariff in various countries and provide a synthesized summary of the practices from a dynamic tariff design perspective for stakeholders to consider. Further, key implementation challenges and pre-requisites for the successful implementation of dynamic tariff are also discussed.

3.2.1 International Case Studies

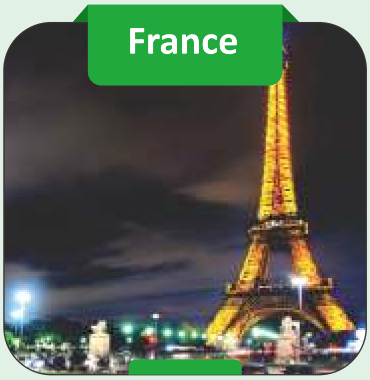
International practices of 16 countries (including states) were studied. The cases and the type of tariff they apply as well as the regulatory intervention and competition in the retail market are presented in the below Table. It is important to note that the focus is on the household level retail customers which are often seen as the most difficult customer from the retailer's perspective for designing dynamic tariffs.

Region	Country	Dynamic Tariff Type	Retail Competition
Europe	Estonia	RTP	Yes
	France	ToU	Yes
	Finland	RTP	Yes
	Great Britain	RTP	Yes
	Norway	RTP	Yes
	Portugal	ToU	Yes
	Sweden	RTP	Yes
USA & LAC	California	ToU – CPR	Suspended
	Connecticut	ToU	Yes
	New York	ToU	Yes
	Brazil	ToU	No
Australia	Victoria	ToU	Yes
	Queensland	ToU	Yes
	NSW	ToU	Yes
Asia	Japan	ToU	Yes
Africa	South Africa	ToU	No

Table 3-2: Summary of Case Studies

As can be seen in Table 3-2, the two common types of dynamic tariff are the ToU tariff and the real-time pricing (RTP), where ToU tariff is the dominant one. However, there are variations in implementation; i.e., not all ToUs are designed the same way. Moreover, a distinction can be made between those countries which have applied dynamic tariffs in the presence of retail competition and those which don't have retail competition. The details of each country are presented in the table below:

Europe



- Consumers can choose between a product provided by a competitive retailer of electricity or a government-set regulated sales tariff available to customers with 36 kV or less.
- Suppliers provide two types of offers: **fixed price offer and variable price (based on either regulated sale tariffs or wholesale market indices).**
- The retail tariffs provided by the French energy utility EDF provide French consumers with an idea of the type of competitive tariff service available to them.
- The '**Heures Pleines / Heures Creuses'** is a time of use tariff with two-time blocks: PeakPeak and off-peak. The PeakPeak and off-peak must not be a continuous block, but can be further divided (e.g., morning and evening peak).
- The second and far more complex product provided by EDF is **tempo option**. In this tariff mechanism, the electricity price varies by time of the day and the day of the year. The days in a year are divided into three categories: **PeakPeak, shoulder and off-peak.** Also, each day has two blocks, **PeakPeak and off-peak**.

- **Npower** offers a time of use retail tariff broadly know as **economy 7**. This tariff consists of two-time blocks for setting the price: **a day rate for 17 hours and a cheaper night rate for 7 hours**. Npower currently offers both a fixed retail price option for two blocks for a contract period of one year and a variable price option. In the second option, the retail electricity price will be modified every month to reflect the wholesale energy price dynamics.
- **Agile Octopus** electricity tariff is an example of real-time pricing, offered by the electricity retailer Octopus Energy. The entire day in this tariff system is split into half-hour blocks of time. The retail prices in these blocks of time are then updated daily to reflect the wholesale electricity market prices during the 30 minutes. Octopus Energy has also introduced the concept of "**plug price**" where, if the energy price becomes negative, the retail customers using Agile Octopus can benefit from it.

- The broad classification of the types of tariffs available to Estonia customers as follows: **fixed, combined and exchange packages.**
- The fixed package includes a flat rate option, which is set for 6 to 36 months.
- The prices follow the wholesale market prices in the exchange package. Hence this package is also called the "**spot tariff**". Although this package includes selecting an RTP, it also includes other options where ToU rates are based on preceding month wholesale market prices. The combined package offers, as the name suggests, a combination of two types of tariffs. Half of the power demand is billed with an RTP and the other half with a ToU tariff.
- An example of an advanced real-time pricing option is the one **Eesti Energia** offers, called the exchange. Here, electricity prices are linked to the electricity exchange, and thus retail prices change every hour. The retail price combines the exchange price, the margin and a monthly fee.

- There are three main types of contracts offered to the consumers, namely: **open-ended contract (variable contract), fixed term contract and spot price contracts.**
- Electricity retailer Fortum's most advanced retail tariff option is called **Tarkka**, a spot price contract. The prices change hourly in this plan and are related to the wholesale market price of electricity. Therefore, there will be 24-time blocks of 1 hour each day.

- Electricity tariff options into three broad categories: **spot price (linked to the power exchange), fixed price and other appointments, which are hybrid contracts.**
- Energy retailer Norges Energi provides an example of a spot price (real-time pricing) bid. In this bid, the energy expenditure of the customer is connected to the electricity exchange. The retail price varies with the power exchange, based on NordPool's area price in the customer's delivery area and varies from hour to hour in line with supply and demand. In addition to the power price, an agreed surcharge is added to cover operating costs, profits and electricity certificates. The premium size may vary depending on the price terms offered at the time of the contract and throughout the contract period.

- ToU retail tariffs with seasonal and day variations: Weekdays - 4-time blocks (PeakPeak, half-peak, normal off-peak, super off-peak), Saturday - 3-time blocks (half-peak, normal off-peak, super off-peak) and Sunday - 2-time blocks (normal off-peak, super off-peak).
- Time-of-day tariff intervals are determined once a year by Energy Services Regulatory Authority (ERSE), by December 15 and incumbent electricity tariff prices for the coming year.

- Apart from the designated contract, the three most commonly offered price structures are **Fixed price, Variable price and Mixed contract.**
- The mixed contract is a mixture of price setting and price variable. Vattenfall, an energy retailer, provides a control price structure related to the wholesale electricity market, and thus real-time pricing when seen in the sense of the competitive tariff taxonomy.
- If electricity is measured every month, the purchase price is the Nordic electricity exchange's electricity price hour by hour, together with the month's electricity usage profile in electricity area, balance cost and costs for the Nordic electricity exchange.
- The month's variable electricity price is set only after the month has ended, as it is only when the spot price is known for all hours and days of the month.

- The tariff system is divided into Group A for high voltage customers and Group B for low voltage customers.
- Utilities are mandated to offer both a variable price and a fixed-price at a six-month default service rate. Residential customers who had to obtain Default Service were automatically placed on the six-month fixed-price rate but offered a month-to-month variable price.
- In Group B, there is a flat tariff and a time of use tariff known as the white tariff introduced in 2011. This tariff consists of three-time blocks: off-peak (weekends and weekdays 12 am-4 am), intermediary (weekdays 4 pm-5 pm, 11 pm-12 am) and peak (weekdays 5 pm to 11 pm) and weekends being off-peak.

- Currently, Japan is at a very early stage of ToU implementation.
- Japanese electricity retailer, Loop Inc conducted a recent successful pilot. The pilot had two-timed blocks: Peak (14:00-22:00) priced at 35 JPY/kWh and Off-peak (22:00-14:00) priced at 20 JPY/kWh.

- In South Africa, Eskom is the state-owned Utility, that is the electricity supplier.
- Eskom offers ToU tariffs options with two-time blocks or three-time blocks.
- The Night saver tariff has two-timed blocks: Peak (weekdays 6 am-10 pm) and off-peak (weekends and weekdays 10 pm-6 am).
- The remaining dynamic tariffs have three time-blocks that also vary seasonally as - Low demand season peak (weekdays: 7am-10am, 6pm-8pm), standard (weekdays: 6am-7am, 10am-6pm, 8pm-10pm, Saturday: 7am-12pm, 6pm-8pm), off-peak (weekdays: 10pm-6am, Saturday 8pm-7am, 12pm-6pm, Sunday all-day) and High demand season: peak (weekdays: 6am-9am, 6pm-7pm), standard (weekdays: 9am-5pm, 7pm-10pm, Saturday: 7am-12pm, 6pm-8pm), off-peak (weekdays: 10pm-6am, Saturday 8pm-7am, 12pm-6pm, Sunday all-day).
- The tariff is regulated and updated annually based on the Multi-Year Price Determination process implemented by National Energy Regulator of South Africa (NERSA) that provides the annual change in tariff each year within the regulatory period (currently 3-years).

Australia

- In Victoria, Origin Energy, one of the big three retailers offer ToU retail tariffs with either two-time blocks (peak/off-peak) or three-time blocks (peak/shoulder/off-peak).
- An example of the former is the Residential Time of Use (Flexible Pricing) offering with Peak Usage (3 pm-9 pm weekdays) at 30.94 c/kWh, Shoulder Usage (7 am-3 pm, 9 pm-10 pm, weekdays and 7 am-10 pm weekends, AEST) at 25.97 c/kWh and Off-Peak Usage – All Other Times at 19.74 c/kWh.
- An example of the latter is the Residential 5-Day ToU (Winner Tariff GHGL): Peak Usage – (7 am-11 pm AEST, Mon-Fri) at 30.220 c/kWh and Off-Peak Usage – All Other Times at 19.480 c/kWh.

- Regional Queensland applies a ToU defined as Tariff 12A for retail consumers. In this tariff design, there are two-time blocks, PeakPeak, and off-peak. Queensland Competition Authority regulates the prices for Queensland region.
- The Tariff 12A offered by Origin Energy, one of the big three retailers, is an example of ToU in Southeast Queensland. It consists of three-time blocks: Peak Usage (Weekdays 4 pm-8 pm) price at 32.912 c/kWh, Shoulder Usage (Weekdays 7 am-4 pm, 8 pm-10 pm, Weekends 7 am-10 pm) priced at c/kWh 23.716 and Off-Peak Usage (Weekdays & Weekends 10 pm-7 am) priced at c/kWh 19.250.

- In NSW, Origin Energy offers ToU retail tariffs with seasonal variations with three-time blocks.
- An example is of the Domestic Seasonal ToU with CL1: Shoulder Usage – All Other Times at 29.524 c/kWh, Peak Usage (2 pm – 8 pm (November 1 – March 31) and 5 pm – 9 pm (June 1 – August 31) Working Weekdays) at 29.524 c/kWh and Off-Peak Usage – All Days 10 pm – 7 am at 29.524 c/kWh. In this offering, there is also a special price for Controlled Load Off-Peak 1 16.324 c/kWh.

United States of America (USA)

- San Diego Gas and Electric offers different types of ToU tariffs for winter season 2019/20. For example, ToU DR 1 has three-time blocks: Peak (4 pm to 9 pm all days) at 34cents/kWh, Off-Peak (weekdays 6 am to 4 pm, 9 pm to 12 am, weekends and holidays 12 am to 2 pm to 4 pm, 9 pm to 12 am) at 33cents/kWh, super off-peak (weekdays 12 am to 6 am, 10 am to 2 pm in March and April, weekends and holidays 12 am to 2 pm) at 32 cents/kWh.
- An exciting option is ToU-DR-P, which has the same structure in terms of the time block as ToU DR1, except that a peak time rebate of 1.16$/kWh is provided to reduce consumption between 2 and 6 pm.

- In Connecticut, the dynamic tariff provided is Rate 7 – "Residential Time-of-Day Electric Service". This is a time of use tariff with two blocks: On-Peak: (Weekdays Noon – 8 pm) and Off-Peak: (All other hours).

- In New York, time of use rates that vary by season is applied by the Consolidated Edison Company of New York. These rates have two-timed blocks: Peak (8 am to midnight) and off-peak (midnight to 8 am).
- Seasonal rates for residential customers are different from June 1 to September 30 (Peak: 23.07 cents/kWh off-peak: 1.63 cents/kWh) and form October 1 to May 31 (Peak: 8.54 cents/kWh off-peak: 1.63 cents/kWh).

Table 3-3: International Case Studies

3.3 Dynamic Tariff Design and Implementation Choices in Practice

Based on the assessment of the various international cases discussed in this section, two primary design choices namely Time Block Length and Price Periodicity are identified. Furthermore, apart from the two primary design choices, it is observed that the design of dynamic tariff is impacted by the choice made by regulators (regulatory intervention) and choice provided to the customer.

3.3.1 Primary Design Choices

Primary design choices are the most fundamental elements of designing choices that need to be made while developing a dynamic tariff structure. Here, it is important to note that setting the price level itself is a challenge. The price level would depend on the market structure, the motivation and goals of the relevant price setter (a retailer in a free market or a regulator).

Time Block Length

Time block length refers to the number of distinct tariff periods a day is divided; i.e., the granularity of the time blocks. For instance, in a real-time pricing approach, there will be 24-time blocks of one hour. This type of tariff can be considered as having a short time block length. Conversely, while in a ToU there may be just two blocks: peak and off-peak or day/night is a short time block length. A price with no variation has the longest time block length.

Price Periodicity

Price periodicity refers to the time interval between the revisions of the tariff. In a real-time pricing approach where the prices are updated for each hour one day in advance, the tariff periodicity is high. Conversely, the tariffs can be revised annually, bi-annually or as much as the length of the design choices made for the most advanced retail tariff available. The price periodicity in the different cases studied in research is illustrated in the below figure.

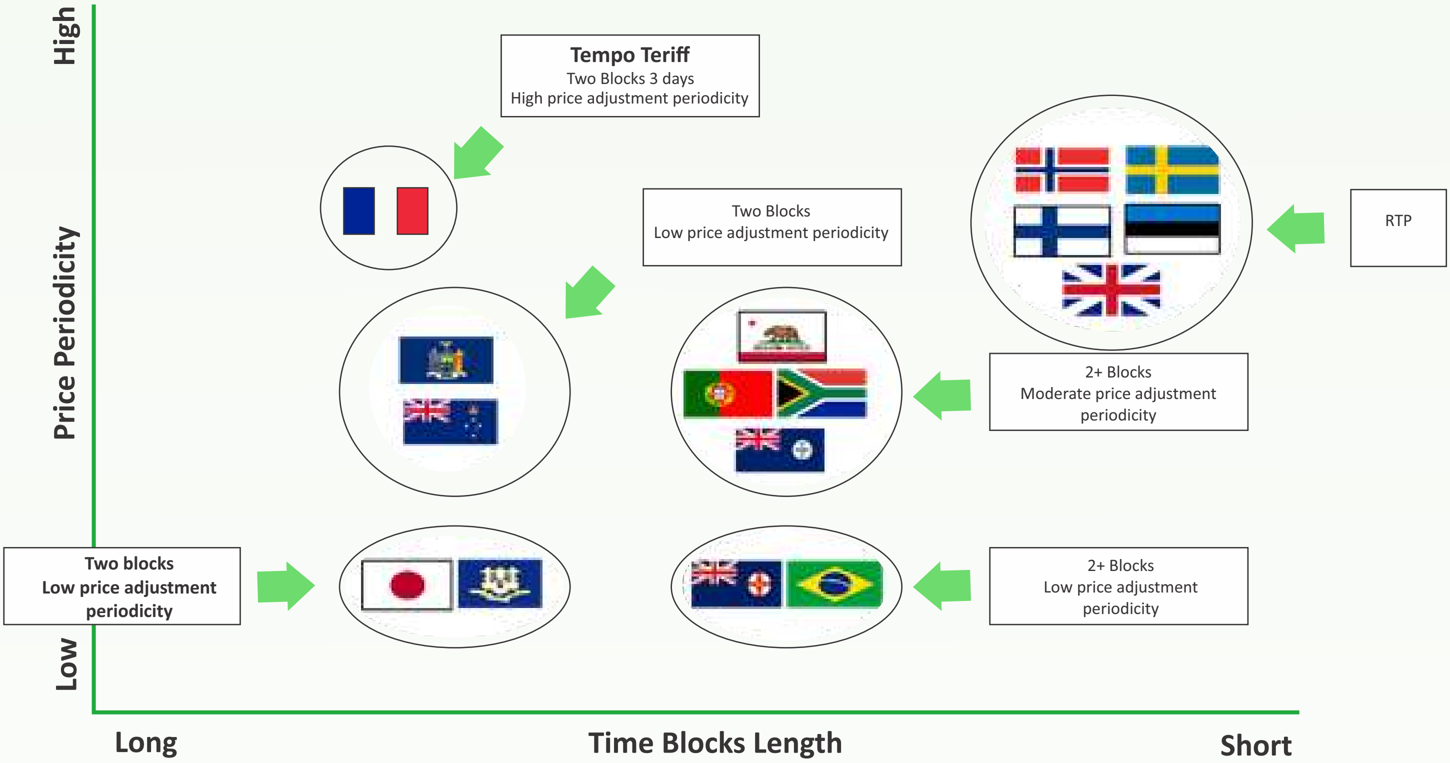


Figure 3-1: Primary Design Choices of Case Studies

In this figure, the X-axis represents the time block length. On this axis, the scale moves from long to a short time block length. Thus, a flat tariff would be at the zero value while real-time pricing would be on the rightmost end.

In terms of time-block length, the application of a 2-block approach is observed in five cases (e.g., Japan, Victoria, France, Connecticut and New York) while a 3-block or more is applied in six cases (e.g., Brazil, Portugal, California, NSW, Queensland and South Africa). The real-time pricing with short time-block length is adopted by six countries including Great Britain, Finland, Estonia, Norway and Sweden.

The Y-axis of the Figure represents price periodicity. The greater the frequency of price adjustment, the higher would be the position of the country in the chart. For instance, prices that are based on long time horizons such as one-year or linked to the regulatory period would be at the lowest end of the Y-axis, while real-time prices that are updated daily would be at the highest (topmost) part of the Y-axis.

In terms of price periodicity, four cases are observed at the lowest spectrum (Japan, Connecticut, Brazil and Queensland) having low price periodicity and no seasonal variation while six cases (New York, NSW, Victoria, California and Portugal) can be observed to have moderate price periodicity. In some cases, the price can be set over a long-time horizon but varies seasonally (e.g.: South Africa), which has been included in the moderate range. Finally, six countries have high price periodicity (e.g., GB, Finland, Estonia, Norway, Sweden and France). Here, except France, which has Temp Tariff, the rest have real-time pricing.

The analysis of the most advanced current practices in the cases accessed indicates that Norway, Sweden, Finland, Estonia and GB are the most advanced in terms of the application of dynamic tariffs. The retailers in all five countries provide their customers with a real-time pricing option. Another aspect that is evident from the assessment is that except these five cases with real-time pricing, all others have opted for Time of Use tariffs. It is interesting to note here that California also offers a critical peak rebate.

3.3.2 Implementation Choices

Apart from the two primary design elements, there are two other key design dimensions which are dependent on:

- Decisions made by the regulators on regulatory interventions
- The level of choice to be provided to the customer which would have a direct impact on the setting of the primary design choices

Choices by Regulators

The level and method of regulatory intervention have a strong bearing on the dynamic tariff design applied. This choice remains solely at the discretion of the regulator and is governed by their overall vision and mandate. For instance, regulators may intervene to protect vulnerable customers against price risks or to ensure that consumers are protected from disconnection in the event of either a retailer going bankrupt or the consumer not having any contract with any retailer.

As presented in Table 3-4, in all the cases assessed, some type of regulatory intervention has been enforced to protect the customers. The most commonly used intervention is mandating a last resort service provider, which may also be the local distribution company, to set the last resort tariff or default tariff as defined by the regulatory authority. In France, an additional subsidy is provided to the poor customers while GB has enforced a price cap. Furthermore, these interventions can also be implemented in combination i.e., a combination of subsidy and a price cap.

Country	Regulatory intervention
Estonia	The regulator has the right to control prices.
France	Regulated tariff option, subsidy for energy-poor
Finland	DSO provides last resort service
Great Britain	Retail price caps and last resort supplier with standard contract
Norway	DSO provides last resort service
Portugal	Last resort tariff
Sweden	Last resort supplier
California	Framework for ensuring adequate supply
Connecticut	Utilities obligated to provide standard service
New York	Customers protected under the Energy Consumer Protection Act.
Brazil	Default service rates
Victoria	Default tariffs
Queensland	Retailer of last resort
NSW	Default offer
Japan	Last resort supplier
South Africa	Eskom is the supplier of last resort.

Table 3-4: Regulatory Interventions Related to the Implementation of Dynamic Tariff

Choices for the Consumers

The choices for the consumers are best described in the form of two questions:

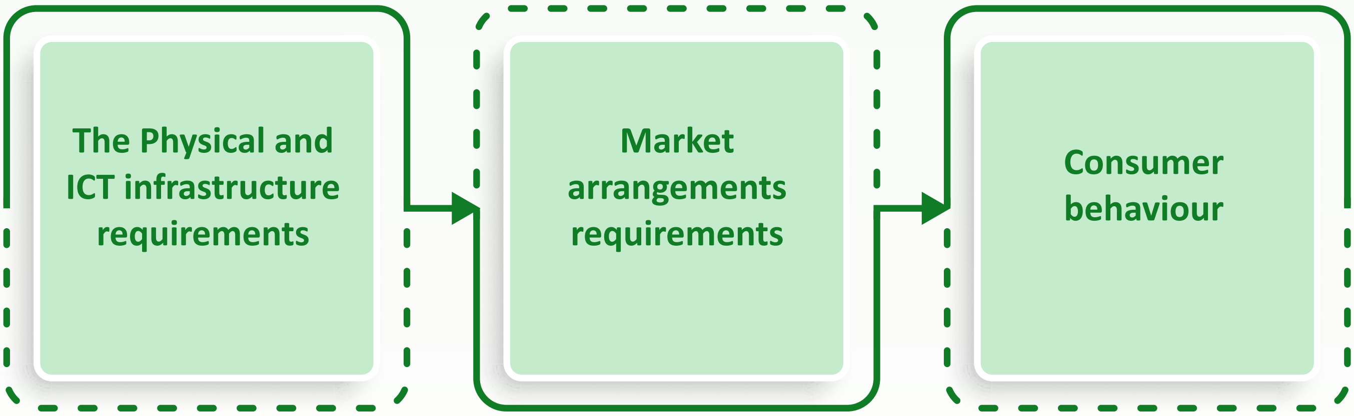
- Can the consumer choose whether to opt for dynamic tariffs or not?
- How many options do consumers have within dynamic tariff?

The first choice is regarding the option to opt for dynamic tariffs. On the one hand, dynamic tariffs can be made mandatory for all consumers (as was applied in Italy) or an opt-out provision may be provided (SDG&E offers customers the option to opt-out of dynamic tariff structure). On the other hand, the consumers may be provided with (different) dynamic tariff offerings along with the traditional flat rates to choose from (opt-in). The design choice made in this context can have spillover consequences for consumer acceptance of these tariff structures. Consumer behaviour barriers are discussed in the next section.

The second choice is related to the variety of offerings available for the consumer to choose from. In countries/states with retail competition, different service providers would offer their variations of dynamic tariffs. For example, a retailer may offer a choice between Time of Use and real-time pricing. Thus, depending upon their constraints and risk appetite, consumers may choose the most suitable dynamic tariff for their needs.

3.4 Dynamic Tariff Implementation Barriers

Three wider implementation barriers which need to be addressed for effective introduction of dynamic tariffs are identified:



3.4.1 Physical and ICT Infrastructure Requirements

The first barrier for implementation of dynamic tariffs can be the absence of an enabling physical and ICT infrastructure. The basic minimum infrastructure required for the implementation of any kind of dynamic tariff is a smart meter. In all the examples that have been discussed in this report, smart meters are installed for customers to enable dynamic tariffs. At the network end, smart grid solutions for monitoring network dynamics are required if grid constraints are to be considered while applying the dynamic tariffs. Finally, through ICT solutions, and an interface, consumers can react, monitor and be informed about the real-time pricing. With the advent of Smart Homes and multiple devices connected to the network over to the Internet, the Internet of Things (IoT) will further broaden the usage of equipment and devices that consumers can control and monitor the usage of power as per the time of use most suitable and economical for the consumer. The technical assessment of the infrastructure requirements for the implementation of dynamic tariffs is outside the scope of this chapter.

3.4.2 Market Arrangement Requirements

The second barrier for implementation of dynamic tariffs can be the absence of market arrangements necessary for price development. For example, the real-time pricing approach is dependent on the price development in the wholesale electricity market. The price in the wholesale market reflects the cost of purchasing energy for the retailer. This price signal is passed on to the consumer. Therefore, the presence of a wholesale market arrangement that reflects this cost dynamic is necessary for the application of real-time pricing. For instance, if the retailer buys all its electricity based on power purchase agreements, its price dynamic may diverge from the wholesale market depending on the contracts.

3.4.3 Consumer Behaviour

The third barrier is the behaviour of the consumer. For dynamic tariff to reach its goals, the consumer needs to react to the price signal that is being provided by the new tariff design. For instance, if the dynamic tariffs are introduced with a goal to reduce congestion during a particular time, then the consumer must react to the price signal and shift load during that time period. Thus, the consumer has to be provided with a sufficient level of knowledge and understanding of the benefits arising from the use of dynamic tariffs.

3.5 Lessons Learnt

Through a case-study based approach with detailed analysis of 16 international case studies across four continents, this chapter assessed the most advanced international applications of dynamic tariffs and identified design choices and implementation constraints while designing a dynamic tariff structure. To set the background for the analysis, the chapter also discussed the motivations for applying dynamic tariffs and presented taxonomy of dynamic tariff designs. The motivation is important as it is reflected in determining the price levels to be implemented in the dynamic pricing tariffs.

Apart from determining the price level itself, two primary design dimensions that need to be considered are:

- The time block length of the different tariff which refers to the number of distinct tariff periods across the day.
- The price periodicity which refers to the time interval between revision/update of the tariff.

The analysis of the various international practices shows that even though the real-time pricing is being adopted in most advanced markets, the time of use tariff is still a dominant type of dynamic tariff that is widely adopted. This, however, can change in the future as power markets mature, infrastructure requirements are fulfilled and the responsiveness of consumers towards the signals sent through dynamic tariff improves. Beyond these two primary design choices, two implementation choices identified are:

- Decisions made by the regulators on regulatory interventions
- The level of choice to be provided to the consumers

These will have a direct impact on the setting of the primary design choices. Regulators have applied interventions such as last resort tariffs, default suppliers, price caps and subsidies. In the context of choice to the consumers, in most cases consumers have an 'opt-in' option and a variety of tariffs to choose from especially where retail competition exists.

Finally, three implementation constraints (barriers) that need to be overcome for successful implementation of dynamic tariffs namely:

- Physical and Information and Communication Technology (ICT) infrastructure requirement such as deployment of smart meters
- Market arrangements (e.g.: liquid power exchange for real-time prices)
- Consumer behaviour dimension (e.g.: reaction to the economic signal)

4. CONSUMER SURVEY AND ANALYSIS

Gujarat is one of the five leading states of India for renewable energy in terms of existing generation capacity as well as future potential. There are 3.6 GW of solar power capacity, 8 GW of wind power capacity and 0.87 GW of biomass capacity operational as of November 2020. India's Ministry of New and Renewable Energy (MNRE) estimates Gujarat's renewables potential to be 72.7 GW, equally balanced between solar and wind energy. This includes the 5GW Dholera Solar Park, the largest proposed solar development in the world to-date. On 15 December 2020, Prime Minister Modi inaugurated the 30-GW renewable energy (solar and wind) park at Kutch, Gujarat. The project is billed as the largest of its kind in the world and it is in line with the Government of India's vision to install 175 GW of renewable energy capacity by the year 2022.

Being one of the most industrialized states in India, Gujarat's electricity demand has grown rapidly at a CAGR of 6.1% annually between FY 2008/09 and FY 2018/19. In FY 2018/19, Gujarat consumed a total of 116.3 TWh of electricity making it the second-largest electricity market in the country only behind the state of Maharashtra. It is also the leading state in terms of per capita electricity consumption with 1,733kWh per person in FY 2018/19.

Gujarat has ToD tariff in place; and adopting ToU would serve as a case to review the effect of real-time pricing of electricity on consumer's behaviour and subsequent impact on generation, transmission and distribution utilities. Also, Gujarat is planning to upgrade its renewable portfolio by several thousand MW in line with the Government of India's ambitious 450 GW of renewable power by 2030. Hence, ToU tariff would be more relevant here, as it could play a pivotal role in integrating RE to cater to the energy mix efficiently and reduce carbon emissions.

ToU tariff is recognized globally across electric utilities, as an important DSM measure which is used as a means of incentivizing consumers to shift a portion of their loads from peak times to off-peak times, thereby improving the system load factor by reducing the demand on the system during peak periods. ToU tariff is fit for addressing current and expected network challenges, and it can be derived from long-established principles of good tariff design. Those principles dictate that tariffs should:

- Be simple, predictable, and understandable.
- Reflect long-run marginal costs.
- Focus on usage-driven components.
- Give consumers the information, the opportunity, and the incentive to manage their consumption in a manner that besides reducing their electricity bills also optimizes the utilization of grid infrastructure.
- Wherever possible and appropriate, provide for the recovery of system costs based on how much a customer uses, when they use it, and where they are located.

In practice, these principles can push the design of tariffs in several directions; for example, a greater ToU differentiation can provide multi-level, multi-party, multi-consumer data inputs and too large data inputs may also complicate the task of designing a simple tariff. However, designing tariffs is a balancing exercise and requires the use of judgment to meet several objectives.

The key objective of the customer survey undertaken as part of this project was to examine the knowledge and awareness of the existing regulatory framework in electricity retail tariff, understand consumers concerns and their willingness to shift to dynamic tariff structure that will facilitate developing an appropriate strategy for implementing ToU/Real-Time Pricing in the retail market within the present legal framework of the Electricity Act, 2003.

4.1 Design and Development of Survey Questionnaire

The survey has been conducted in selected parts of the UGVCL service area. A non-probability sampling technique has been used in consultation with UGVCL covering all relevant consumer categories i.e. Large Commercial, Industrial, Schools/Colleges, Institutes, Utilities (WTP, STP, Municipal Board, Jal Board etc.), Residential and Agricultural consumers. This chapter of the report presents the details of the consumer survey and analysis on possible impact of the Time of Use (ToU) Tariff in the state of Gujarat. The survey included questions related to: understanding of customer responses to different tariff structures and consumer benefits and concerns on ToU adoption. A sample survey questionnaire was developed to obtain information from each consumer to assess the possible impact of ToU tariff on the consumers, as compared to the existing tariff schedules. The questionnaire covered following details:

- Consumer number and category
- Major electrical equipment and its operation pattern (e.g., hrs per day operation etc.)
- Connected Load; Bill Amount; type of economic activity (commercial, industrial, residential, agricultural etc.)
- Perceived benefits/disadvantages of ToU tariff related to reduction/increase in bill amount
- Pattern of use of appliances such as lighting, cooling, heating, TV, radio, motors, fans etc. to analyze the possibility of adopting demand response associated with Time of Use tariff
- Consumer knowledge and expectations regarding tariff components and Time of Use Tariff regime
- Consumers willingness to upgrade appliances in their premises to take advantage of ToU tariff regime

The purpose of this survey is to derive effective implementing strategies, obtain consumer viewpoint and specifically, this survey is expected to measure consumer satisfaction with the existing tariff schedule which is flat/block rate tariff for LT category and ToD tariff for HT category in Gujarat. It helps to assess the socio-economic impact and techno-commercial benefits i.e., willingness of the consumers well versed with smartphones and familiar with technology adopting the ToU tariff.

The survey was structured to host 17 questions to assess if individuals from different backgrounds know about their sanctioned load (kW). This sanctioned load is the load which the DISCOM has agreed to supply from time to time as per the government terms and conditions and shall be subjected to relevant orders of the GERC. Many appliances/machines need to run 24 hours x 7 days a week and through survey, the usage and consumption of such machinery/appliances were determined. In accordance with this, we also wanted to know whether or not individuals or businesses faced any problems due to a frequent power outage or fluctuation in their area. Moreover, it was also checked if consumers are willing to shift the operational time of usage for connected load/appliances like Air Conditioner, Electric Geyser, Electric Pump, Production Line etc., from day to night time.

Besides, the most crucial aspect of the survey was to gauge awareness of people of Naroda district where smart meters are installed in 2018 about ToU tariff, besides also understanding if people knew about different types of tariff schemes such as real-time or time of use/critical peak pricing etc., that are prevalent in different countries. Further, through the survey, we tried to determine consumer's willingness towards adopting market-determined electricity charges to save money by adopting variable electricity charges that varied for different times as per the demand from day to night, or from weekday to weekend.

The survey also attempted to determine consumer willingness to install rooftop solar PV in the next two years to decrease their daily load consumption and future-proof the grid system. If the consumers are interested, we tried to determine the capacity of solar PV and energy storage systems that they would require. Through the survey, we also tried to find out about their response towards the purchase and adoption of electric vehicles over the next two years. As smart meters can connect to a smartphone through WiFi/mobile network and by using an App, consumers can visually see their real-time electricity consumption and accordingly alter usage for savings in the electricity bills. Likewise, smartphone usage, adoption, and the awareness of different apps that can be used for saving on electricity bills are also key areas on which response was sought from consumers.

It was also desirable to know whether the consumers are willing to change their electricity consumption pattern (times) if lower rates are offered at different time slots and make them aware as to how they can shift their load to those time slots. During the survey it was explained that if they can shift their heavy usage at the time when the electricity rates are low then they can make some savings. It was also tried to ascertain the kind of electricity rate design that consumers expect so that they could have the optimum electricity price. Further relating to infrastructure requirements, consumers were asked whether receiving and installing a subsidized Smart Switches (programmable thermostat) for heavy appliances would be a sufficient incentive to sign up for the ToU program. We also tried to find out if their existing appliances are near to completion of their useful life, would they like to replace them with smart appliances (including the features of smart switching) and thereby, optimize on operational cost.

The last but not the least, it was tried to understand whether the consumers believe and expect that the electricity bill should also show what the customer would have paid for the same electricity usage under a different rate structure based on time of electricity consumption and reassure themselves about the money that they would have saved (Shadow Billing) before actual implementation of the ToU Tariff. The detailed survey questionnaire is given in Annexure I.

4.2 Survey Methodology

This survey aimed to derive effective implementation strategies, obtain consumer viewpoint and assess the possible impact of Time of Use (ToU) tariff on the consumers, as compared to the existing tariff schedules. Specifically, this survey was expected to:

- Measure consumer satisfaction with the existing tariff schedule which is basically flat/block rate tariff for LT category and ToD tariff for HT category in Gujarat

- Anticipate both the quantitative and qualitative changes required in working conditions of consumers with ToU Tariff relative to those without
- Assess the socio-economic impact and techno-commercial benefits i.e., the consumers well versed with smartphones, of ToU tariff on consumers adopting the same
- Assess consumer preferences with respect to the types of electricity tariff

4.2.1 Sampling Plan

In sampling surveys, selected samples are determined and surveyed for collection of relevant data through the sampling method. Here, for research purposes, a sampling plan is prepared. This plan called for three major decisions. Sample Unit, Sample Size and Sample Procedure.

Sample Unit:

(Who is to be surveyed?)

The research aimed to understand the awareness of consumers related to electricity tariff and their willingness to participate in ToU. Hence, the sampling unit contains the respondents having basic knowledge of electricity tariff and having electricity bills generated on their name.

Sample Size:

(Number of people to be surveyed)

The sample size of a survey most typically refers to the number of units chosen to gather data. It has been determined both by qualitative approach and quantitative approach. Statistical formula was used to determine the quantitative sample size which is given below:

- Determining sample size is a very important issue because samples that are too large may waste time, resources and money, while samples that are too small may lead to inaccurate results. According to (Saunders et al., 2000) researchers normally work to a 95 percent level of certainty.
- This means out of 100 times, at least 95 of these samples would be certain to represent the characteristics of the population. In this research the confidence level has been determined at 99% and confidence interval at 4%.
- A survey has been planned to determine what proportion of people in a certain region are satisfied with electricity tariff. It is believed that the proportion cannot be greater than 0.50. At 99 percent confidence level and confidence interval 4%, the sample size has been found out using the formula given below:

$$n = \frac{z^2pq}{d^2}$$

Here Z =2.054, p = 0.50, q = 0.50, d = 0.2,

Z = (2.054)2 (0.50) (0.50)/0.02,

n = 1040

Sample Frame

- Number of Data Sources Received from DISCOMs was 932, out of which 932 consumers were surveyed; 89% was the response from total surveyed consumers.
- A total of 932 customers were approached in the survey and were administered the research questionnaire telephonically, out of 932 respondents, 162 consumers responded positively.

Sampling Technique

(How should the respondents be chosen?)

The research aimed to understand consumers' awareness related to electricity tariff and their willingness to participate in ToU. Hence, the sampling unit contains the respondents with a basic knowledge of electricity tariffs and electricity bills generated on their name.

- There are two types of sampling techniques that may be divided as probability and non-probability. Probability is a sampling procedure in which each element of the population has a fixed probabilistic chance of being selected for the sampling. Non-probability does not use chance selection procedure, but rather rely on the personal judgment of the research. Non-probability can be classified into four different sampling manners:
- Convenience sampling, judgment sampling, quota sampling and snowball sampling (Malhotra and Birks, 2006).
- This research adopted a non-probability sampling method for investigation, since the dominant aspect of non-probability sampling is that it provides researchers greater freedom and flexibility in selecting the individual population units than does probability sampling (Parasuraman, 1991).
- Here, convenience sampling is considered one of the appropriate methods in order to obtain data effortlessly. Parasuraman (1991) indicated convenience sampling is a procedure in which a researcher's convenience forms the basis for selecting a sample of units. Frequently, respondents are selected because they happen to be in the right time and right place, so that implies selecting any respondent who is readily available (Malhotra and Birks, 2006).

Summary of Research

Geographical Area covered	Data Source & Type	Survey Sample	Number of Data Sources Received
UGVCL, Gujarat.	UGVCL/Consumer Details	8 Categories of Customers in UGVCL service Area	932

Number of Consumer Surveyed	Number of Consumer Responded Positively	Limitations of the survey
932	162	The consumer survey was done in UGVCL area only; survey across all Gujarat DISCOMs will fetch better results.

Sample Profile

Category	Responses
Agriculture LT	16
HT WW	1
Industries LTD	43
Large Commercial HT	43
LT	1
LT WW	26
Residential LT	23
School Colleges LT	9
Total	**162**

Table 4-1: Sample Profile

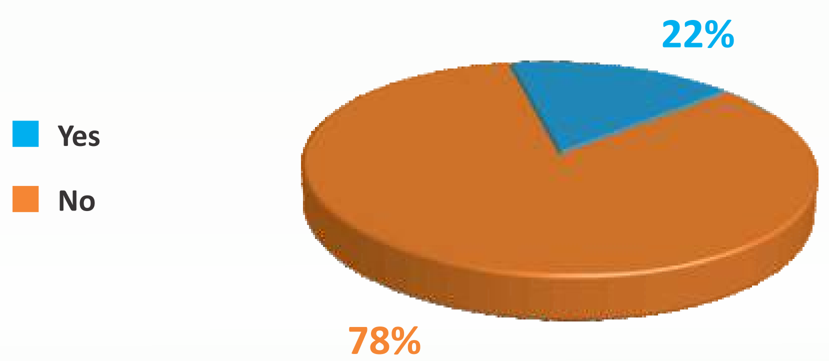
4.3 Survey Results

A consumer survey was conducted across the UGVCL area to understand the awareness of consumers on the ground and their willingness to participate in the ToU program. We selected 1,000 individuals from different sectors to collect data for the survey.

- Through the survey, it was found that 78% of individuals are not using any machinery/appliances 24x7 all 7 days a week. However, 22% of individuals said yes on using machinery/appliances that run 24x7.

Frequency Percentage		
Yes	36	22.22
No	126	77.78
Total	162	100

Is there any Machinery/Appliance that need to be run 24X7 all 7 days a week?



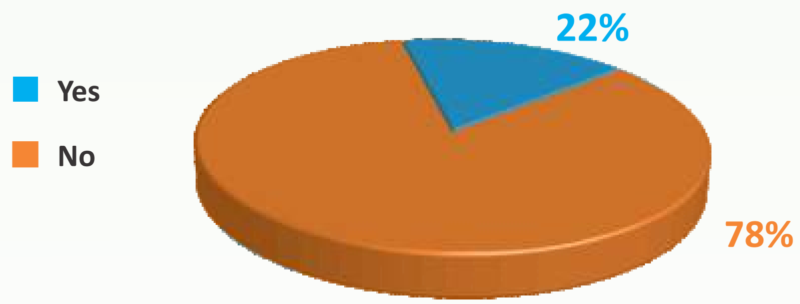
The load consumed by the individuals by running machinery/appliances 24x7 is:

Load	Frequency
0.1 kW	16
15kw	1
30 kW	43
74 kW	43
8 kw	1
No Idea	26
Total	**36**

- In the district of Naroda, only 22 percent of people face frequent power fluctuations/interruptions. The rest of 78 percent do not face any problems regarding this issue.

	Frequency	Percentage
Yes	36	22.22
No	126	77.78
Total	162	100

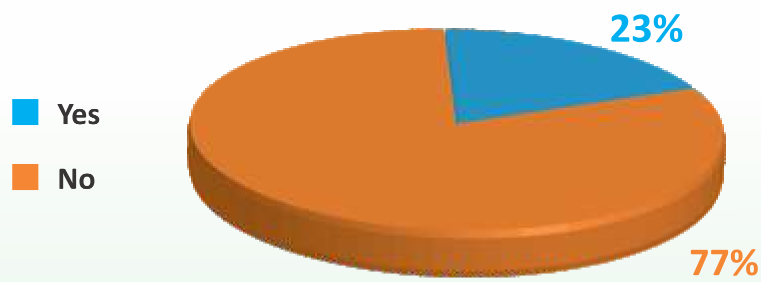
Do you face frequent Power fluctuations/Interruptions?



- From the survey, we found that 77 percent of the people are not flexible to shift their operations from day to night. However, 23 percent of individuals have no problem in shifting their operations.

	Frequency	Percentage
Yes	38	23
No	124	77
Total	162	100

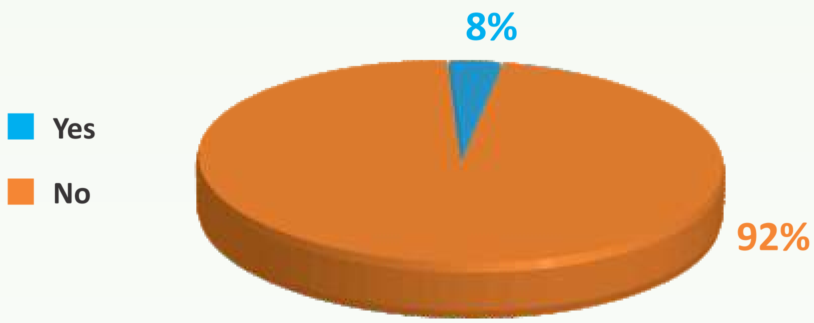
Do the connected load/appliance* have the flexibility to shift their operations during the day/night?



- Due to lack of knowledge about ToD tariff, only 8 presents of individuals are under this tariff scheme. 92 percent of the people either don't know about their tariff scheme or are not under ToD tariff.

	Frequency	Percentage
Yes	13	8
No	149	98
Total	162	100

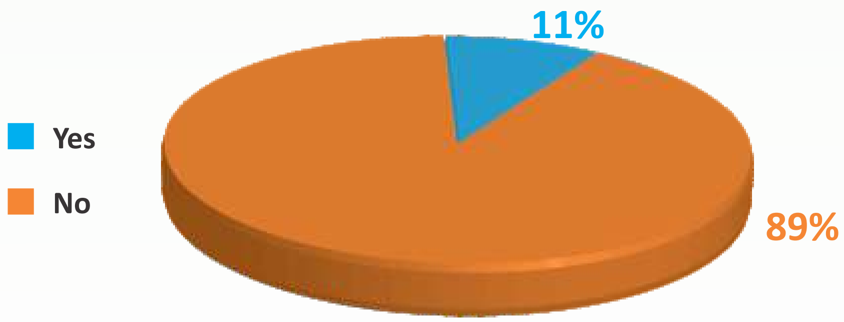
Do you under ToD Teriff?



- Through our survey, we wanted to check Consumer awareness regarding different tariff schemes such as real-time or time of use/ critical peak pricing etc. that are available in other countries. Only 11 percent of individuals have knowledge of such schemes. The rest 89 percent have no recognition of the existence of these tariff plans in other countries.

	Frequency	Percentage
Yes	18	11
No	144	89
Total	162	100

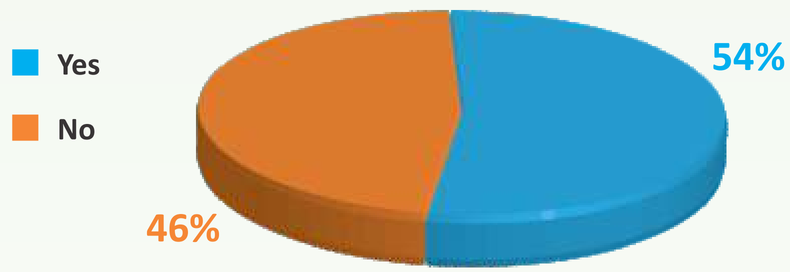
Are you aware that there are different tariff schemes such as real-time or time of use/critical peak pricing etc. in other countries?



- One of the primary questions related to whether the people believe that changing (Dynamic) electricity rate determined by the market conditions would make a difference in saving money for the consumers. Through the survey, we found that 54 percent of individuals believe that dynamic pricing can help reduce their electricity bill.

	Frequency	Percentage
Yes	88	54
No	74	46
Total	162	100

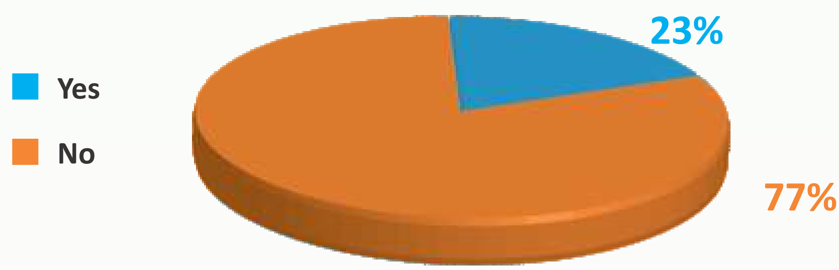
Do you believe that the changing(Dynamic) electricity rate determined by the market conditions would really make a difference to you save money?



- Rooftop PV is an upcoming technology in India that allows the user to generate electricity through the panels mounted on the rooftop of residential or commercial buildings or structures. From the survey, we found that only 23 percent of individuals are looking forward to installing rooftop solar PV in the coming 2 years. The rest 77 percent were not interested due to their lack of awareness of the advantages of this technology.

	Frequency	Percentage
Yes	37	23
No	125	77
Total	162	100

Are you looking forward to install roof top solar PV in next 2 Years?



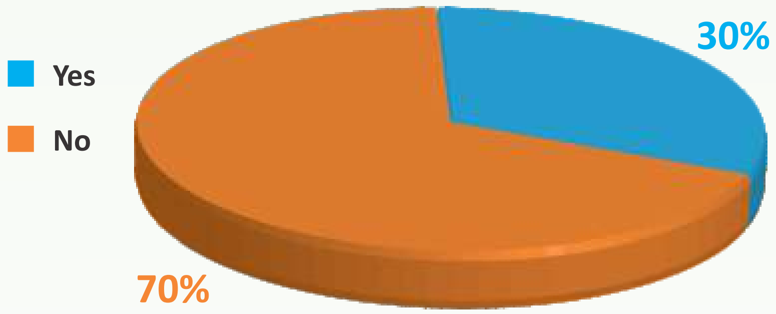
Through the survey response, we also found what capacity (kW) and how much energy storage system (kWh) would be required by the people who wanted to install this technology. We see that the majority of consumers have not decided on the load and storage capacity they need.

Load	Frequency
2 kW	1
3 kW	1
5 kW	4
6 kW	1
10 kW	2
15 kW	1
25 kW	1
36 kW	1
50 kW	1
Not decided	22
Total	**36**

- The adoption of electric vehicles in the automotive market has been overwhelming; many countries have adopted electric vehicles as their daily driver. As these vehicles are making their way in India, 30 percent of the individuals from our survey were planning to buy an electric vehicle in the next 2 years.

	Frequency	Percentage
Yes	48	30
No	114	70
Total	162	100

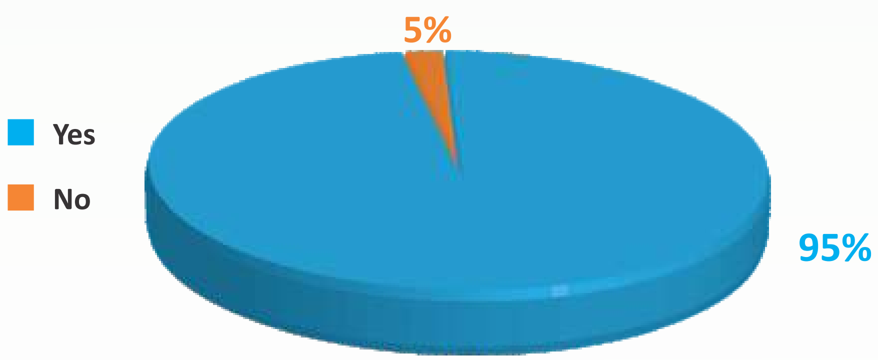
Are you planning to buy electric vehicle in the next 2 years?



- Smartphones have become a necessity for consumers across utilities and different consumer types of consumers. 95 percent of people are using different smartphone apps and this will lead to a quick ToU adoption in Gujarat.

	Frequency	Percentage
Yes	154	95
No	8	5
Total	162	100

Do you have smartphone and use different apps?



- 86 % of people are willing to use an app for saving electricity. It shows consumer inclination towards digital applications and a huge potential for ToU where real-time pricing signals are required.

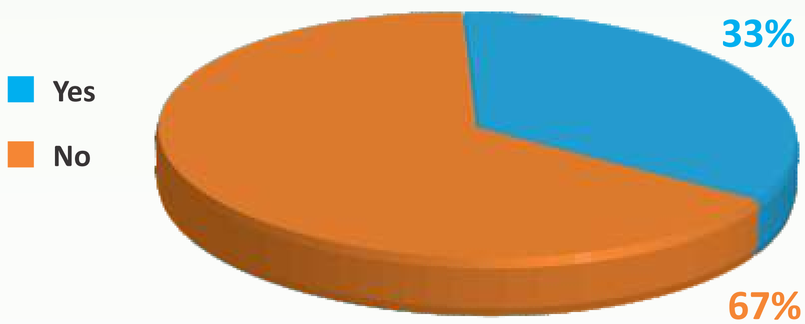
	Frequency	Percentage
Yes	140	86
No	22	14
Total	162	100

Would you use an app for saving on electricity bills?

- 33 percent of people are willing to change their consumption pattern, and this provides a big opportunity to implement ToU in the DISCOM.

	Frequency	Percentage
Yes	54	33
No	108	67
Total	162	100

Would you be prepared to change your electricity consumption pattern (times) if lower rates are offered at different time slots?



- 25% of people already have a plan to shift their load consumption ranging from 25% load to 100% load during the day.

	Frequency	Percentage
100%	7	4
75%	4	3
50%	7	4
25%	13	8
Less Than 10%	10	6
None	121	75
Total	162	100

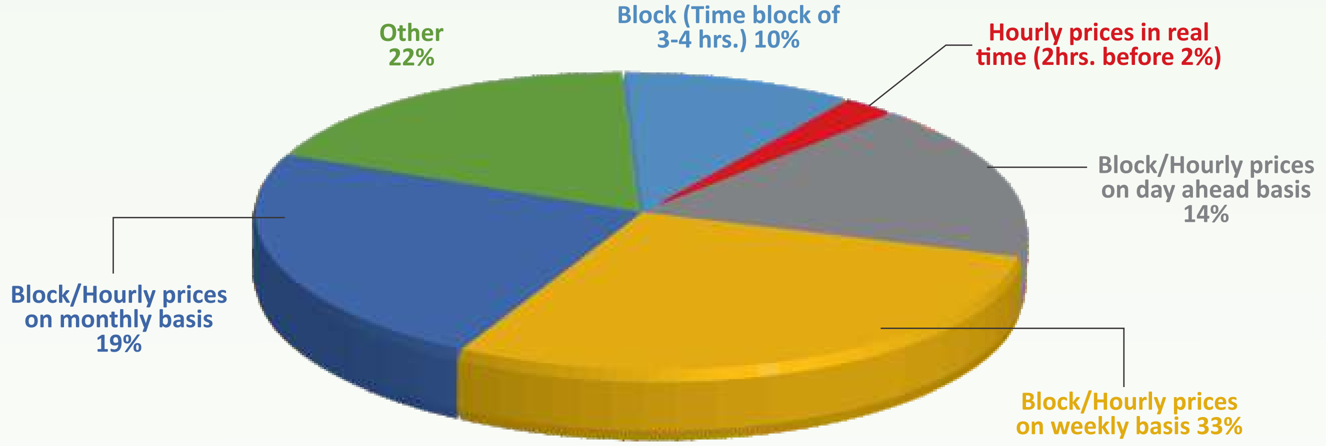
Out of your total load how much load you can shift to different time slots in a day?

- 78 percent of the consumers are ready for a different type of ToU tariff.

	Frequency	Percentage
Block (Time block of 3-4 hrs.)	16	10
Hourly prices in real-time (2 hrs. before	4	2
Block / Hourly prices on a day-ahead basis	23	14
Block / Hourly prices every week	53	33
Block / Hourly prices every month	31	19
Other	35	22
Total	162	100

Other Options	Percentage
Depends on need	1
Fixed six months	1
Fixed-rate	3
It depends on the comfort level of usage	1
No idea	9
None	16
Any	4
Total	35

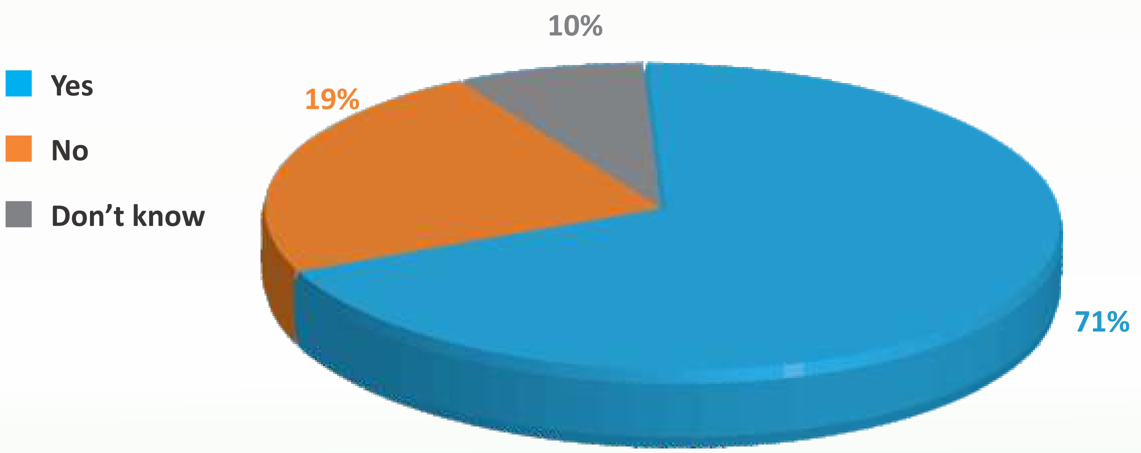
Which Alternate Electricity Rate Design Do You Recommend?



- 71 percent of consumers are willing to adopt smart devices to be able to participate in ToU schemes.

	Frequency	Percentage
Yes	115	71
No	31	19
Don't know	16	10
Total	162	100

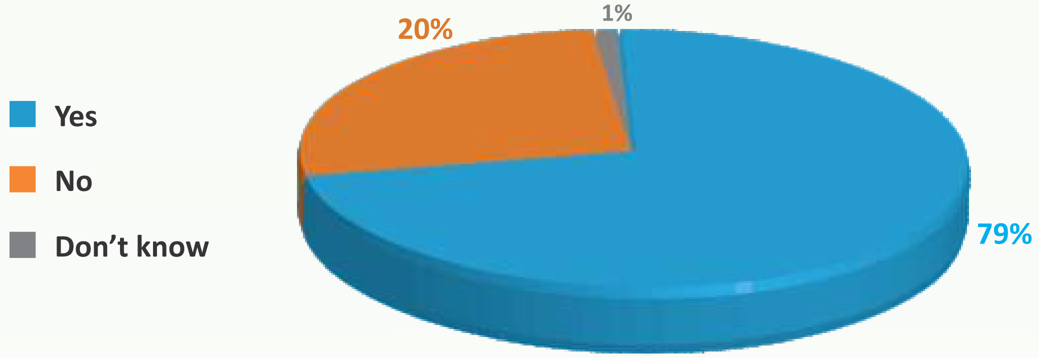
Would Receiving a subsidized smart switches (Programmable thermostat) for heavy appliances that're installed for you be sufficient incentive to sign up for such a program?



- 79 percent of individuals believe in replacing their old appliances with smart appliances (including the feature of smart switching) which would help in the utilization of ToU tariff and would also optimize the operational cost.

	Frequency	Percentage
Yes	128	79
No	32	20
Don't know	02	1
Total	162	100

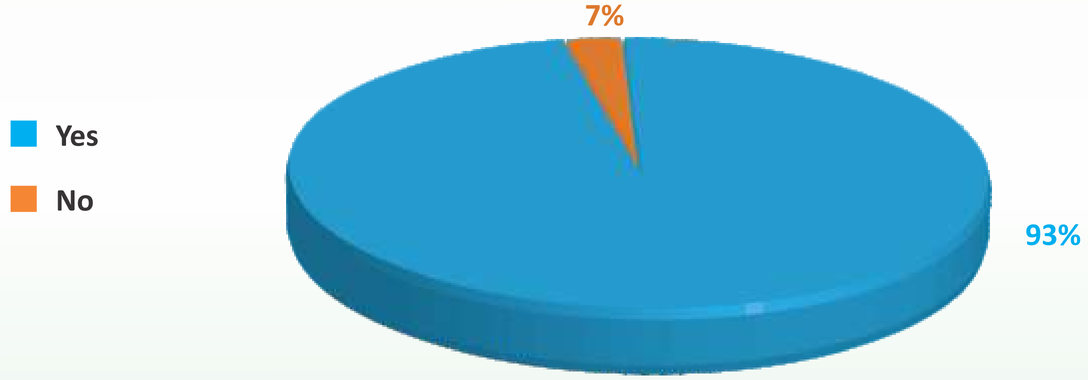
If your existing appliances are near to completion of their useful life, then, do you believe that replacing the existing appliances with smart appliances (including the features of smart switching) would optimize on operational cost?



- 93 percent of consumers are willing to understand potential ToU saving for the same amount of power consumption before enrolling to such schemes. Maximum consumers are price sensitive and are looking for better options.

	Frequency	Percentage
Yes	150	93
No	12	7
Total	162	100

Do you believe the electricity bill should also show what the customer would have paid for the same electricity usage under a different rate structure based on time of electricity consumption and the money that the consumer would have saved (Shadow Billing)



4.4 Data Analysis and Interpretation

In this survey, 17 questions were asked to consumers to analyse the response for the Time of Use (ToU) scheme for energy management to be applied in Gujarat.

- In the first question, a total of 162 responses were received out of which 77.78 % voted NO for any need of machinery/application running 24x7 all 7 days a week, however, 22.22 percent voted YES
- In the following question more than three-quarters of people voted that they do not face any frequent power interruption or fluctuations. On the other hand, people in a certain area faced frequent power fluctuations/interruption
- 23% of people have the flexibility to shift their operation during the day/night for connected load/ appliances. However, 77 % did not show any flexibility
- From the response, it is clear that most of the population are not under Time-of-Day tariff, as there is very little awareness among people that there are different tariff schemes such as real-time or time of use/ critical peak pricing etc.
- 54% people agree that changing (dynamic) electricity rate determined by the market conditions could save money, however, the rest do not think there would be any significant saving due to this
- Due to lack of knowledge and awareness, only 37 out of 162 voted towards, looking forward to installing rooftop solar PV in the next 2 years. Out of those 37 people, 22 were not sure of what capacity or how much energy storage system is needed by them
- As electric vehicle seems to be the future of automotive, approximately 30 percent of people are planning to buy an electric vehicle in the next 20 years
- Smartphones have taken over the market and 95 percent of consumers that took this survey vote that they have a smartphone and use different apps
- It was asked in the survey that does people use apps to save money and 86 percent voted YES, however when they were asked are, they prepared to change their electricity consumption pattern (time) if lower rates are offered 67% of them refused to do so
- People were asked out of their total load how much load they can shift to different time slots in a day
- 71% of people agreed on receiving a subsidized smart switch (programmable thermostat) for heavy appliances that are installed for sufficient incentive and approximately 79 percent are willing to buy smart appliances (including the features of smart switching) which would help optimize operational cost
- More than 90% of the people believe that the electricity bill should show the customers what they would have paid for the same electricity usage under a different rate structure based on time of electricity consumed and the money that the customer would have saved (shadow billing) before actual implementation of the Electricity Consumption Management Program

4.5 Key Findings

The current pricing approach in the power sector in Gujarat receives less attention on demand side management, resulting in high retail prices to meet the cost of production. This study was focused on the awareness of consumers related to electricity tariff and their willingness to participate in ToU. Consumer survey was undertaken of 8 different types of consumers in the UGVCL area and 162 consumer's responses were analyzed for the study. It was found that the consumers are interested to shift their load and majority of the consumers do not face any power fluctuation, they are flexible to shift their operation during the day/night for connected load/ appliances, which clearly indicates the willingness to participate in ToU. Majority of customers are not under Time of Day tariff, it creates a huge scope for consumers to avail ToU facilities. Awareness level is very low among consumers and it demands an aggressive consumer awareness program from DISCOM.

Some people are planning to buy electric vehicles in the next 2 years which will encourage ToU implementation across the state, a very significant portion of consumers are using different smartphone Apps, this will lead to a quick ToU adoption in the state. Consumers are willing to use apps for saving electricity, it shows consumer inclination towards digital applications and a huge potential for ToU where real time pricing signals need to be communicated to the customers. Usage of smartphones will play a minor role in the adoption of ToU. Consumers are willing to understand potential ToU saving for the same amount of power consumption before enrolling to such schemes. Consumers seem price sensitive and are looking for better options. Consumers are willing to adopt ToU and there is a huge untapped market that exists in the state and technological advancement will help to establish a well framed ToU in Gujarat.

5. ANALYSIS OF LOAD CONSUMPTION PATTERNS AND DEVELOPMENT OF THE ToU TOOL

5.1 Analysis of Power Scenario in Gujarat

As on 31.10.2020 the all-India generation installed capacity is 3,73,436 MW which includes 87,269 MW from RES. GoI has planned an ambitious capacity addition target of 175GW from RES by the year 2022.

Gujarat's gross state domestic product (GSDP) grew at a CAGR of 9.9% between FY 2010/11 to FY 2018/19 and contributed 8% to India's total GDP. The state's per capita GDP grew at a CAGR of 8.6% from Rs 87,481 (US$1,715) to Rs 131,583 (US$2,585) during the same period. It is one of the most industrially focussed states in India, with three quarters of Gujarat's state GDP coming from the industrial sector.

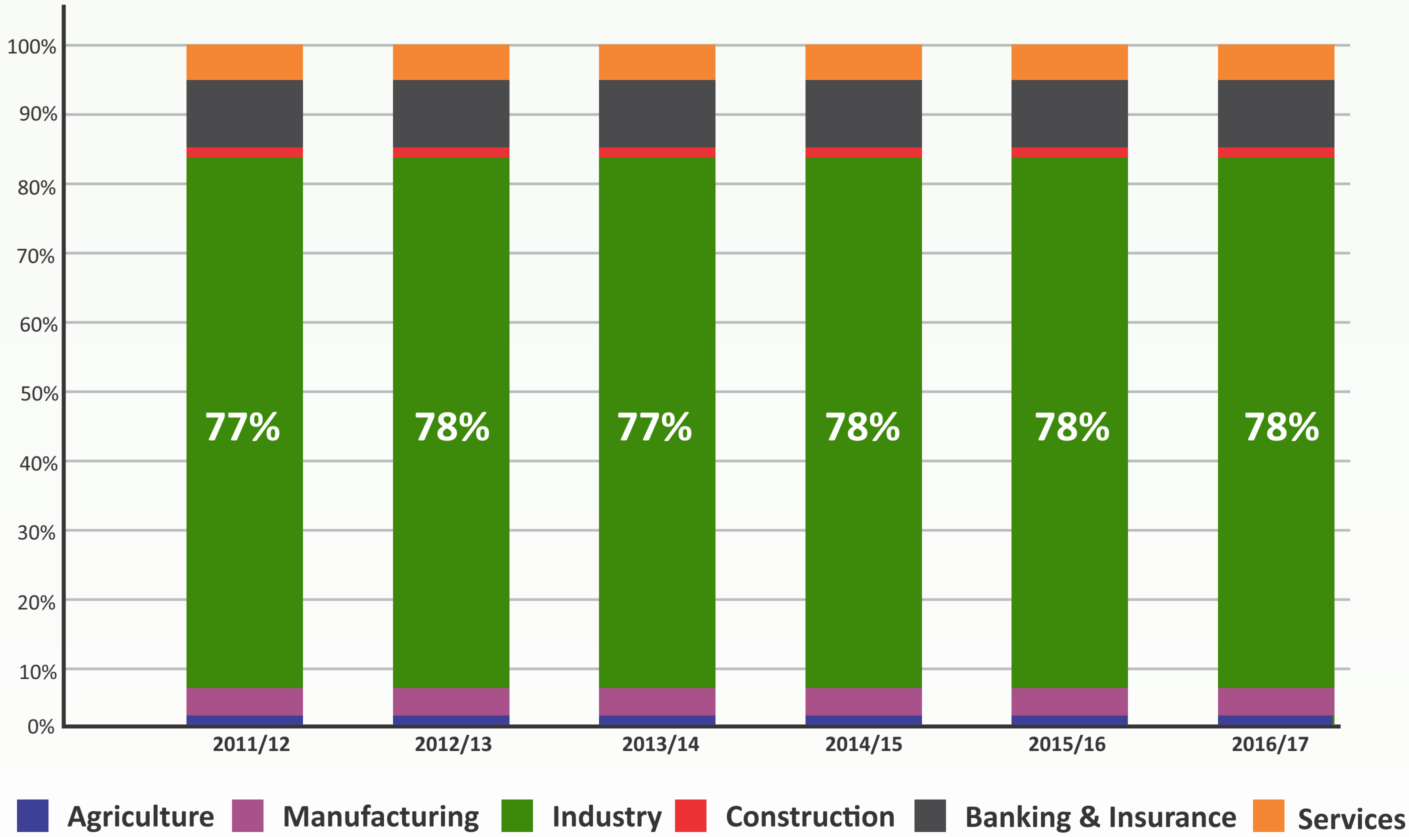


Figure 5-1: Gujarat's GSDP- Industrial Sector's Contribution

As of March 2019, Gujarat had thermal generation capacity of 22.3GW comprising 15.8GW of coal-fired capacity and 6.6GW of gas-fired capacity. This formed 69.1% of total generation capacity and 81.1% of the total generation in Gujarat. In terms of renewable energy, Gujarat is one of the top states for wind with 6GW installed as of FY 2018/19. Another 2GW of solar and 0.5GW of biomass capacity makes the total renewable capacity 8.6GW. Renewables make 26.8% of generation capacity and 11.8% of total consumption in Gujarat.8 New renewable capacity of 1.3GW was added during FY 2018/19.

The power establishment of Gujarat after unbundling of erstwhile Gujarat Electricity Board is shared by four Government owned Distribution Companies - UGVCL, DGVCL, MGVCL and PGVCL and private distribution companies like Torrent Power Limited and MPSEZ.

Demand and Supply Profile

Gujarat has high demand for electricity during April to June and then October to December, according to 2018/19 figures (Figure 5-2). During July to mid-September, Gujarat demand remains low due to the monsoon season. The highest demand experienced during a particular day in FY 2018/19 was 18,221 MW on 21 September 2018.

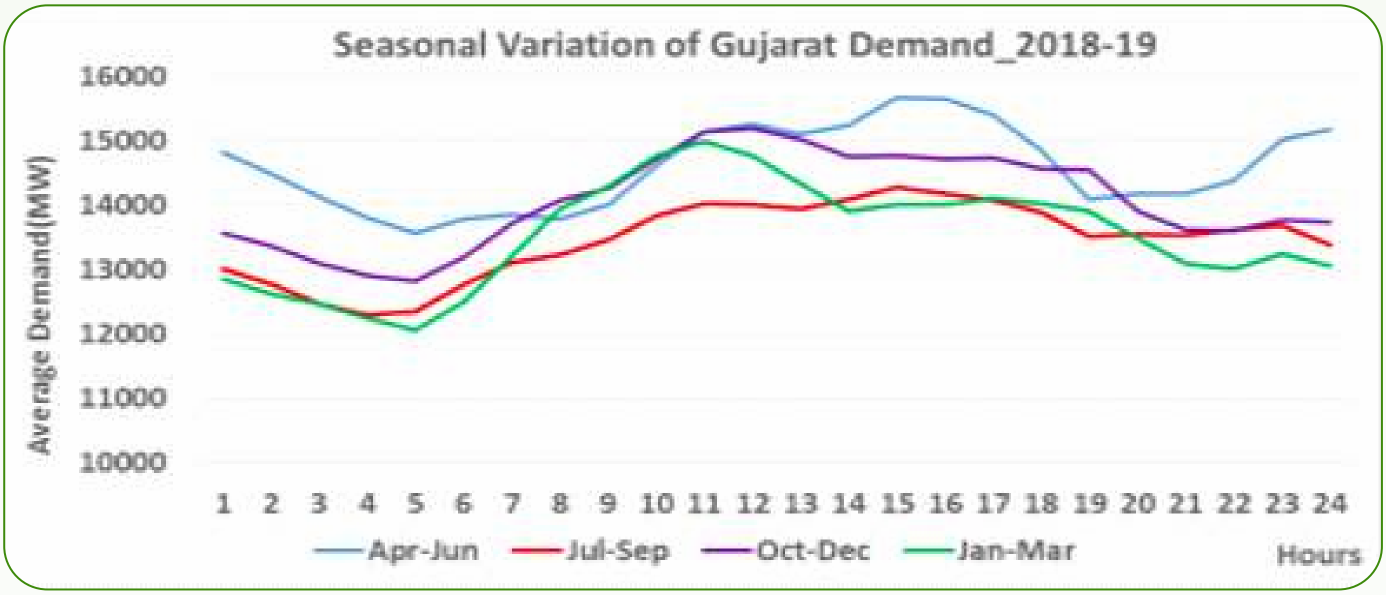


Figure 5-2: Primary design choices of case studies

Source: Western Load Dispatch Centre

Significantly, Gujarat's peak demand occurred between the day hours of 10.00am - 2.00pm, for three quarters of the year from July through to March. During the April to June quarter, peak demand occurred between 2.00pm - 7.00pm, highlighting the value of demand response management and gas- peakers.

5.2 Analysis of Power Scenario in UGVCL

UGVCL is one of the pioneer power distribution utilities in India in the electricity sector. Incorporated under the companies Act, 1956 in September 2003 as a result of unbundling of erstwhile Gujarat electricity board according to power sector reforms initiated by the Central and State Governments, the company became commercially operational from April-2005. The company is a wholly-owned subsidiary of GUVNL, a Government of Gujarat undertaking.

The company serves more than 35 lakh consumers of various categories, such as residential, commercial, industrial, agricultural and others, through 143 sub-division offices and 21 division offices throughout its operational area divided into four circles. The business affairs are managed/taken care of by the corporate office, presently headquartered at Mehsana. The operations are managed by more than 9,258 employees who work across 499 substations.

The various sources of power purchased by GUVNL on behalf of four distribution companies consist of (i) Generating plants of Gujarat State Electricity Corporation Limited (ii) Central sector power plants - NTPC and NHPC, (iii) Renewable sources of power - hydro, solar, wind, and other renewable energy sources (iv) IPPs and (v) Power tied up through competitive bidding etc. The power purchase sources have been differentiated into existing capacity and additional capacity envisaged during the control period.

The existing contracted capacity tied up by GUVNL as on 31st March 2018 is 22,616MW. The additional capacity envisaged during FY 2019-20 to FY 2020-21 is around 1,995MW. Add sentences on the capacity for UGVCL.

5.3 Analysis of Power Scenarios in Naroda Area

Naroda is an industrial area near to Ahmedabad and it was one of the first test beds for Smart Grid Pilots across the country. UGVCL selected this area to understand technical sophistication of Smart Grid implementation and executed a pilot project in Naroda sub division with 24,000 consumers.

5.3.1 Smart Grid Pilot Project in Naroda

To undertake a pilot case for both the Non-Residential General Purpose (NRGP) and Low-Tension Maximum Demand (LTMD) customers with the objective to shift the load of peak period to regular/off-peak period to flatten the load curve with added incentives to consumer and no extra burden (preferably savings) to DISCOMs. The data for the same has been analyzed in following sections.

5.3.2 Power Consumption

UGVCL has projected the energy sales for FY 2019-20 and FY 2020-21 based on historical trends of past years. Wherever the trend seemed unreasonable or unsustainable, the growth factors have been corrected to arrive at more realistic projections.

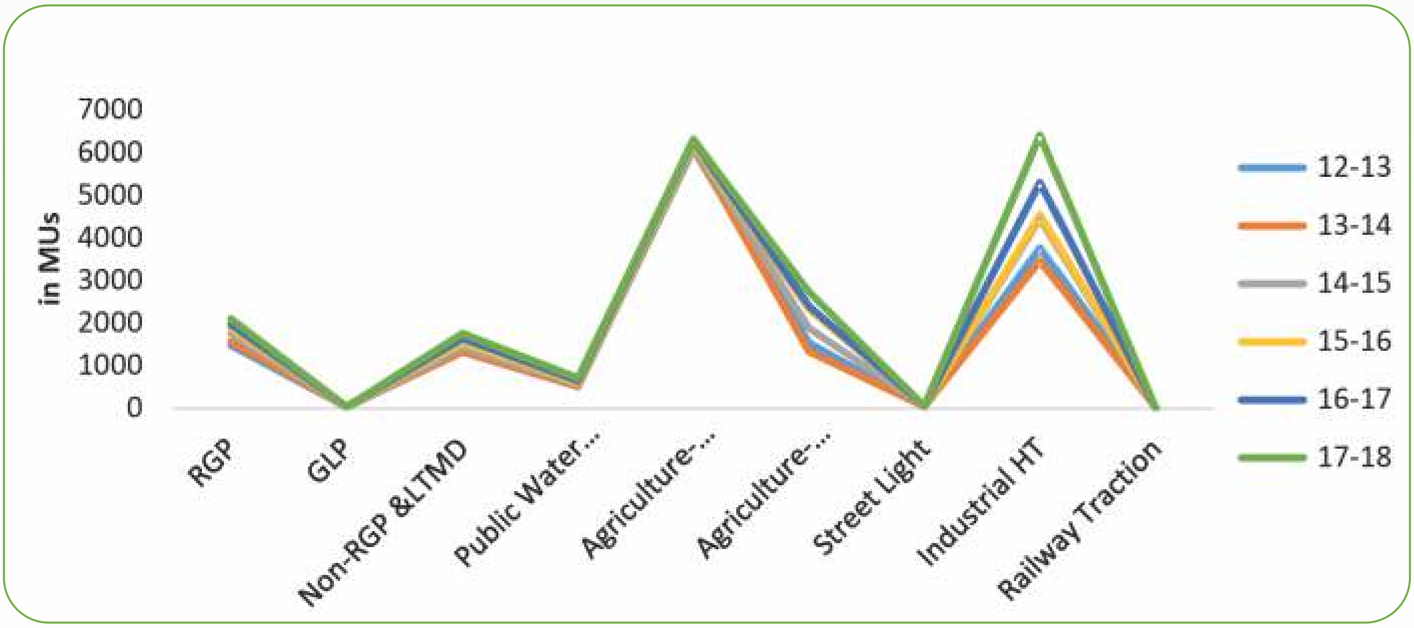


Figure 5-3: Historical trend in category-wise units sold (in MUs)

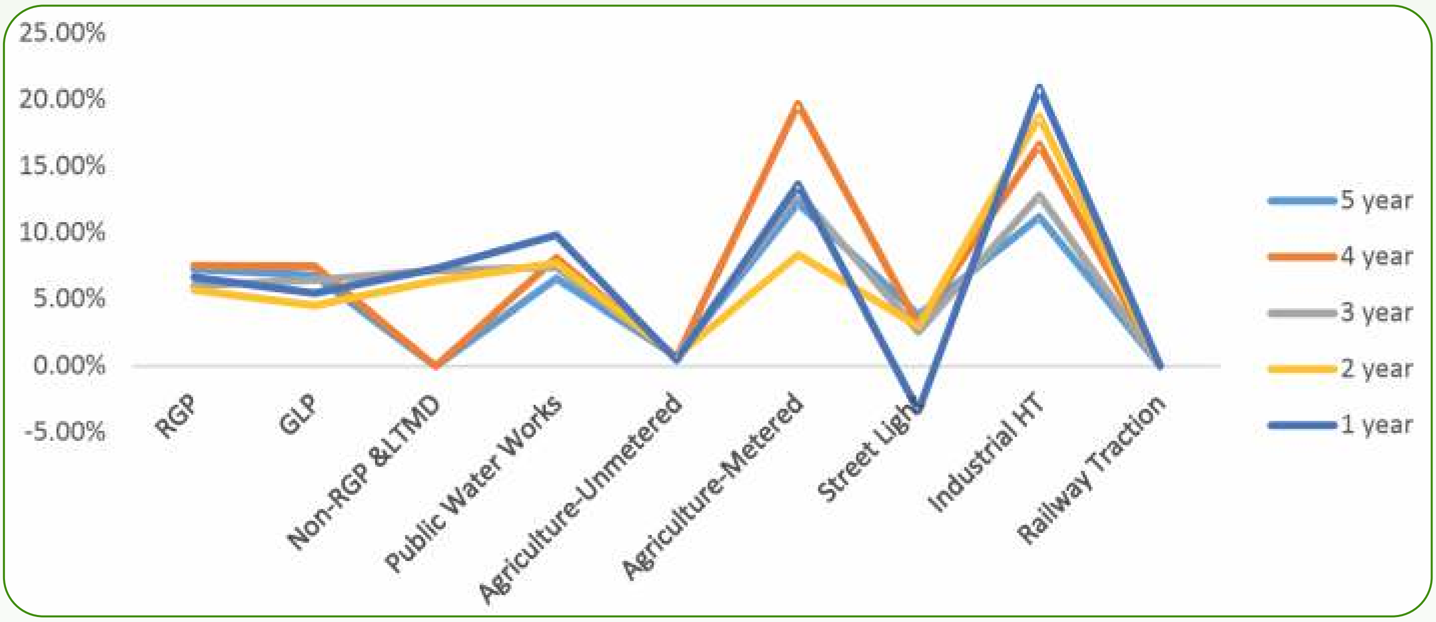


Figure 5-4: Category-wise growth rate of units sold

As shown in Figure 5-3, NRGP and LTMD have consumed a considerable amount of power in the sub-division, and its consumption is almost similar to Residential General Purpose RGP. The importance of these consumers has enhanced in the last few years considerably. As shown in Figure 5-4, the 5-year and 4-year growth rate have not been impressive, however, for the last three years, the sector has performed well with more than 5% growth in consumption.

S. No	Consumer Category	Description
1.	RGP	Residential General Purpose
2.	GLP	General Lighting Purpose
3.	NRGP	Non-Residential General Purpose
4.	LTMD	Low-Tension Maximum Demand
5.	WW	WaterWorks
6.	MSI	Manufacturing and Service Industry

Table 5-1: Consumer Categories

5.3.3 Consumer Profile

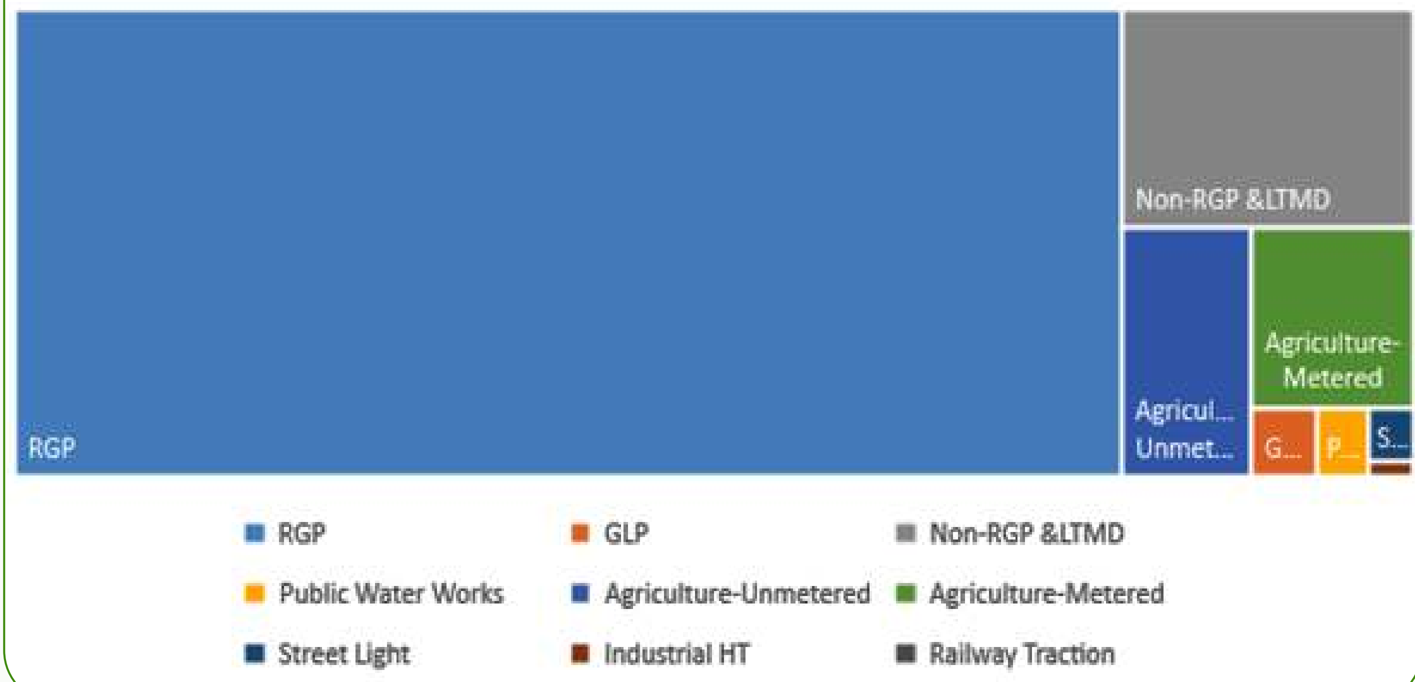


Figure 5-5: Category-wise number of consumers (2012-18)

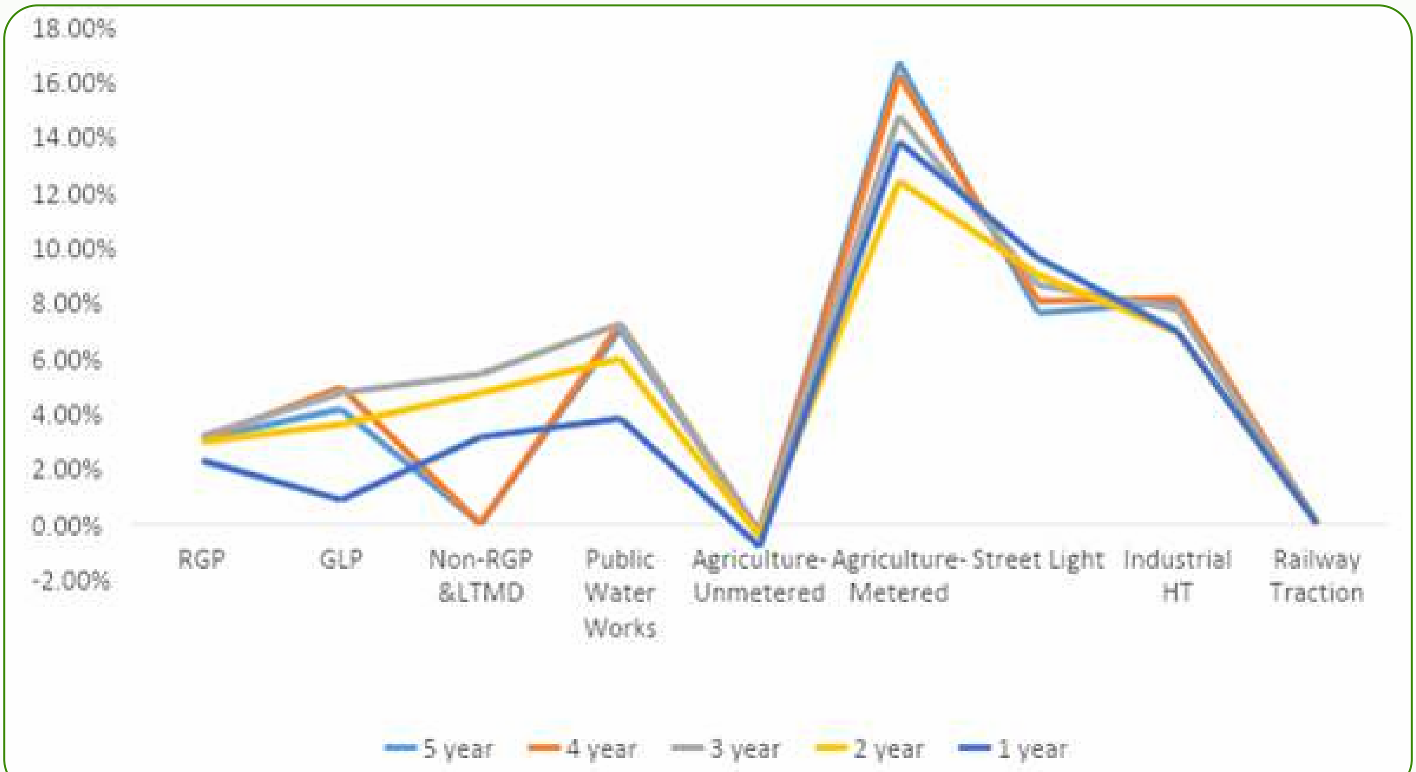


Figure 5-6: The growth rate of the number of consumers

Similar to energy consumption, NRGP and LTMD consumers hold the second-highest position in the area in terms of number of consumers. As shown in Figure 5-5, this category is second to RGP in terms of the total number of consumers and has shown considerable growth in the last three years as illustrated in Figure 5-6.

5.3.4 Category-wise Projected Growth Rates of Energy Sales

UGVCL has projected promising growth for the sector in the future with sales and consumers growing at ~7% and ~5% respectively for the next two years shown in the Figure below.

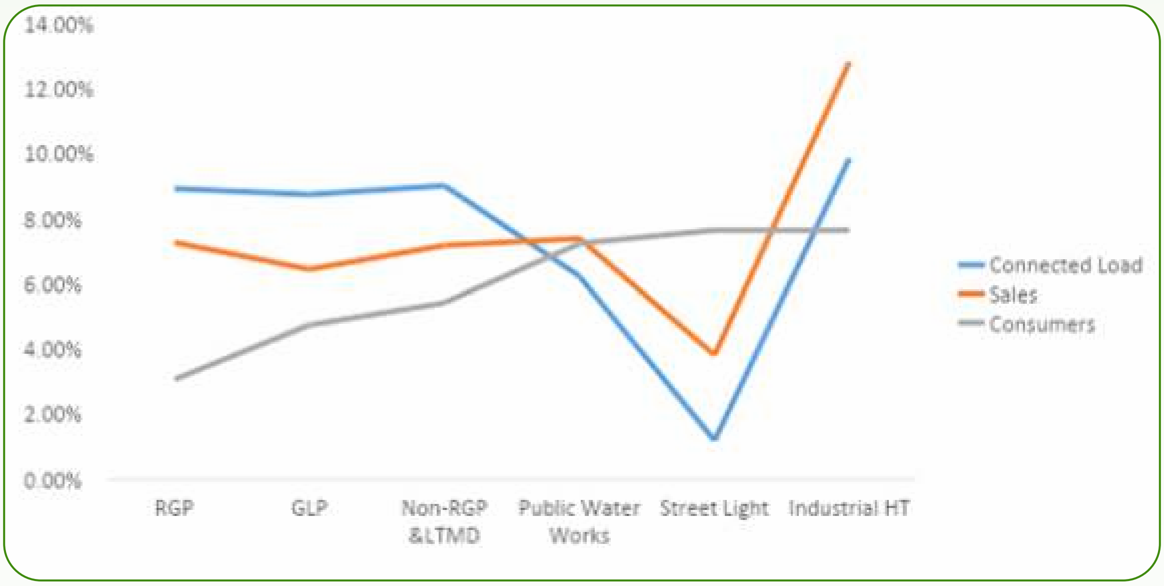


Figure 5-7: Projected growth rates by type of Load

UGVGL expected the 3-year growth rate (CAGR for FY 2012-13 to FY 2015-16) for Non-RGP and LTMD category to be 5.50% for FY 2019-20 and FY 2020-21. However, the entity has revised its estimate and adopted 7.17% as the 3-year CAGR. It considers it reasonable based on the sales of FY 2017-18 and projected sales in the Non-RGP and LTMD segment which respectively are stated at 2025 MUs and 2170 MUs for FY 2019-20 and FY 2020-21.

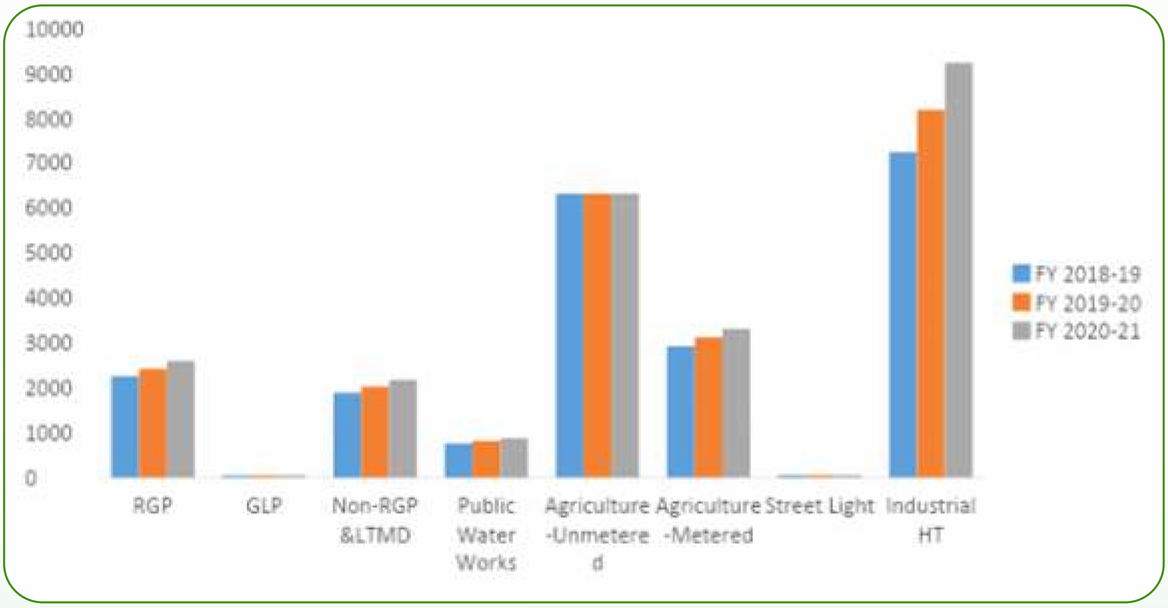


Figure 5-8: Projected energy sales for FY 2018-21 (in MUs)

5.3.5 Revenue from Existing Tariff

The UGVCL estimates the category-wise revenue based on the existing tariff to be Rs. 4461.60 Crore in respect of category-wise sales projected in terms of MUs for FY 2019-20, with NRGP and LTMD contributing close to ~22% of the total revenue.

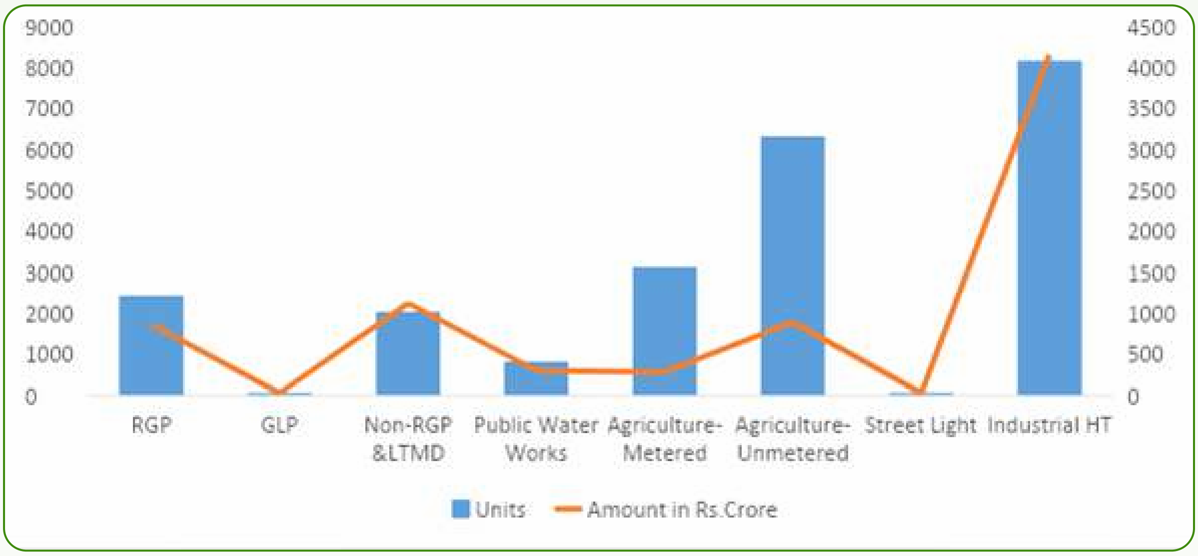


Figure 5-9: Sales (MUs) and revenue (CRS.) from existing tariff projected for FY 2019-20

5.4 Development of ToU Analytical Tool

An excel-based analytical simulation tool has been built based on monthly consumption data for 13 months from January 2019 to January 2020 from the Naroda Smart Grid Pilot Project area. We received the 15-minute interval data of the customers having smart meters in this smart grid project. For each month, the consumption has been averaged by the time of use in 15-minute intervals for a 24-hour period.

The ToU Tool we developed for this project has been tested to undertake the analysis of the impact of peak shifting by offering different levels of discount on tariff to customers and estimate the savings in power purchase cost to DISCOM and savings in electricity bill for customers.

The scenarios tested are to shift 5%, 10%, 15% and 20% load from peak hours to non-peak hours to assess the impact on the overall load curve as well as to estimate the savings in power purchase cost to DISCOM in each of the scenarios. Similarly, the tool was used to estimate the customers savings if the load is moved from peak hours with high tariff to regular or off-peak hours with reduced tariffs.

Further, the following periods have been used for defining peak, non-peak and regular hours:

Peak

6 am to 10 am &
6 pm - 10 pm

Regular

10 am -6 pm

Off-peak

10 pm -6 am

Similarly, we have assumed following power purchase cost and ToU Tariff during peak, regular and off-peak hours:

INR per kWh			ToU Tariff (assumed) for different levels of Load Reduction			
Time slots	**Buy Rate**	**Sell Rate**	**5%**	**10%**	**15%**	**20%**
Peak	6.00	8.00	10	9.8	9.6	9.6
Regular	4.00	7.00	5	5	5	5
Off-peak	3.00	6.00	3	4	4	4

The ToU Tool has the features to change these numbers as per actual or different scenarios can be modelled to estimate both savings in power purchase cost for DISCOM as well as savings in the electricity bills for the customers. Using this tool, the DISCOM can arrive at appropriate ToU tariff and ideal load shifting conditions which will be a WIN-WIN scenario for both the DISCOM and their customers.

5.5 Peak Load Shifting and Related Scenarios

The peak load shifting exercise has been analysed separately for NRGP and LTMD categories of customers and explained in the following sections.

5.5.1 NRGP Profile

Consumption Pattern: Plotted the consumption of NRGP consumers across both the sub-categories, namely NRGPC and NRGPL. As shown in Figure 5-10, for NRGPC consumers the peak comes around twice in a day, 11:15 and 20:15. Similar is the case for NRGPL consumers (Figure 5-11). The load curve for both the sub-categories is distinctly different. However, the scale of the NRGPC consumer is much higher as compared to the latter. Therefore, upon combining both we observe that the peak and shape of the load curve for all NRGP consumers taken together is almost the same as NRGPC.

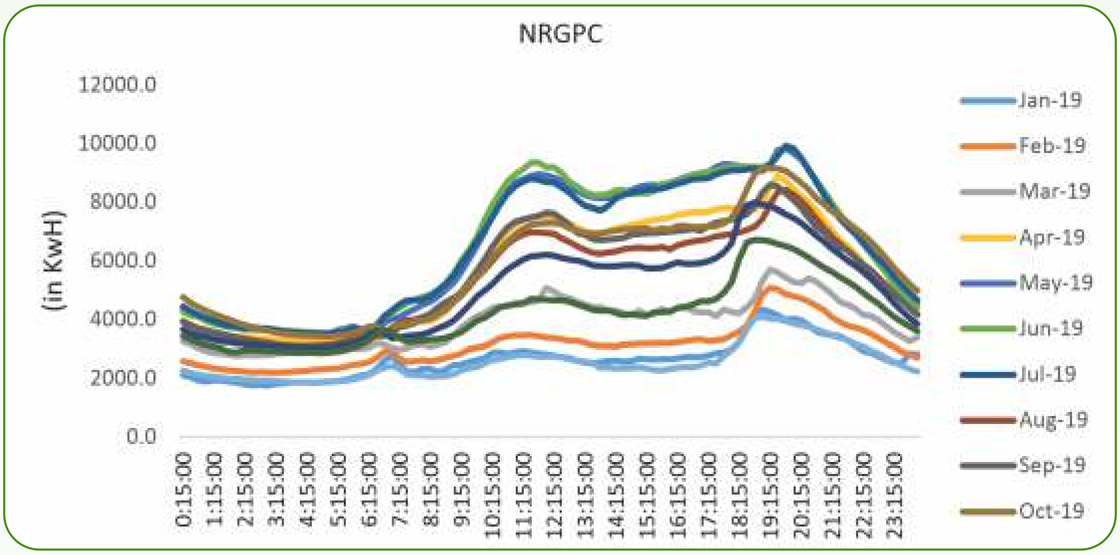


Figure 5-10: Consumption pattern for NRGPC consumers during Jan' 19- Jan' 20

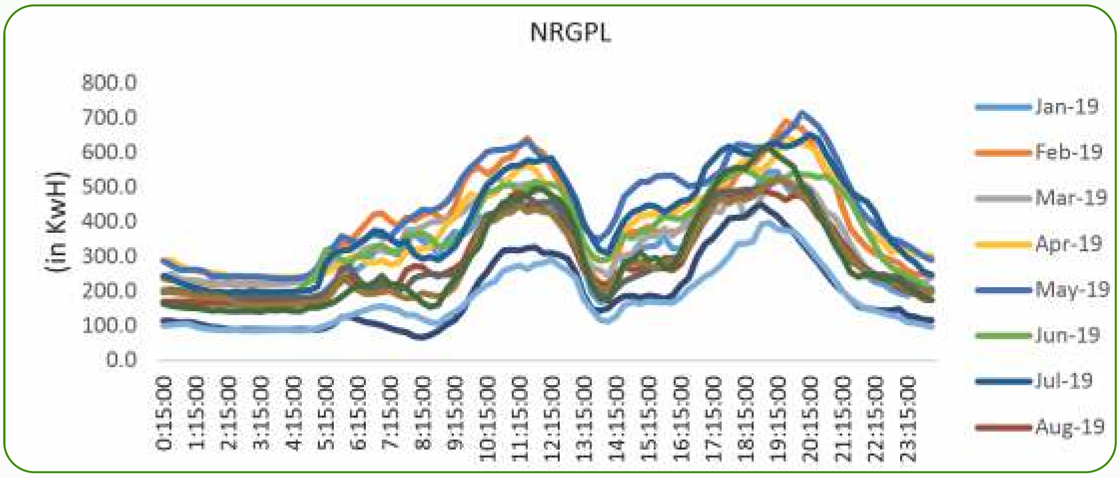


Figure 5-11: Consumption pattern for NRGPL consumers during Jan' 19- Jan' 20

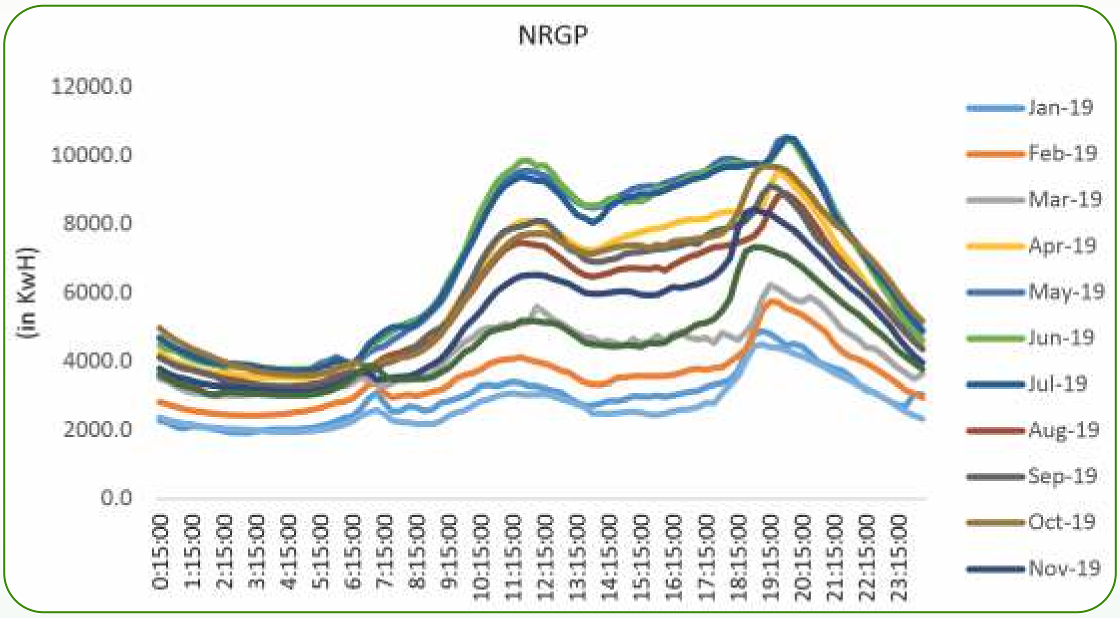


Figure 5-12: Consumption pattern for NRGP consumers during Jan' 19- Jan' 20

Tariff Rate

Day time:

This tariff applies to the services for the premises that are not covered in any other tariff categories and have aggregate load up to and including 40 kW.

Consumers under this category may opt to be charged as per category – 'RATE: LTMD'.

Fixed charges per month	
(a) First 10kW of connected Load	Rs.50/-per kW
(b) For the next 30kW of connected Load	Rs.85/-per kW

Energy charges

For installation having contracted load up to and including 10kW: for entire consumption during the month	435 paisa per Unit	For installation having contracted load exceeding 10kW: for entire consumption during the month	465 paisa per Unit

Nighttime:

This tariff is applicable for aggregate load up to 40 kW and uses electricity exclusively during night hours from 10:00PM to 06:00AM next day. (The supply hours shall be regulated through a time switch to be provided by the consumer at his cost.)

Fixed charges per month	
50% of the Fixed charges specified in Rate Non-RGP above.	
Plus	
Energy charges	
For entire consumption during the month	260 Paisa per Unit

5.5.2 LTMD Profile

Consumption Pattern: Plotted the consumption of LTMD consumers across both the sub-categories, namely LTMDC and LTMDL. As shown in Figure 5-13, for LTMDC consumers the peak comes around twice in a day, 13:15 and 21:15. In the case of LTMDL consumers (Figure 5-14) the peak takes place once at 10:30. The load curve for both the sub-categories is distinctly different. However, the scale of the LTMDC consumer is much higher as compared to the latter. Therefore, upon combining both we observe that the peak and shape of the load curve for all LTMD consumers taken together is almost the same as LTMDC.

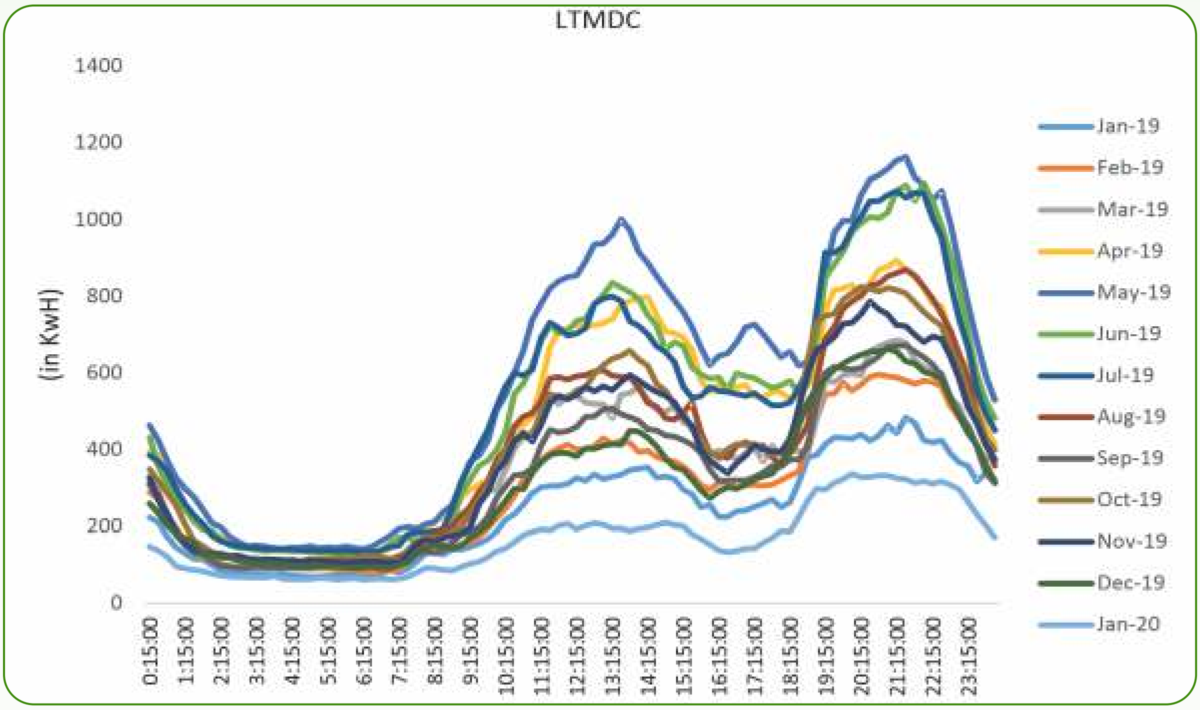


Figure 5-13: Consumption pattern for LTMDC consumers during Jan' 19- Jan' 20

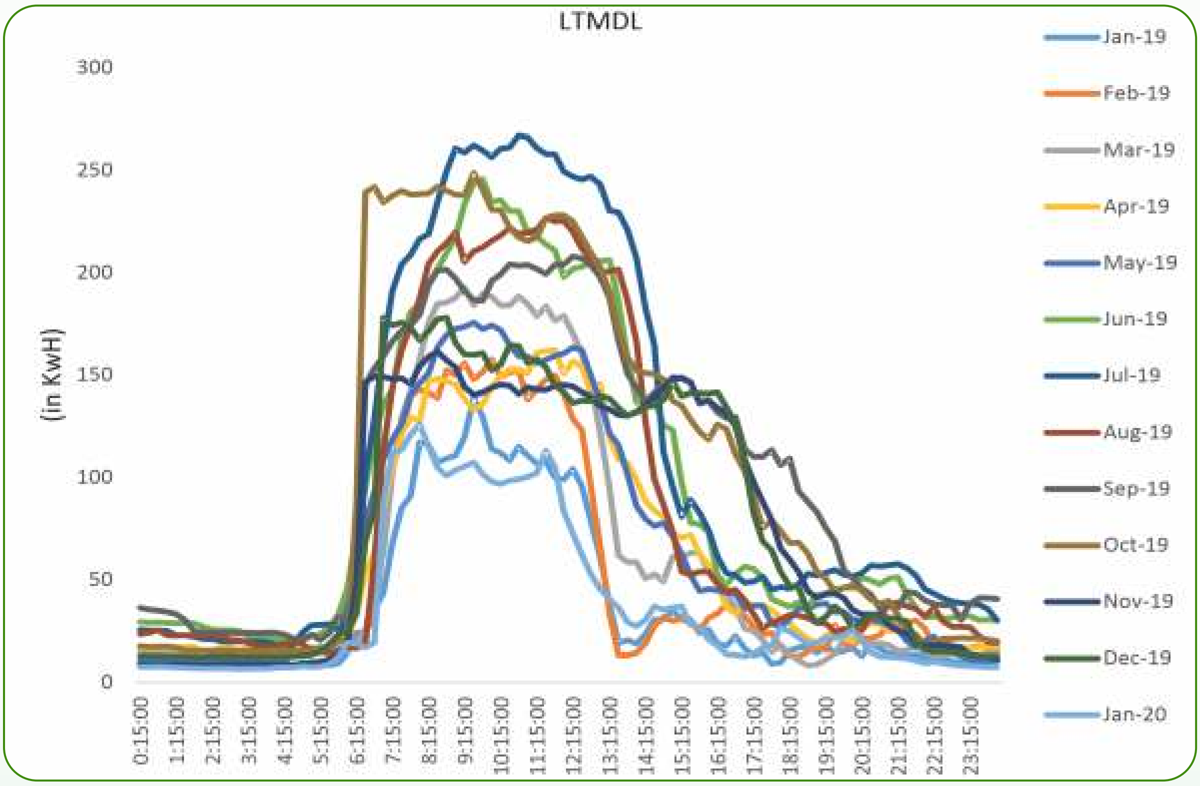


Figure 5-14: Consumption pattern for LTMDL consumers during Jan' 19- Jan' 20

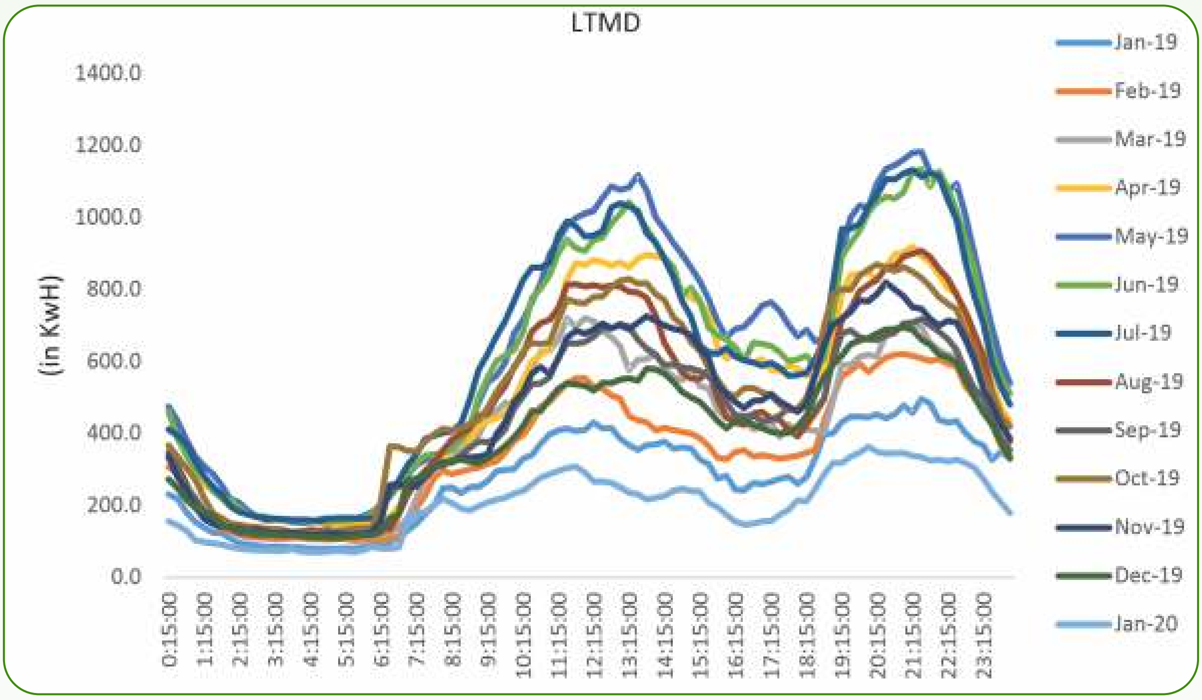


Figure 5-15: Consumption pattern for LTMD consumers during Jan' 19- Jan' 20

Tariff Rate

Day time:

This tariff applies to the services for the premises that are not covered in any other tariff categories and have aggregate load above 40 kW and up to 100 kW.

This tariff shall also apply to consumers covered in category- 'Rate: Non-RGP' so opts to be charged in place of 'Rate: Non-RGP' tariff.

Fixed charges		
For billing demand up to the contract demand		
(a)	(I) For the first 40kW of billing demand	Rs. 90/-per kW per month
	(ii) Next 20kW of billing demand	Rs. 130/-per kW per month
	(iii) Above 60kW of billing demand	Rs.195/-per kW per month
(b)	For billing demand over the contract demand	Rs.265/-per kW

Energy charges

For entire consumption during the month	460 Paisa per Unit

+

Reactive energy charges:

For all the reactive units (kVArh) drawn during the month	10 paise per kVArh

Nighttime:

This tariff is applicable for an aggregate load above 40kW and using electricity exclusively during night hours from 10.00PM to 06.00AM next day. (The supply hours shall be regulated through a time switch to be provided by the consumer at his cost.)

Fixed charges
50% of the Fixed charges specified in Rate LTMD above

Energy charges

For entire consumption during the month	260 Paisa per Unit

+

Reactive energy charges:

For all the reactive units (kVArh) drawn during the month	10 paise per kVArh

5.6 Approaches and Assumptions for the Development of Analytical Tools

For implementing the dynamic tariff for the consumers, an alternative approach can be adopted by the utility by analysing the load curve to identify peak hours and off-peak hours. Thereby, based on the consumption pattern, the consumption can be offset from peak load period to non-peak period and a differential pricing can be incorporated based on the respective load pattern.

For instance, below Figure depicts the power consumption pattern for the 13-month period from January 2019 to January 2020 wherein consumption peak occurs twice a day - firstly during midnight, and secondly around 3pm.

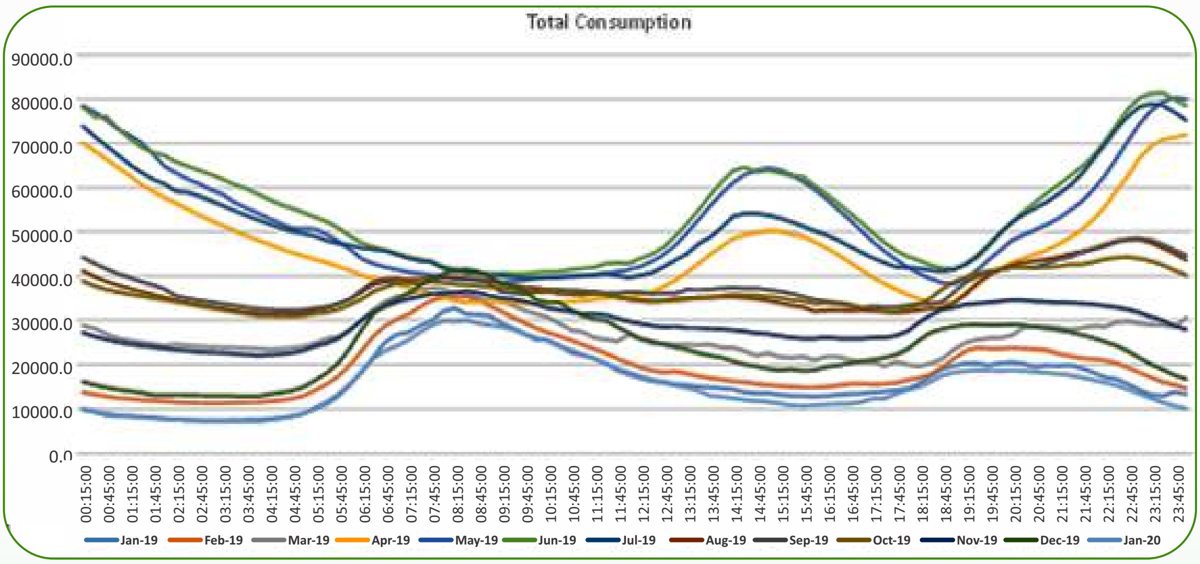


Figure 5-16: Total consumption pattern for all consumer in Naroda area (in KWh) (Jan-19 to Jan-20)

5.6.1 Generation Based Approach

From analysing the total load curve, we propose to formulate a generator-specific calibrated model which would be able to propose a tariff structure that incentivises to level the load curve by the re-distributing of the additional load from the peak hours to low-consumption/non-peak hours of the day. Thereby, the utility can bring down its purchasing cost of power by shifting from an expensive peak load time to purchasing from generators which have comparatively lower price during off-peak hours, and consequently also re-designing tariff structure for its customers with higher tariffs during peak hours and lower tariffs during non-peak hours.

5.6.2 Category Based Approach

Under this approach, we propose to formulate a category-specific calibrated model which would be able to propose a tariff structure to level the load curve by the re-distributing of additional load during the peak hours to low-consumption time of the day. Based on the consumption pattern of different categories of consumers, differential pricing can be incorporated with a focus on a respective load pattern.

For instance, shown below Figure-5-17 depicts the power consumption pattern for NRGP category of consumers for the period January 2019 to January 2020. The consumers of this category show peak load twice in a day- First, during 12 noon and second, during 8pm.

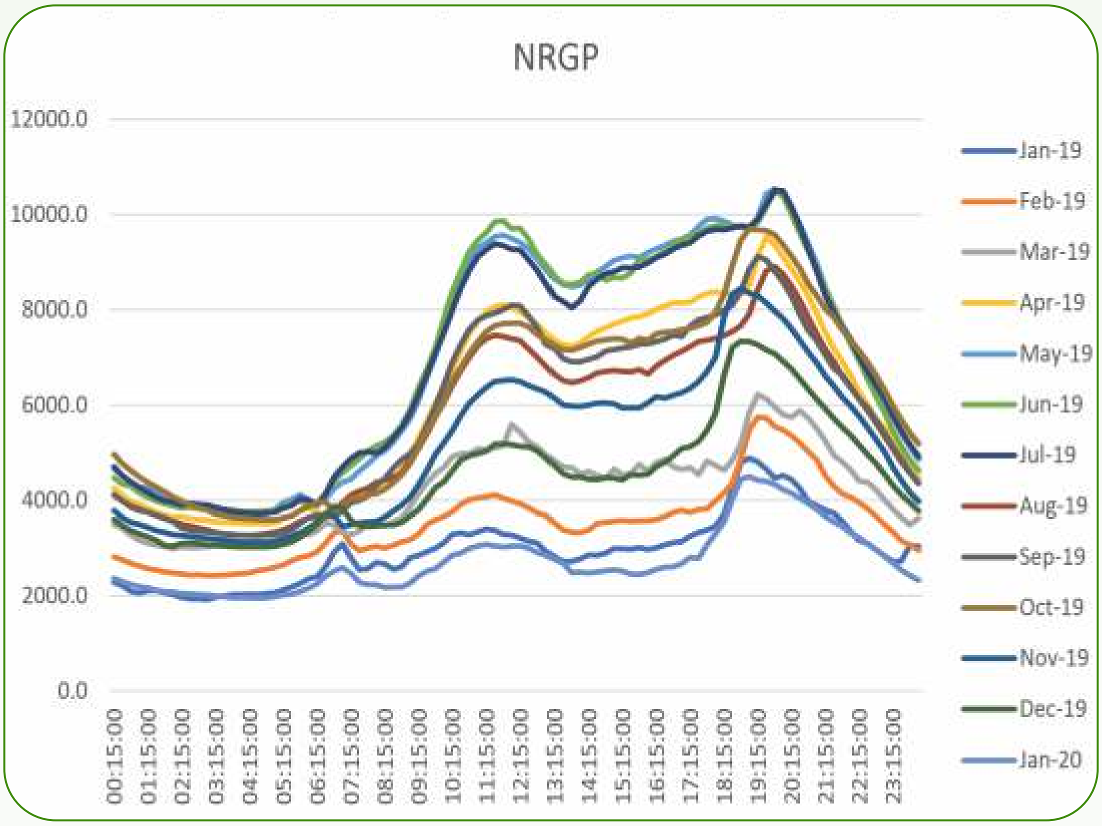


Figure 5-17: Consumption pattern for NRGP consumer in Naroda area (in KWh) (Jan-19 to Jan-20)

Taking into consideration our requirements for the analysis, it was decided to opt for the category-based approach for NRGP and LTMD consumers.

5.6.3 Development of an Analytical Framework for Dynamic Tariff

Based on the key insights provided by the load analysis in the earlier sections, propose to take a robust framework-based approach for undertaking a pilot level dynamic pricing project in the Naroda region.

As evident from Figure 5-12 and Figure 5-15, NRGP consumers have an average consumption much higher as compared to LTMD consumers. Therefore, to understand the effectiveness of dynamic pricing on shifting the load and flattening the load curve, it is essential to focus on the top cohort of consumers in the NRGP category.

Figure 5-18: Illustrative framework of dynamic pricing implementation

Based on the illustration above, the approach would be to focus on taking a consultative path with all relevant stakeholders and agree upon dynamic pricing for a selected group of high-demand consumers. These consumers would be given an optional mechanism to re-align their consumption from peak to off-peak periods in a manner which would help in flattening the load curve as illustrated in Figure 5-10. There would be a detailed study and project management to understand the customer requirements, facilitating in the shifting of the consumption to off-peak times and an analysis of the impact on the load curves. Further, the project management team will address smooth transition, monitor load behaviour and impact on consumers as a part of the simulations and accordingly provide response assessment to maintain grid stability and consumer business continuity while flattening the load curve. The process will be iteratively incorporating the feedback and control mechanisms to avoid major disruptions.

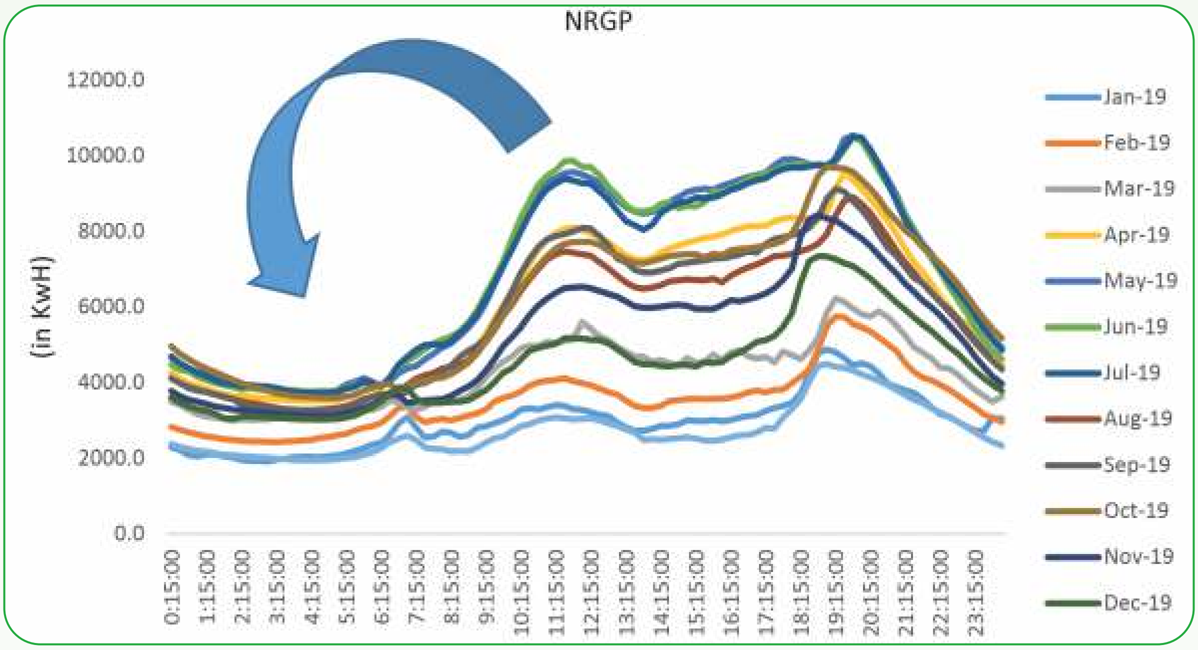


Figure 5-19: Dynamic pricing model- Shift in the load curve

5.6.4 LTMD

LTMD peaks at two distinct time intervals (as shown in Figure 5-20) across two quarters, namely April-May-June and July-August-September. We have proposed quarter-wise shift of these two peaks at different scales (5%, 10%, 15% and 20%) as illustrated respectively quarter 1 load shift (Apr-June) in Figure 5-21, 5-22, 5-23, 5-24 and quarter 2 load shift (July – Sep) in Figure 5-25, 5-26, 5-27 and 5-28.

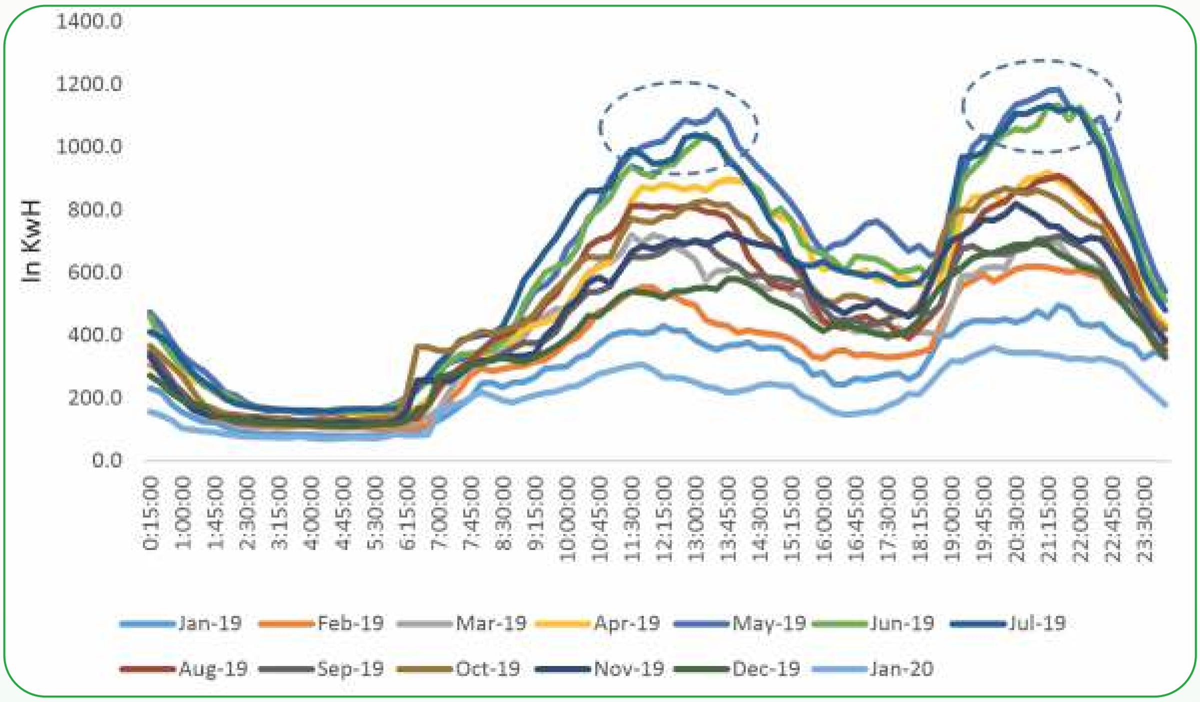


Figure 5-20: Load curve for LTMD consumers

Quarter 1 load shift:

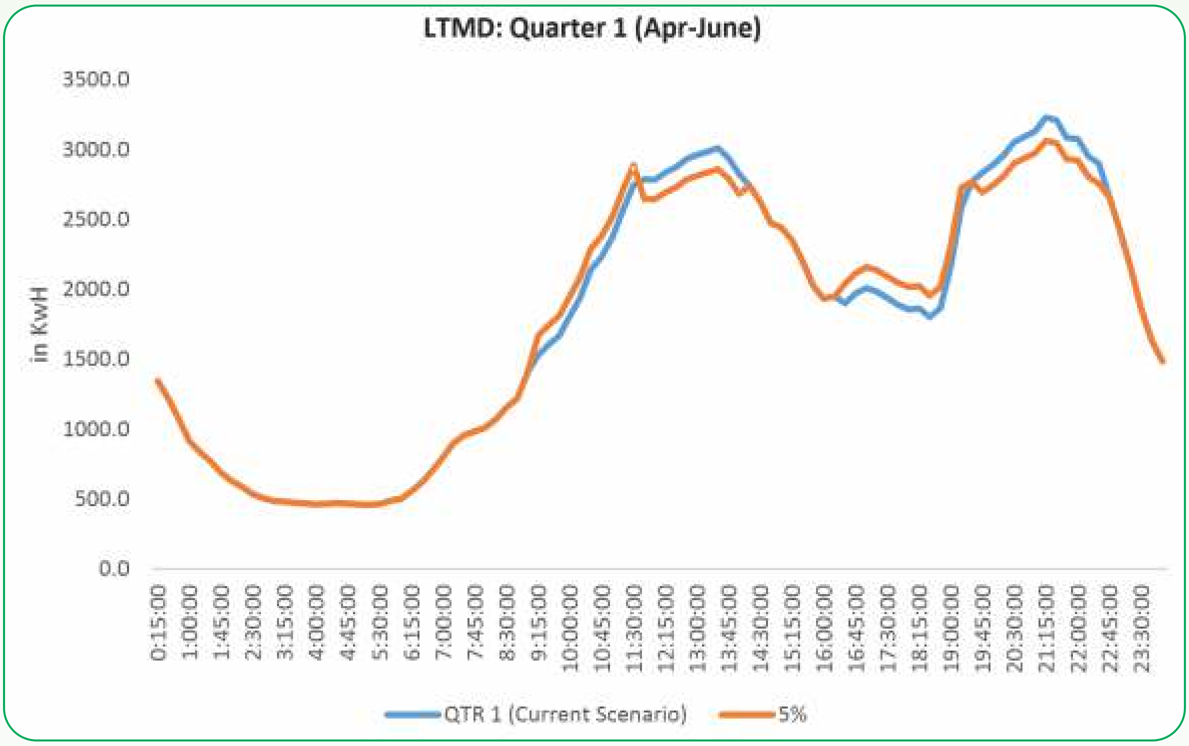


Figure 5-21: Change in LTMD load curve in Apr-May-June due to 5% load shift

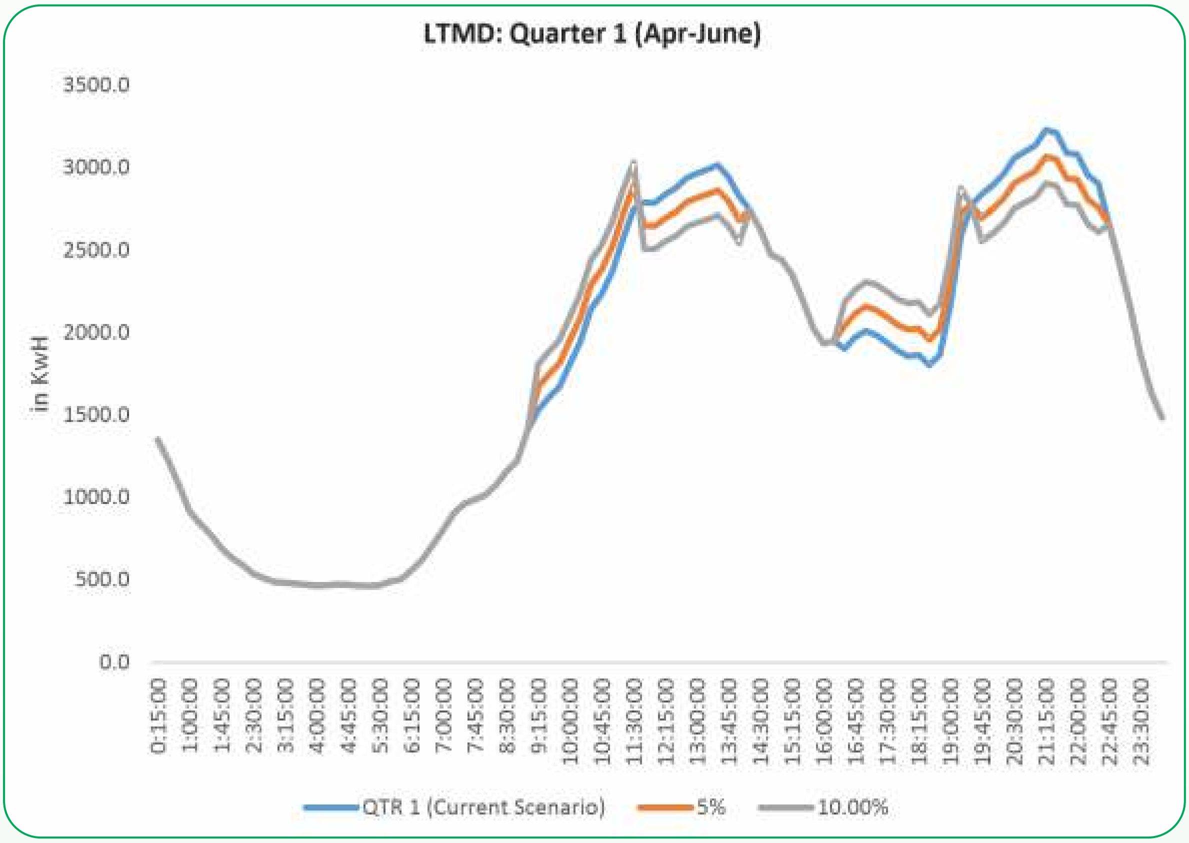


Figure 5-22: Change in LTMD load curve in Apr-May-June due to 5% and 10% load shift

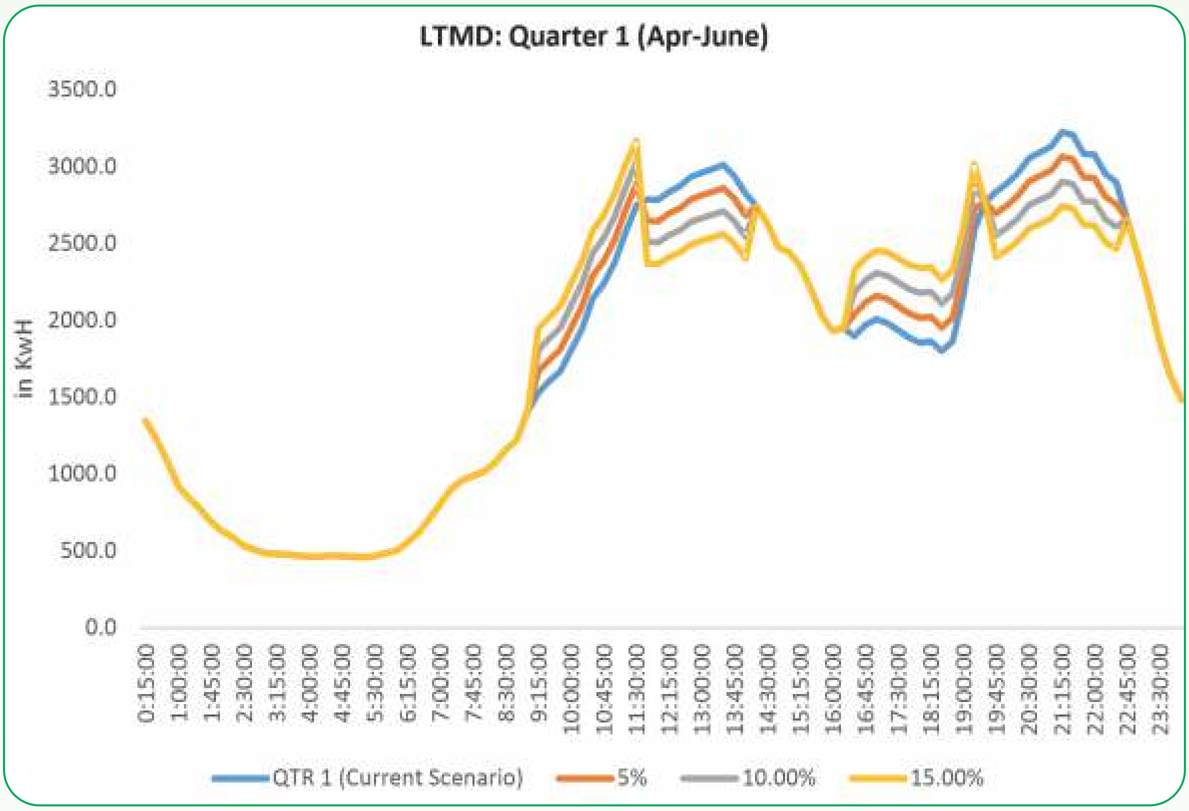


Figure 5-23: Change in LTMD load curve in Apr-May-June due to 5%, 10% and 15% load shift

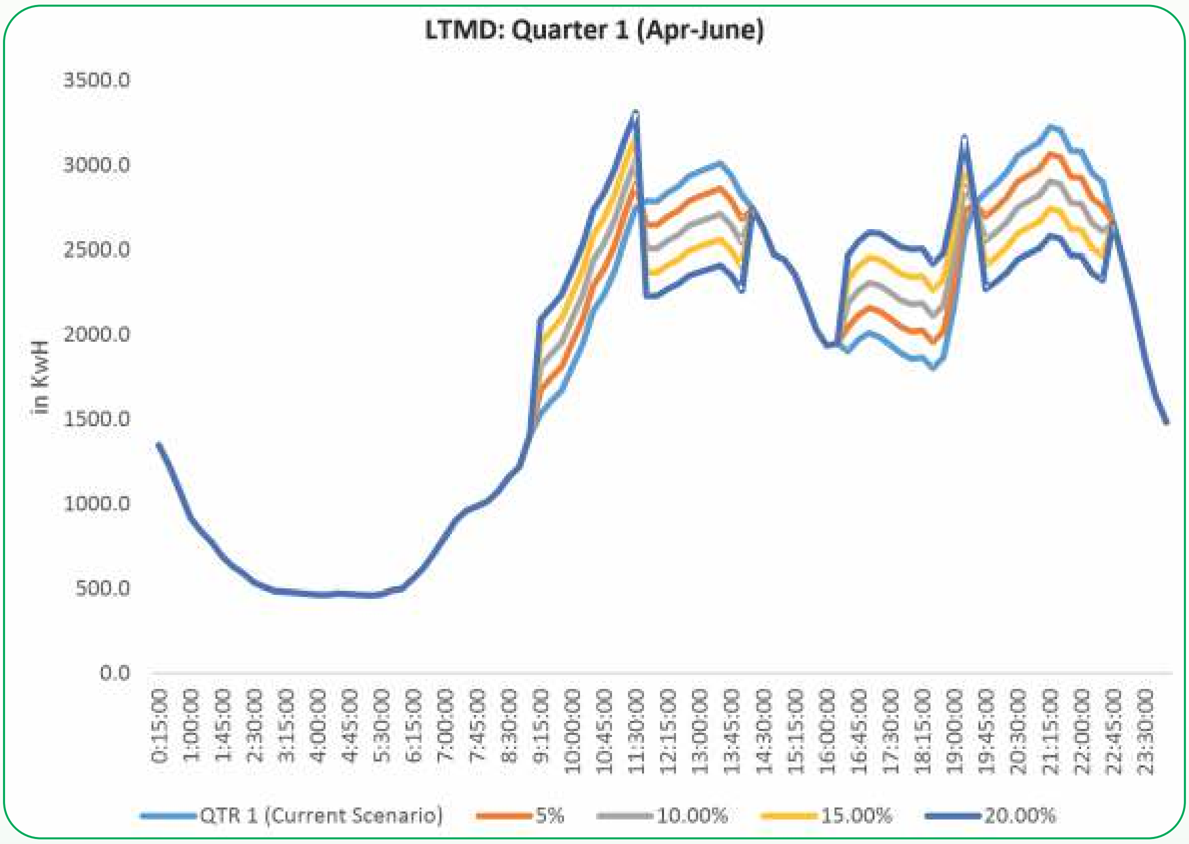


Figure 5-24: Change in LTMD load curve in Apr-May-June due to 5%,10%, 15% and 20% load shift

Quarter 2 load shift:

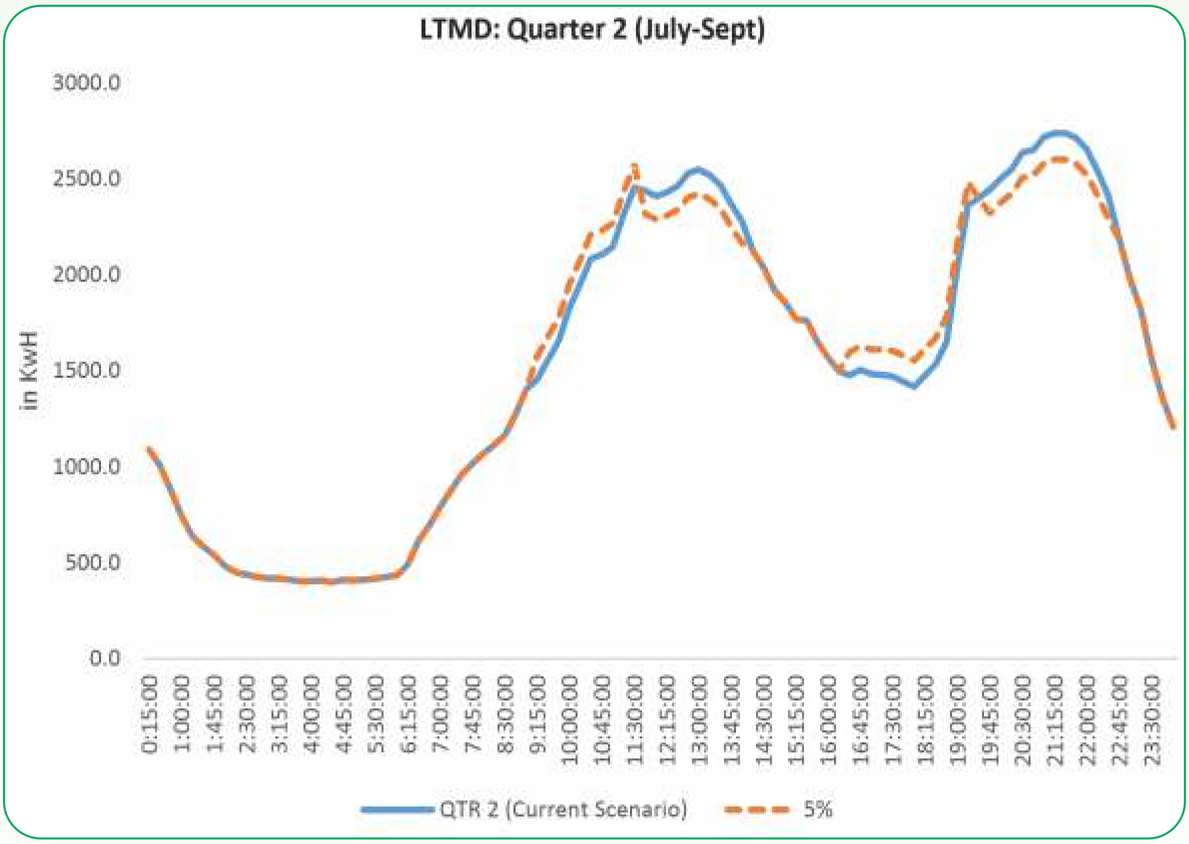


Figure 5-25: Change in LTMD load curve in July-Aug-Sept due to 5% load shift

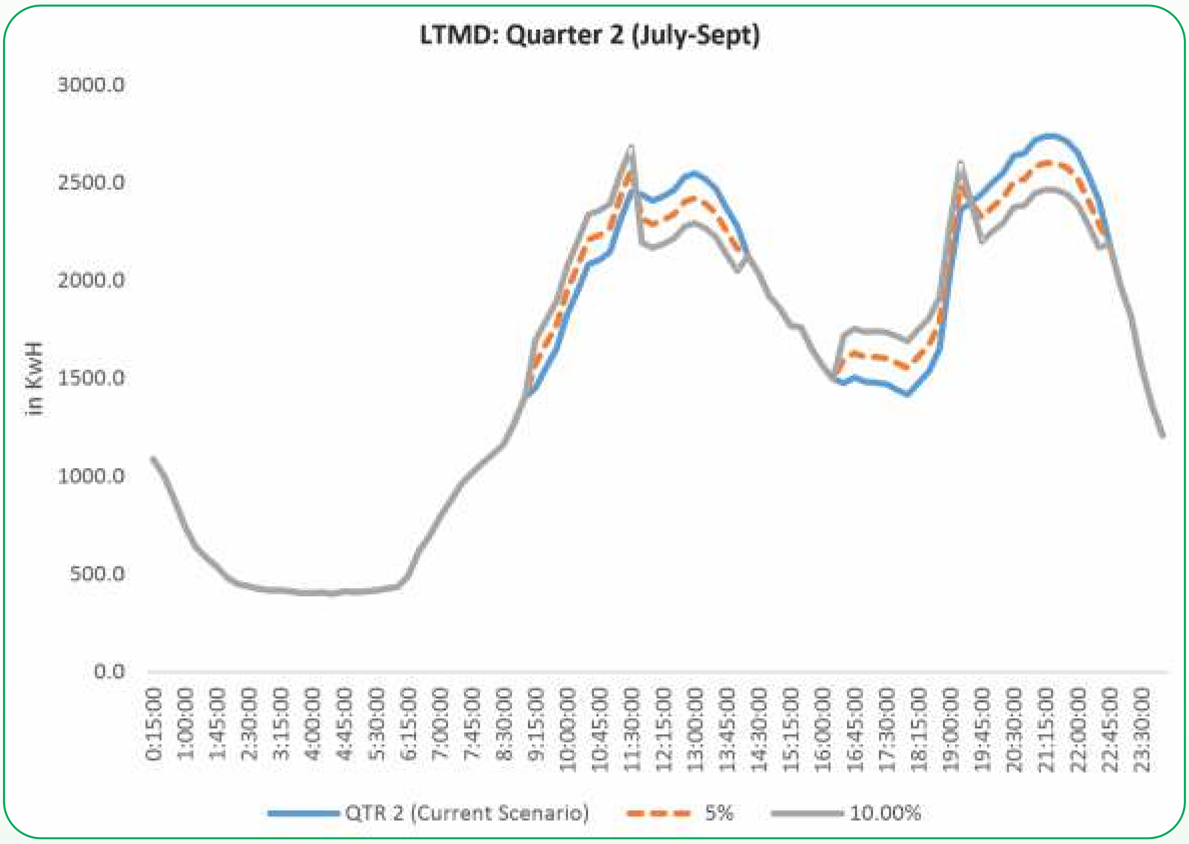


Figure 5-26: Change in LTMD load curve in July-Aug-Sept due to 5%, 10% load shift

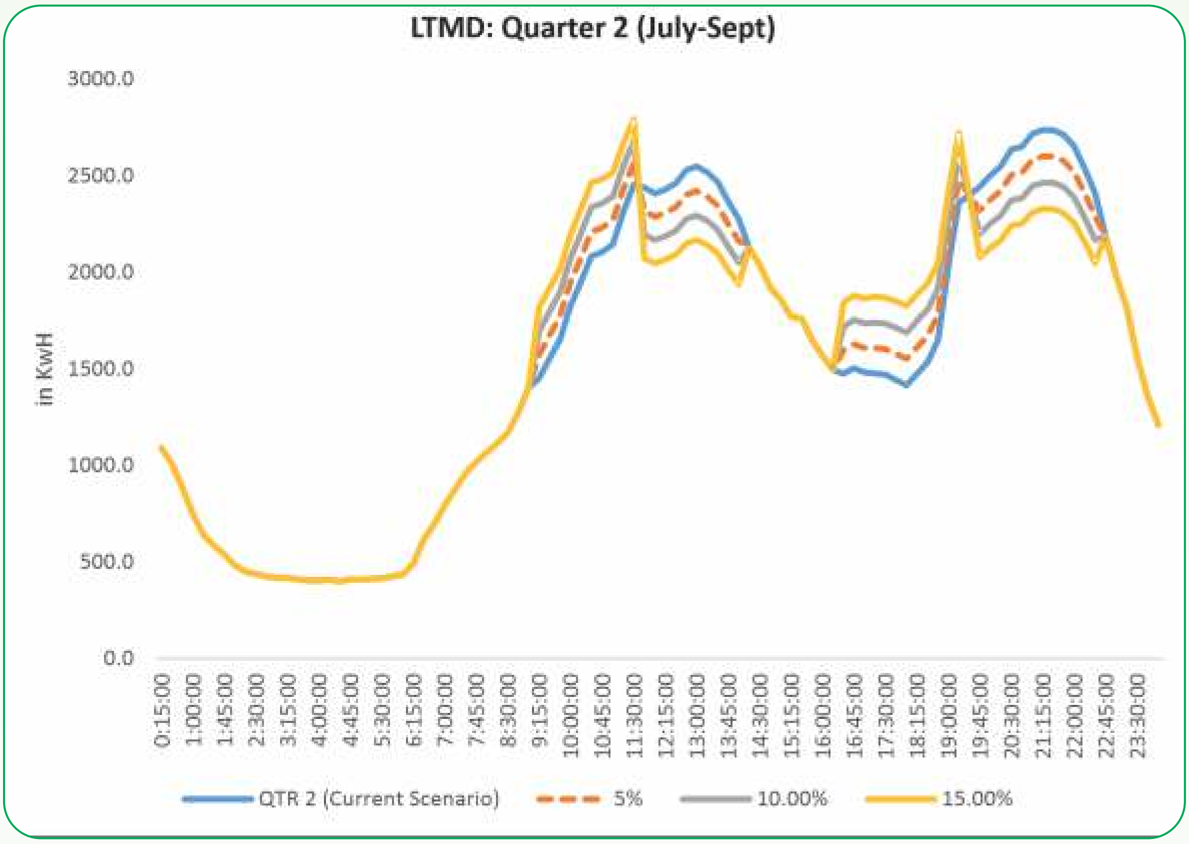


Figure 5-27: Change in LTMD load curve in July-Aug-Sept due to 5%, 10%, and 15% load shift

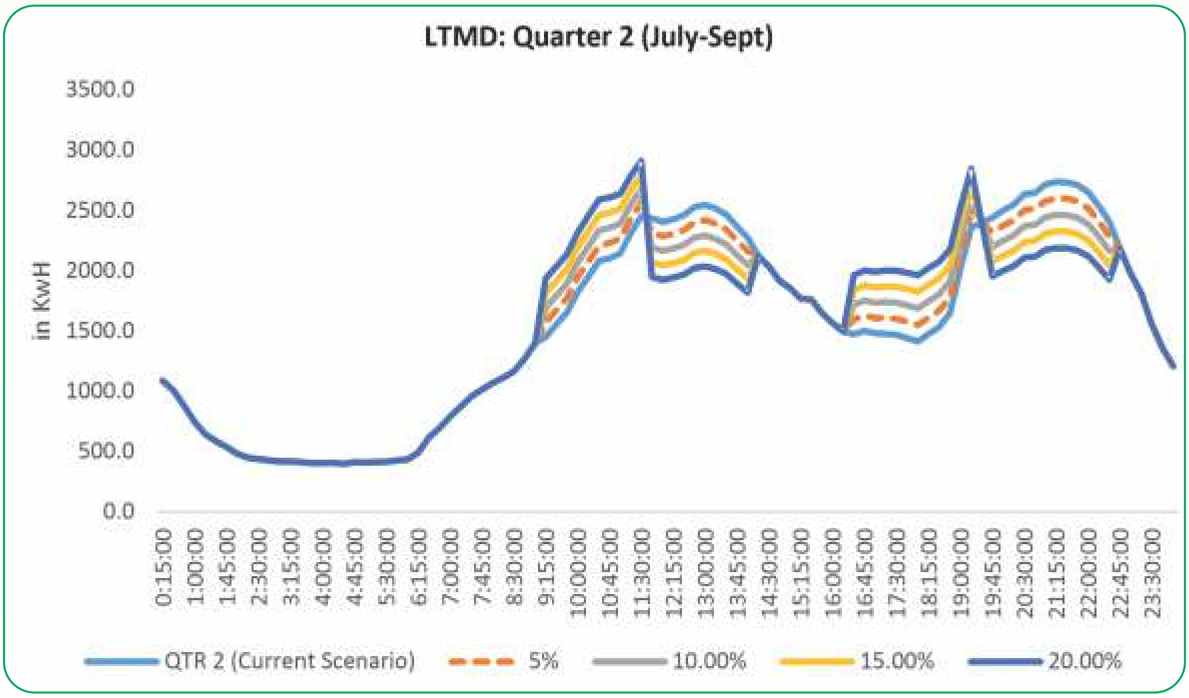


Figure 5-28: Change in LTMD load curve in July-Aug-Sept due to 5%, 10%, 15% and 20% load shift

Figures 5-21 to 5-28 indicate that the load curve moves the peak load to the left for a non-peak period, thereby reducing the total load during the peak period. We see a pattern in both quarters where this change will help flatten the overall load curve.

At the same, the impact of these shifts on revenue and costs of the DISCOM is illustrated below using differential pricing (ToU) for regular, peak and off-peak periods.

In per KWh (assumed rates)			ToU Tariff (assumed) for different levels of Load Reduction			
Time slots	Buy Rate	Sell Rate	5%	10%	15%	20%
Peak	6.00	8.00	9.1	10.4	10.4	10.4
Regular	4.00	7.00	5	5	5	5
Off-peak	3.00	6.00	3	4	4	4

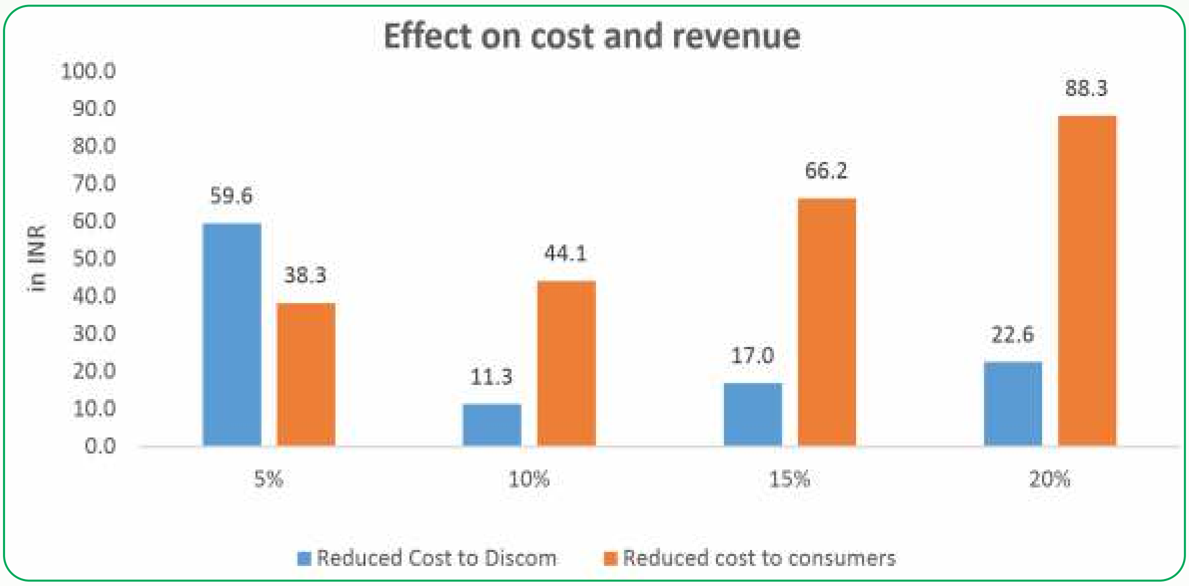


Figure 5-29: Financial impact on DISCOM and LTMD customers for the suggested ToU pricing above

Please note in the previous figure, (i) reduced cost to DISCOM is the difference between their revenue and cost respectively in both the scenarios (ii) reduced cost to consumers is the savings in total cost incurred comparing both the scenarios.

5.6.5 NRGP

NRGP peaks at two distinct time intervals (as shown in Figure 5-30) across two quarters, namely April- May-June and July-August-September. We have proposed quarter-wise shifts of these two peaks at different scales (5%, 10%, 15% and 20%). At the same, we have shown the impact of these shifts on revenue and costs of the DISCOM.

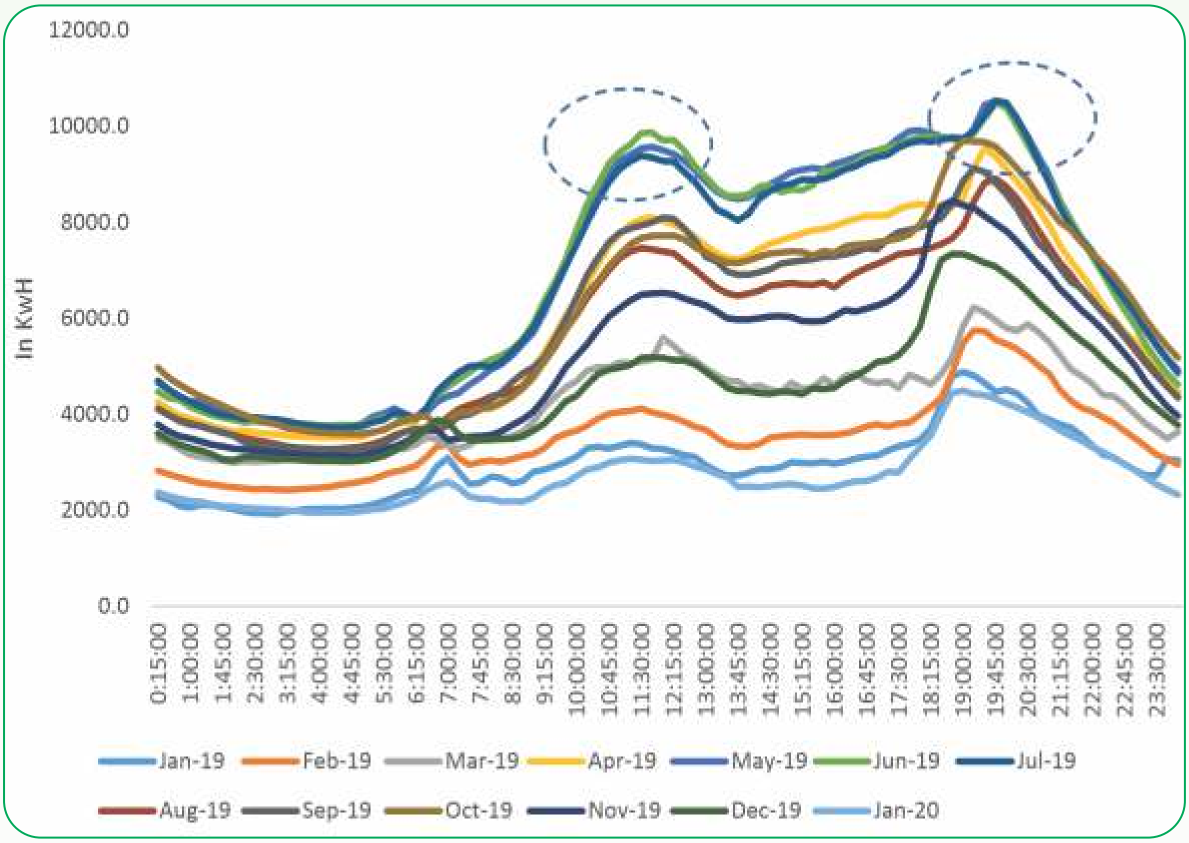


Figure 5-30: Load curve for NRGP consumers

Quarter 1 load shift:

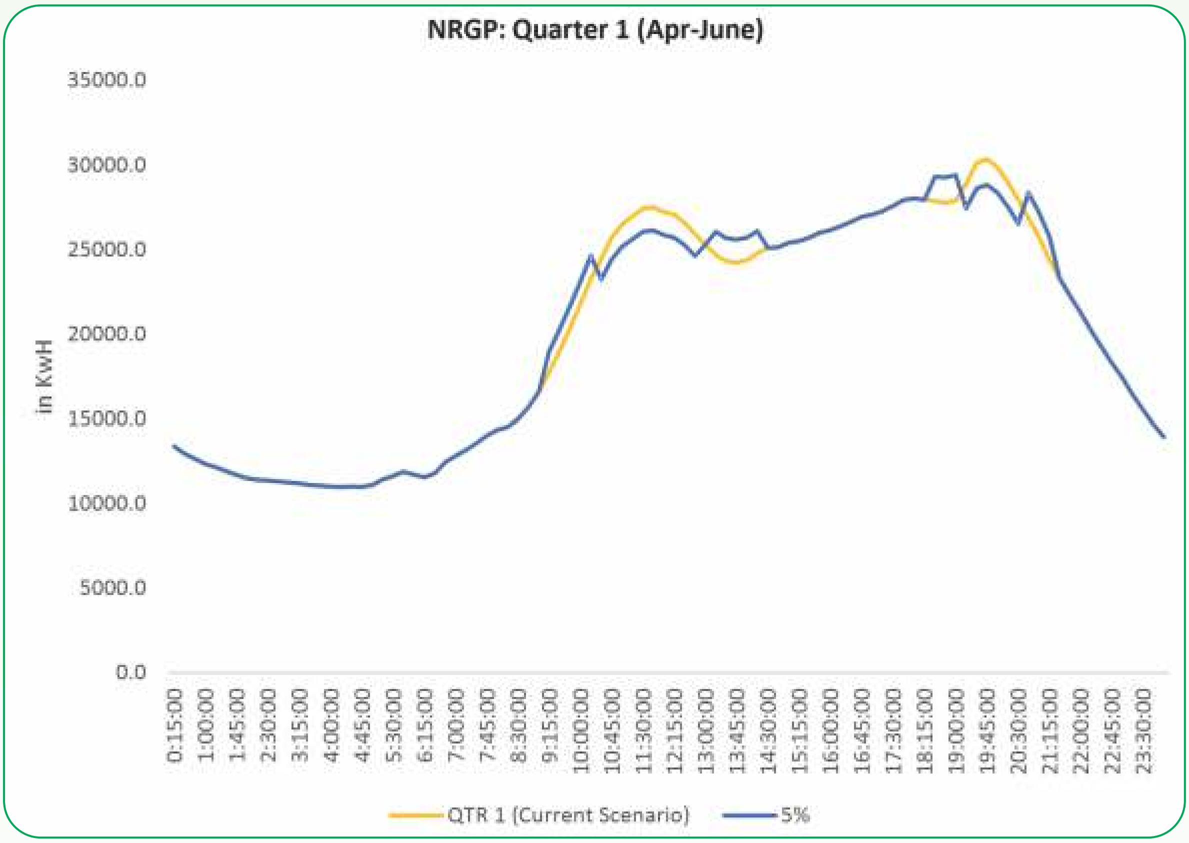


Figure 5-31: Change in NRGP load curve in Apr-May-June due to 5% load shift

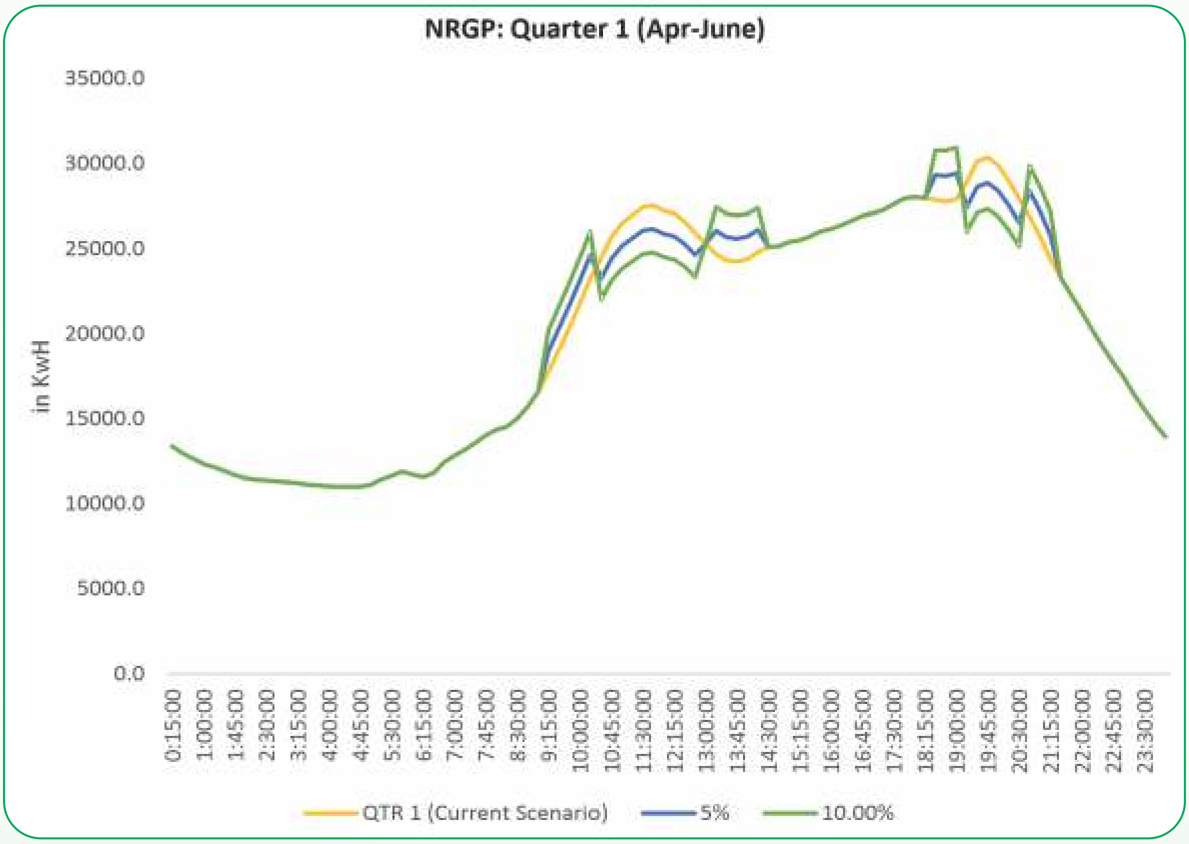


Figure 5-32: Change in NRGP load curve in Apr-May-June due to 5%, 10% load shift

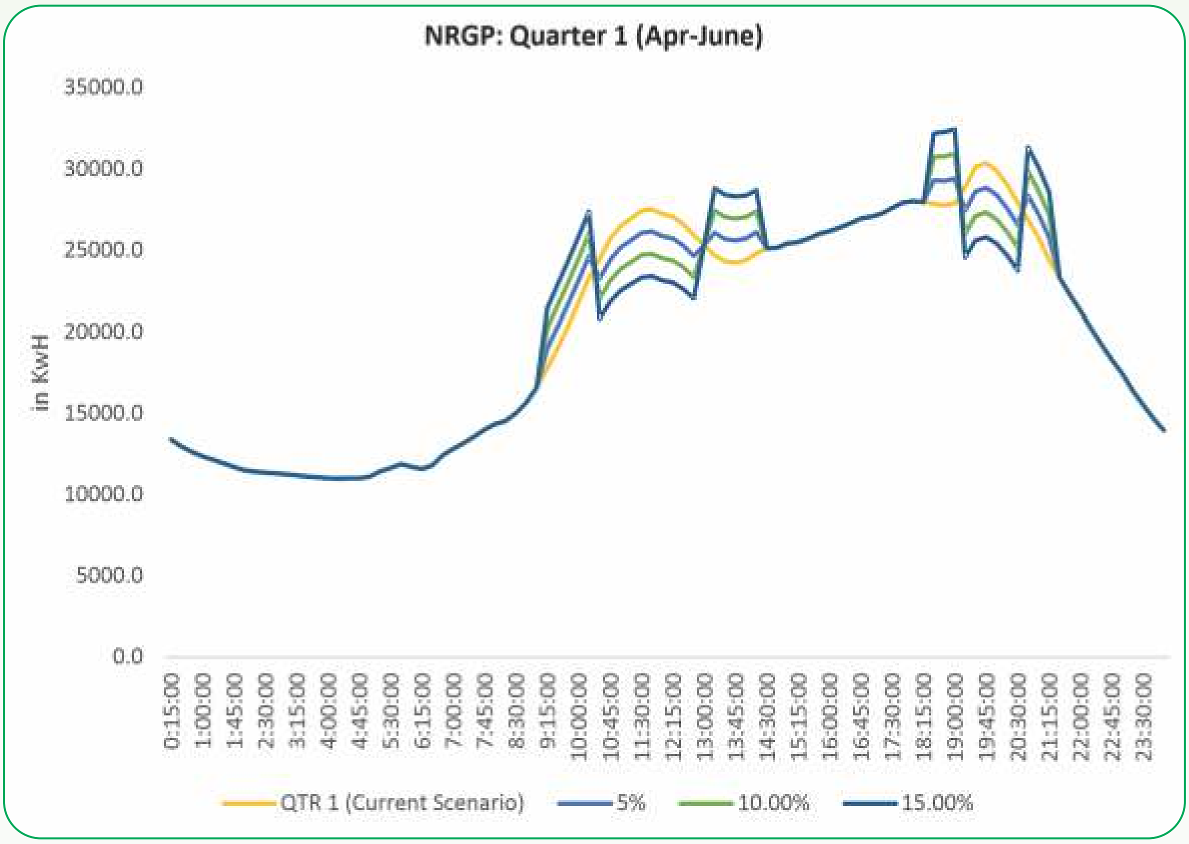


Figure 5-33: Change in NRGP load curve in Apr-May-June due to 5%, 10% and 15% load shift

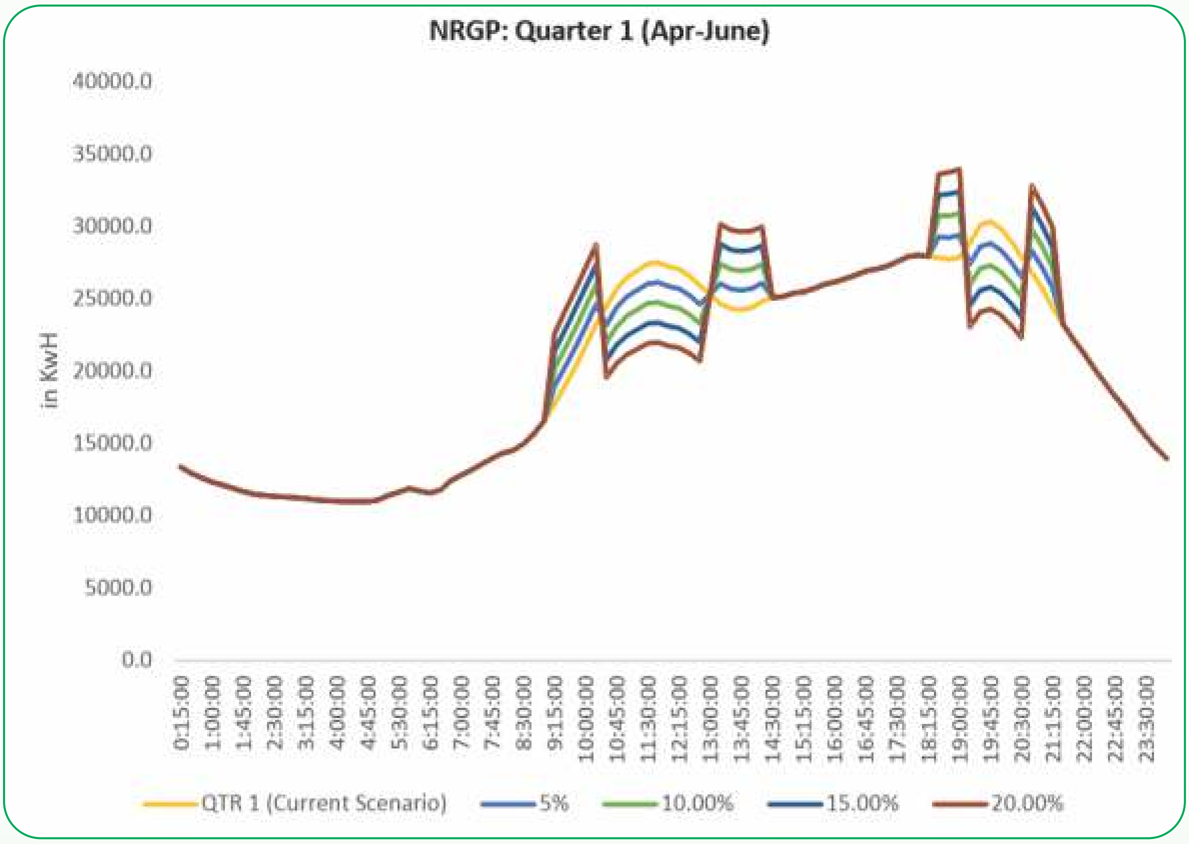


Figure 5-34: Change in NRGP load curve in Apr-May-June due to 5%, 10%, 15% & 20% load shift

Quarter 2 load shift:

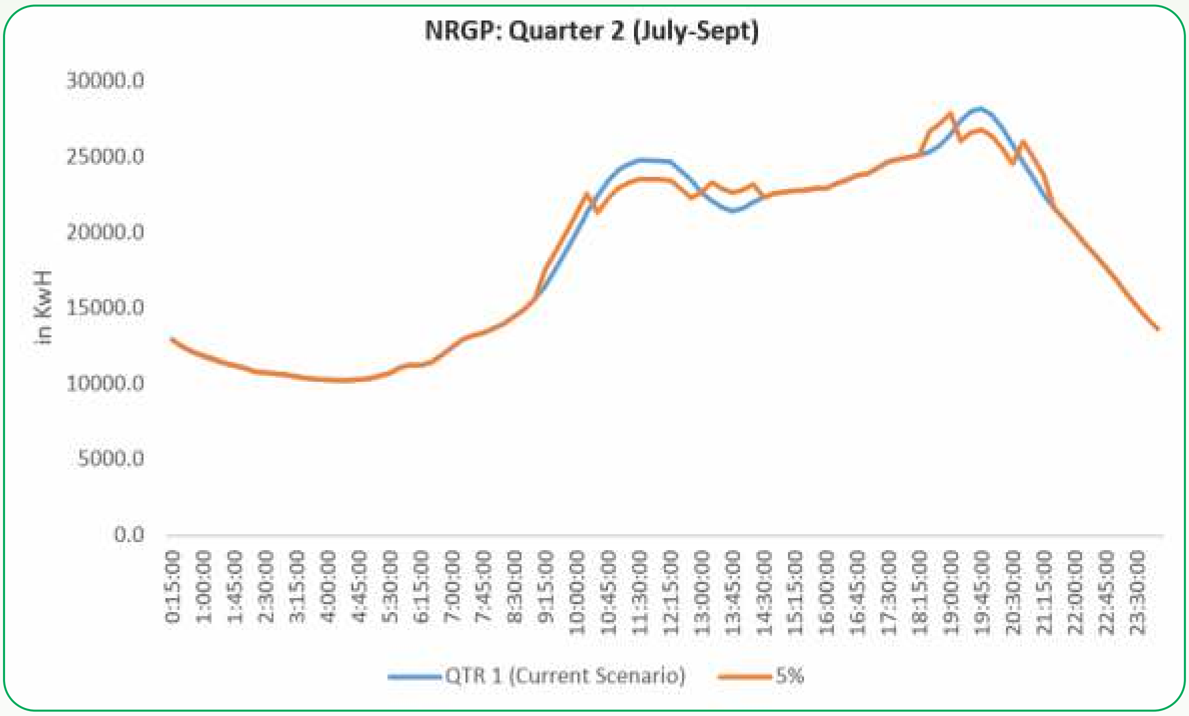


Figure 5-35: Change in NRGP load curve in July-Aug-Sept due to 5% load shift

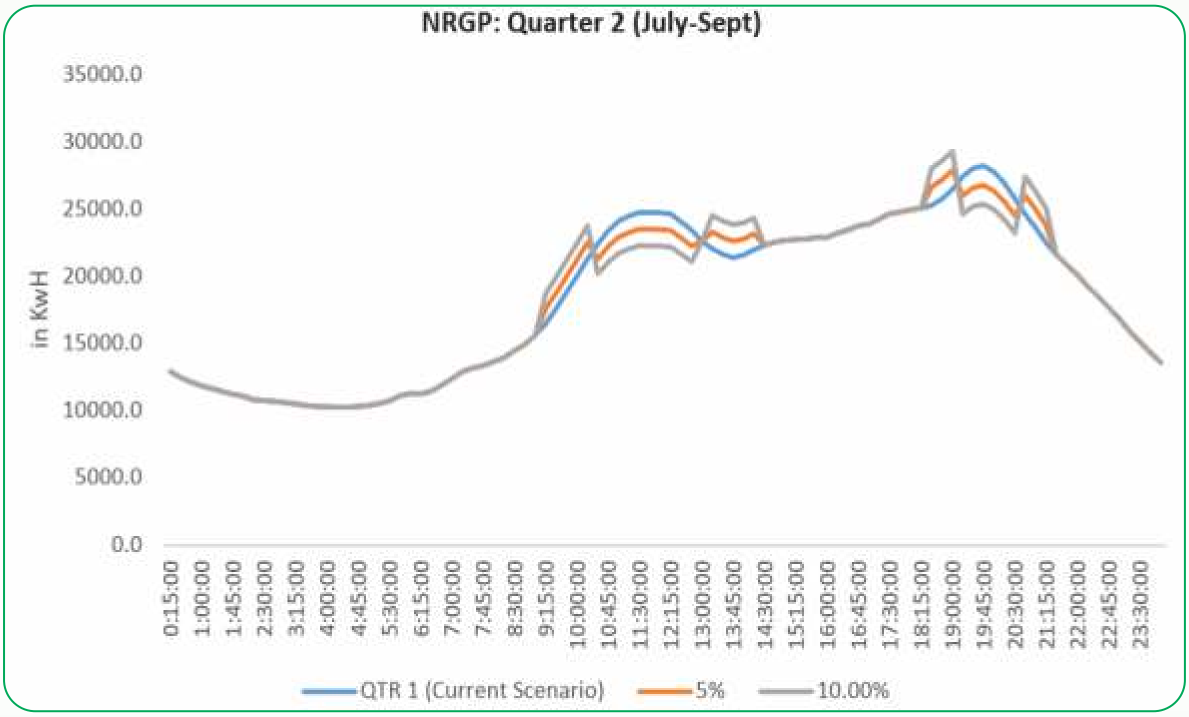


Figure 5-36: Change in NRGP load curve in July-Aug-Sept due to 5%, 10% load shift

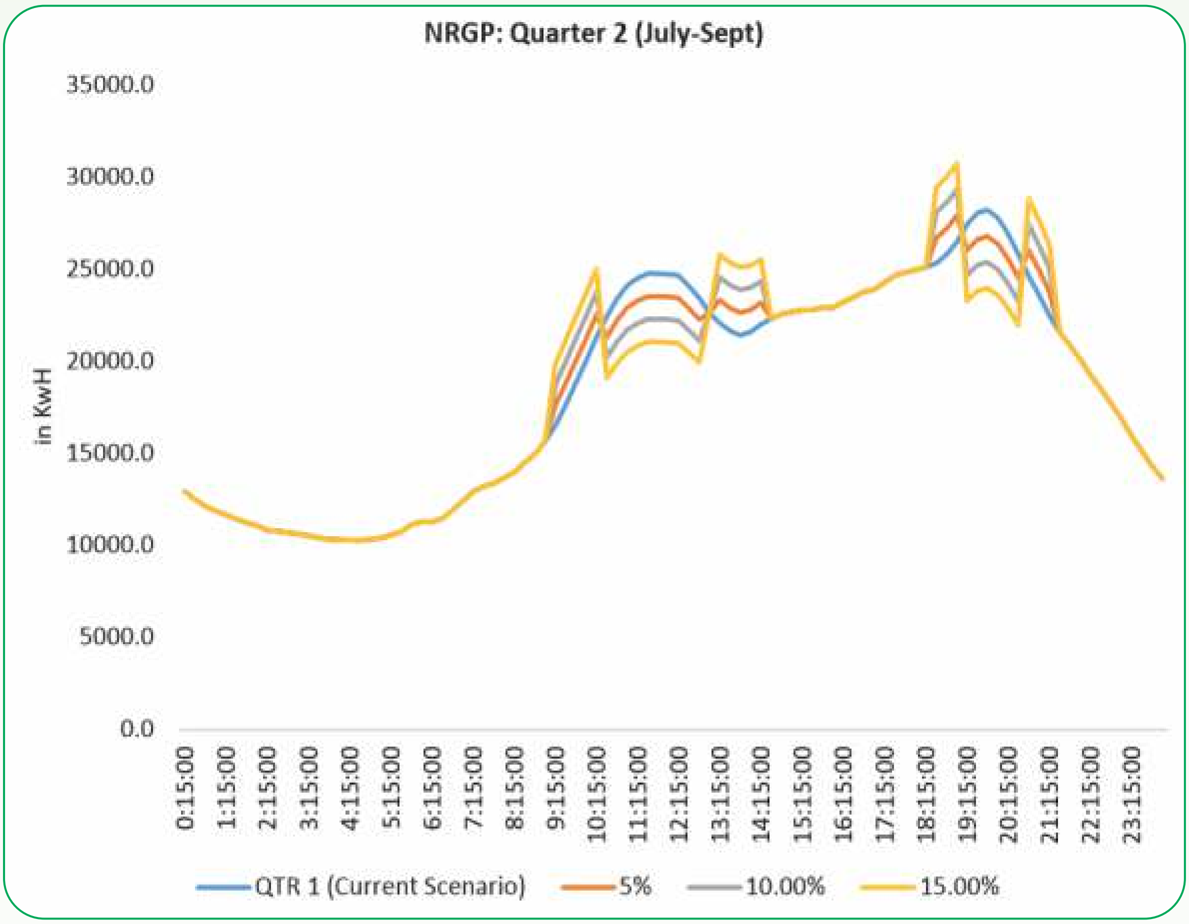


Figure 5-37: Change in NRGP load curve in July-Aug-Sept due to 5%, 10% and 15% load shift

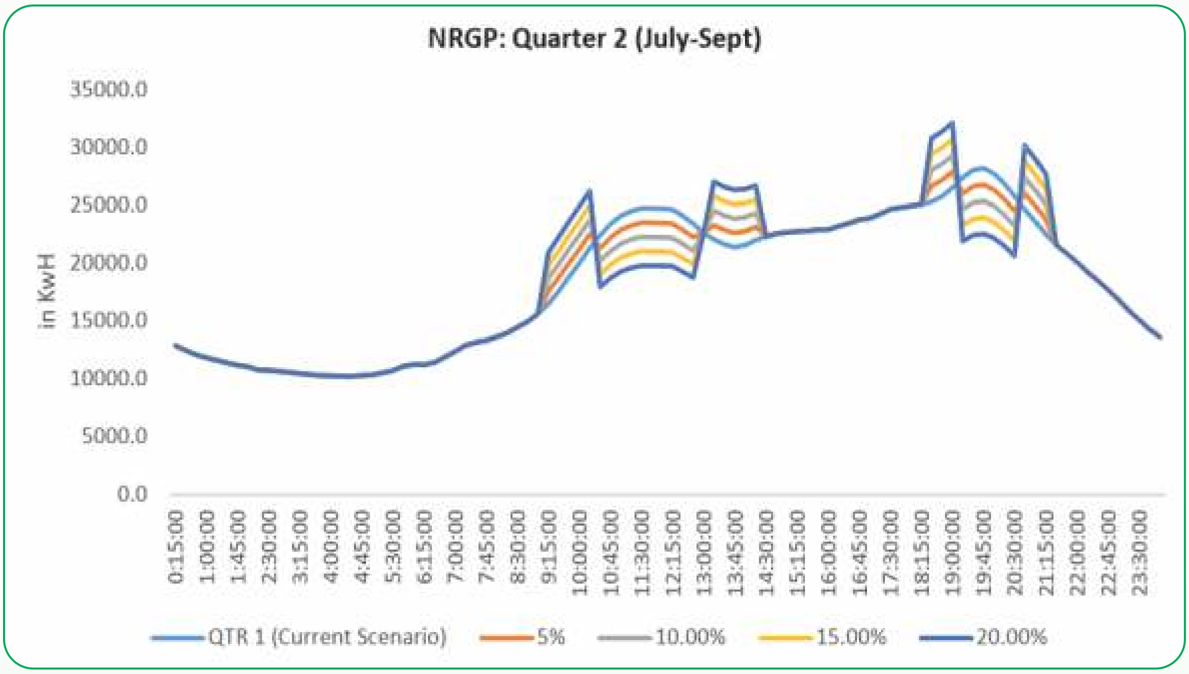


Figure 5-38: Change in NRGP load curve in July-Aug-Sept due to 5%, 10%, 15% & 20% load shift

Figures 5-31 to 5-38 indicate that the load curve moves the peak load to the left for a non-peak period, thereby reducing the total load during the peak period. We see a pattern in both quarters where this change will help flatten the overall load curve.

At the same, the impact of these shifts on revenue and costs of the DISCOM is illustrated below using differential pricing (ToU) for regular, peak and off-peak periods.

INR per kWh			ToU Rate			
Time slots	Buy Rate	Sell Rate	5%	10%	15%	20%
Peak	6.00	8.00	9	9.8	9.6	9.6
Regular	4.00	7.00	5	5	5	5
Off-peak	3.00	6.00	3	4	4	4

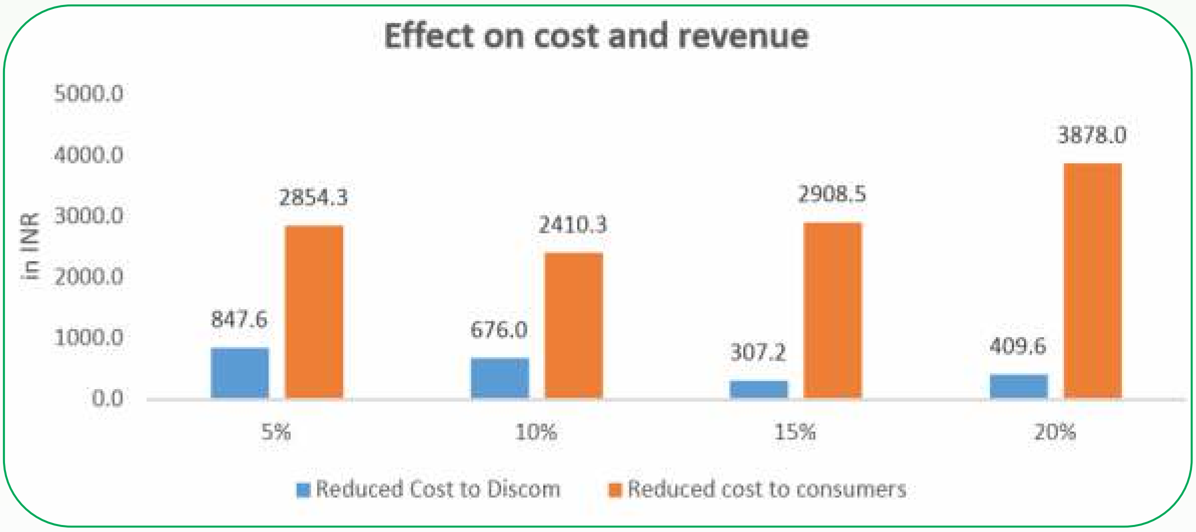


Figure 5-39: Financial impact on DISCOMs and NRGP customers for the suggested ToU pricing above

Please note in the above figure, (i) reduced cost to DISCOMs is the difference between their revenue and cost respectively in both the scenarios (ii) reduced cost to consumers is the savings in total cost incurred comparing both the scenarios.

5.6.6 LTMD Night Shift Analysis

Taking into consideration the best-case scenarios for reducing load on the existing infrastructure, we have analysed shifts from the peak hours to late night hours. This will help to understand the impact of maximum possible reduction.

We observe that the load curve has shown a major change in terms of load reduction on one hand during peak hour and revision to a higher load level in the night-time. As compared to the ToU scenarios the peaks are much less intense which points towards comparatively low change in load, thereby proving beneficial in the long run.

LTMD night shift analysis peaks at two distinct time intervals (as shown in Figure 5-40) across the first quarter, namely April-May-June. We have proposed quarter-wise shifts of these two peaks at different scales (5%, 10%, 15% and 20%) as illustrated respectively in Figures 5-41, 5-42, 5-43 and 5-44.

Overall scenario

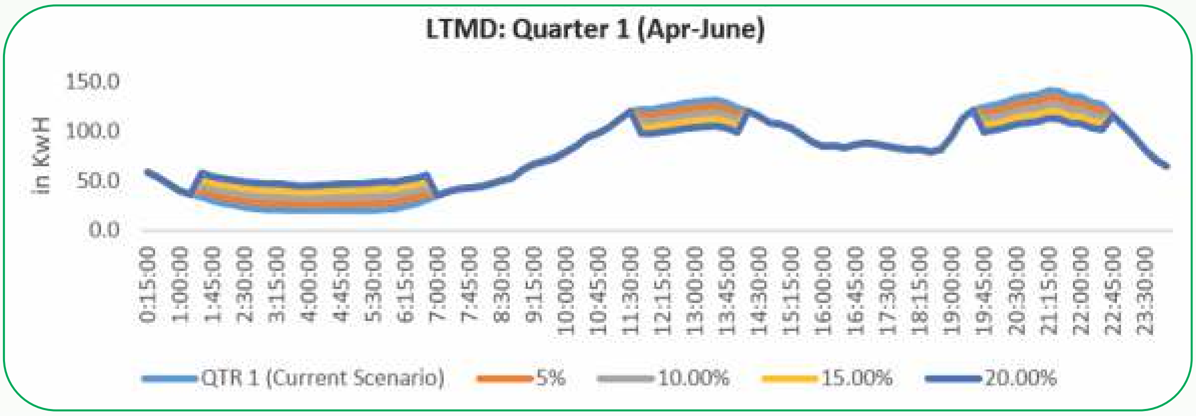


Figure 5-40: Load curve for LTMD night shift analysis consumers – First-quarter overall scenario

Quarter 1 load shift:

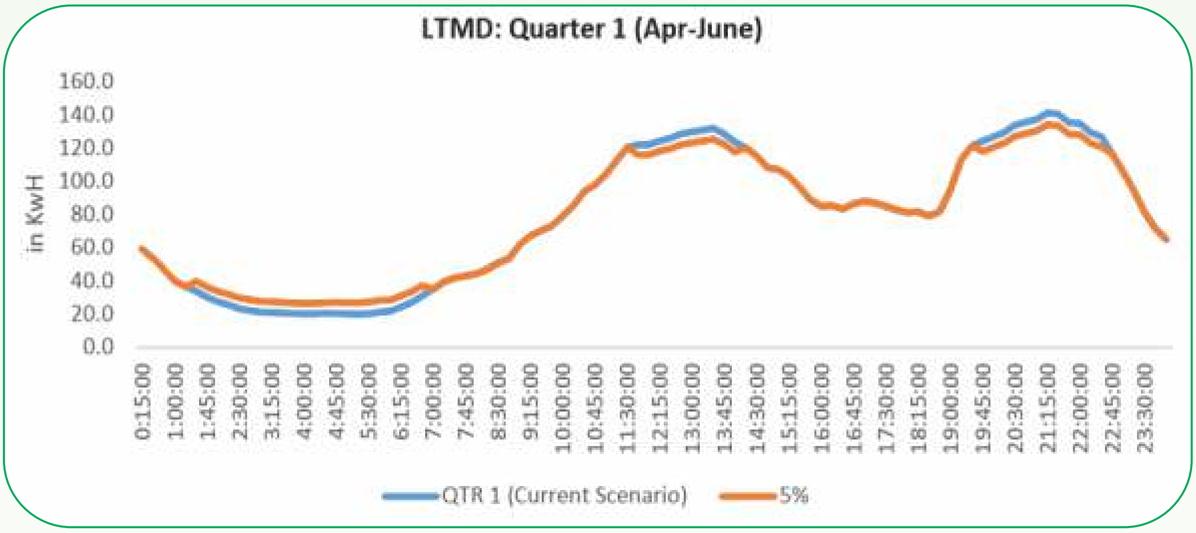


Figure 5-41: Change in LTMD night shift load curve in Apr-May-June due to 5% load shift

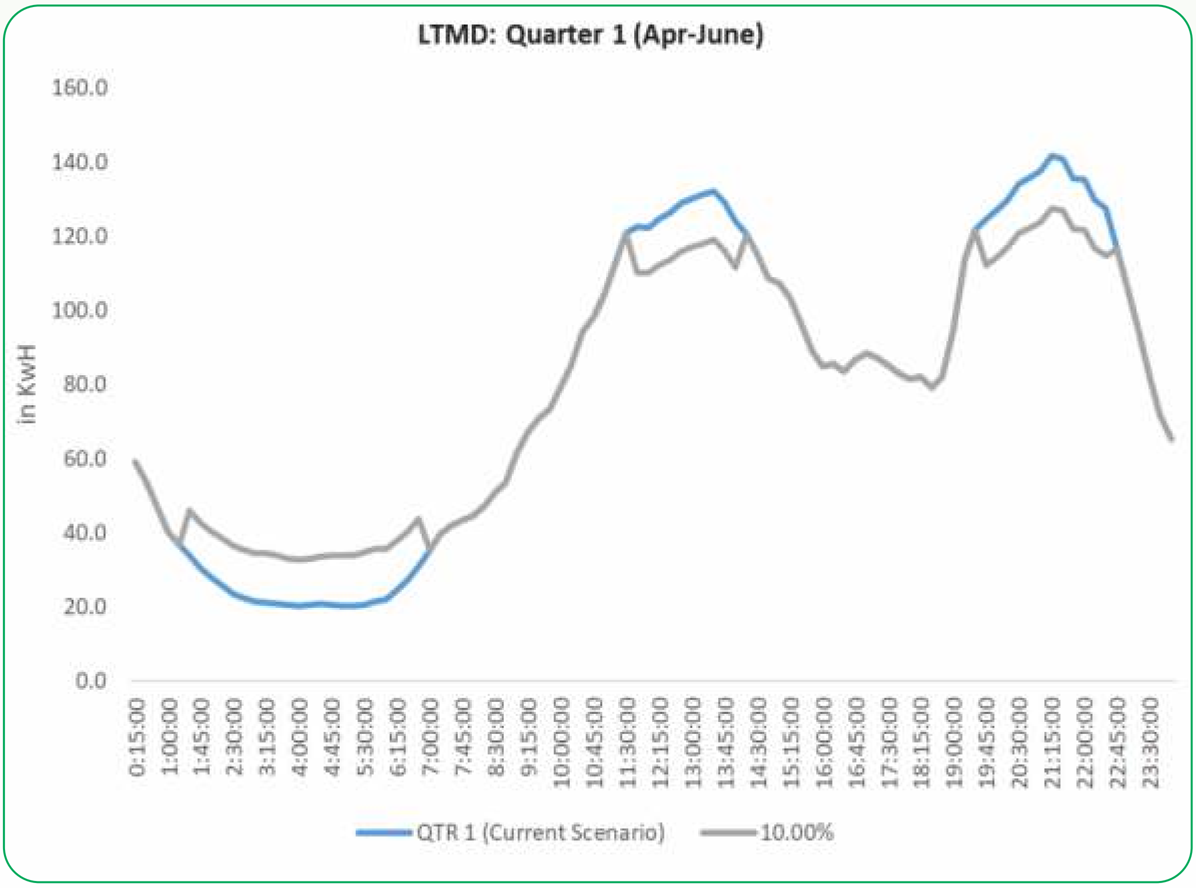


Figure 5-42: Change in LTMD night shift load curve in Apr-May-June due to 10% load shift

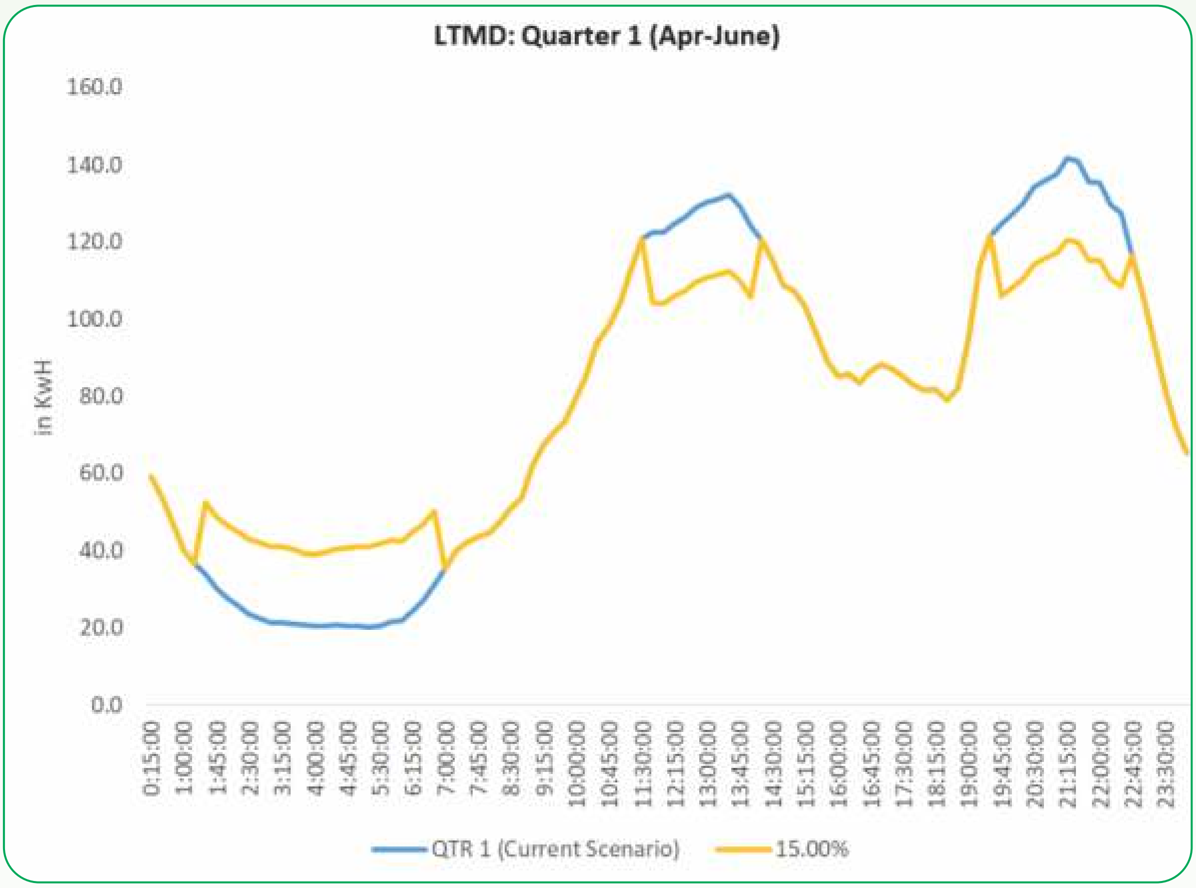


Figure 5-43: Change in LTMD night shift load curve in Apr-May-June due to 15% load shift

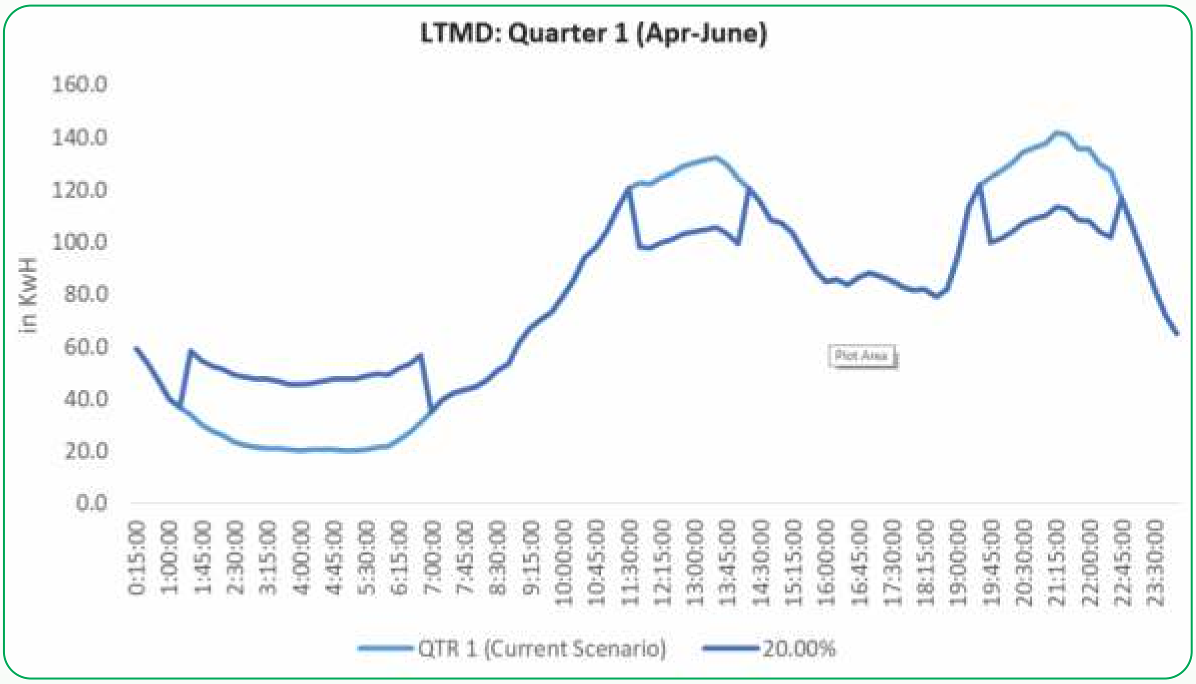


Figure 5-44: Change in LTMD night shift load curve in Apr-May-June due to 20% load shift

LTMD night shift analysis peaks at two distinct time intervals (as shown in Figure 5-45) across the second quarter, namely July-August-September. We have proposed quarter-wise shifts of these two peaks at different scales (5%, 10%, 15% and 20%) as illustrated respectively in Figures 5-46, 5-47, 5-48 and 5-49.

Overall scenario

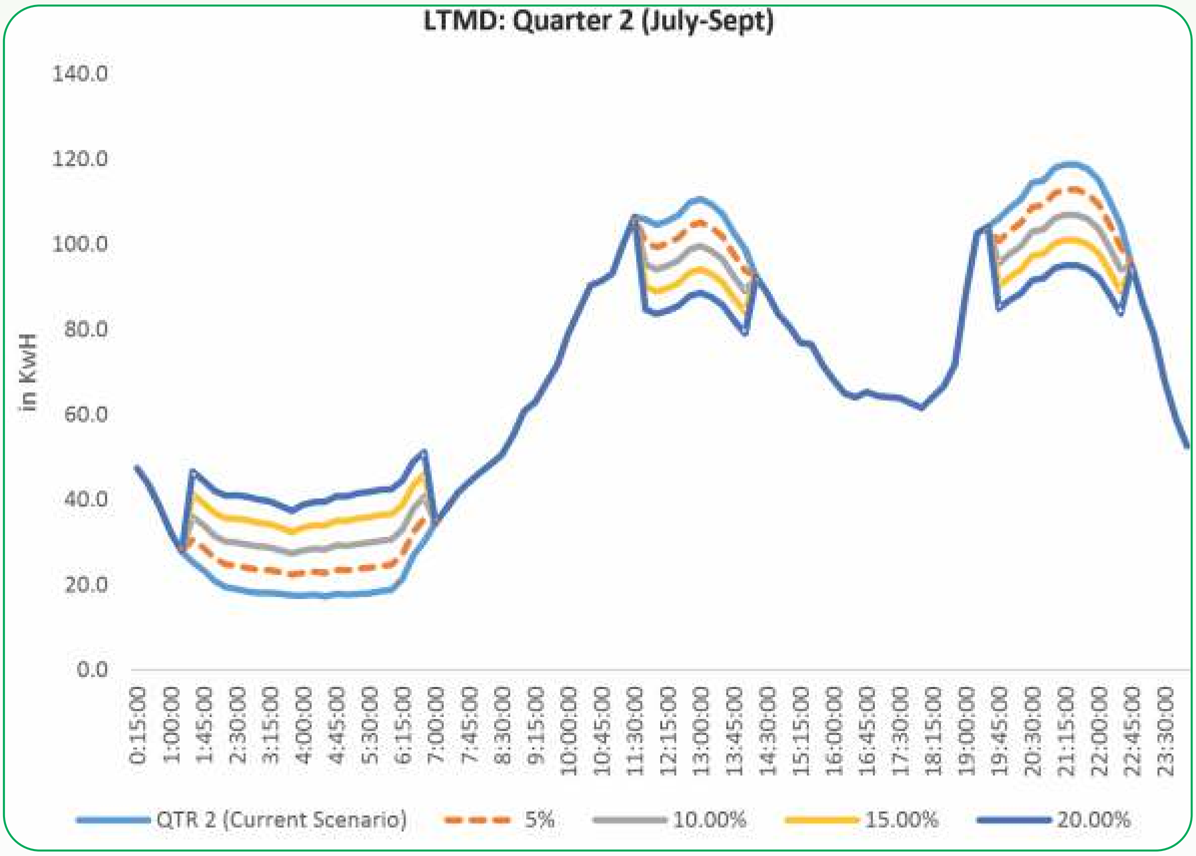


Figure 5-45: Load curve for LTMD night shift analysis consumers – Second quarter overall scenario

Quarter 2 load night shift:

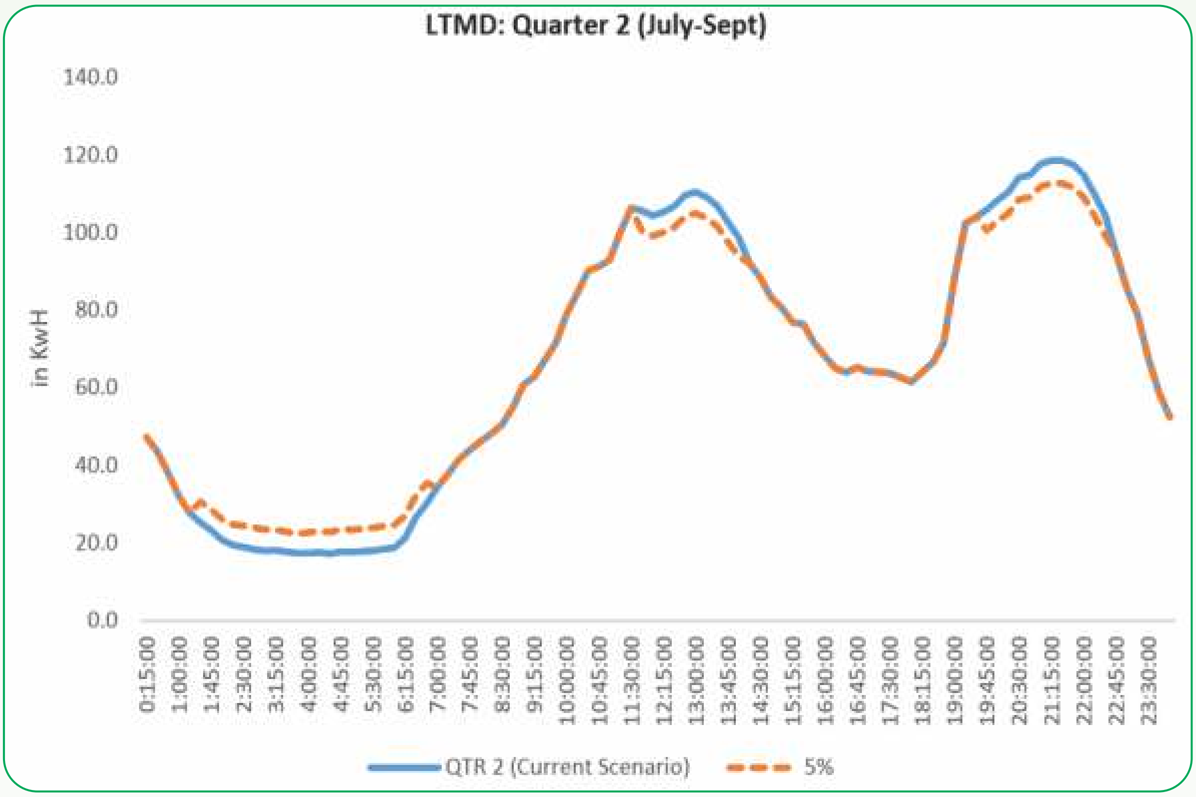


Figure 5-46: Change in LTMD night shift load curve in July-August-September due to 5% load shift

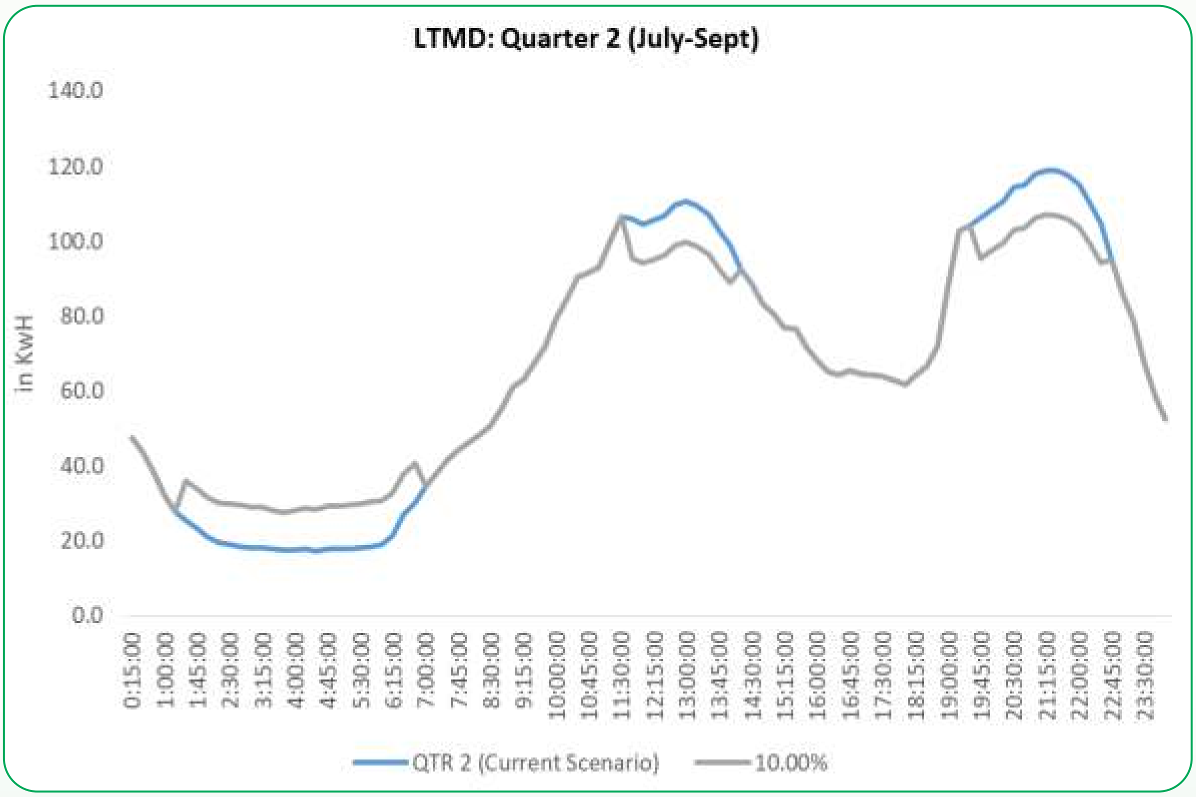


Figure 5-47: Change in LTMD night shift load curve in July-August-September due to 10% load shift

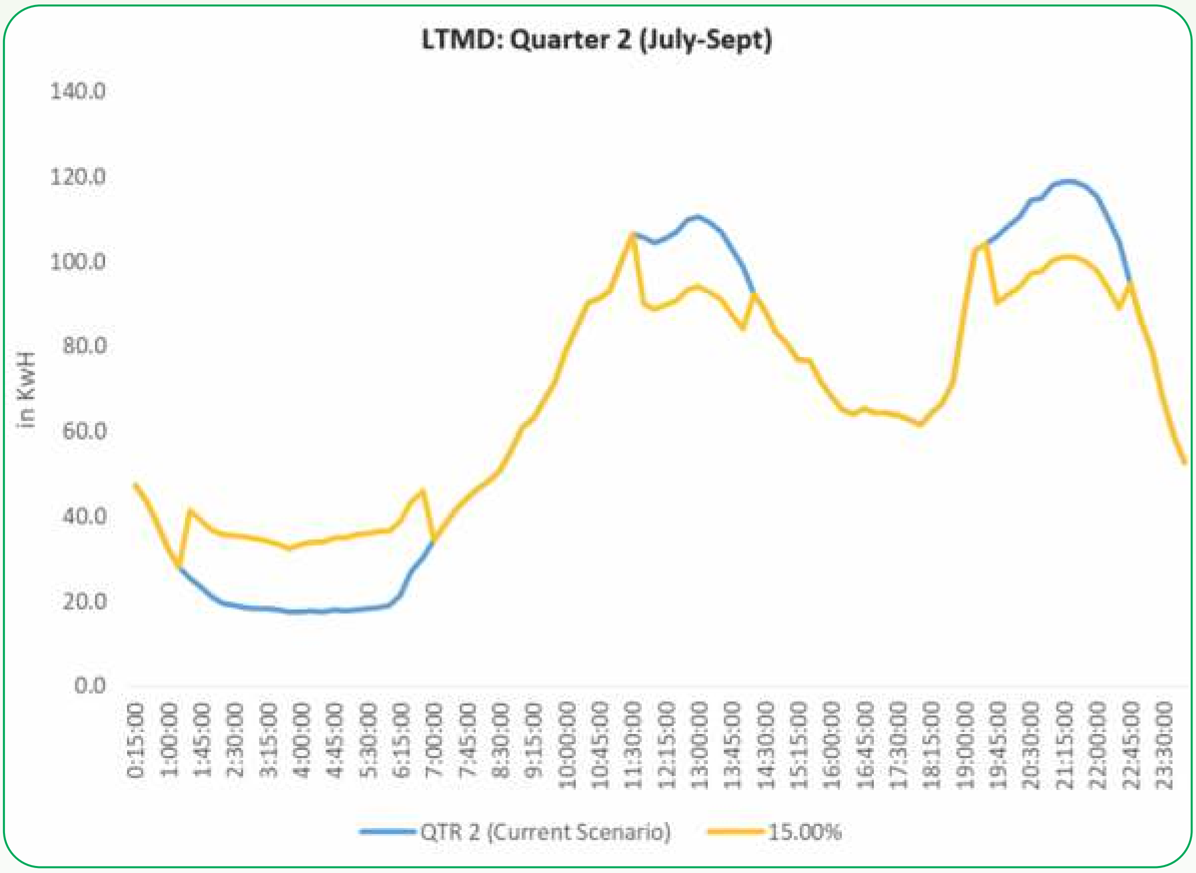


Figure 5-48: Change in LTMD night shift load curve in July-August-September due to 15% load shift

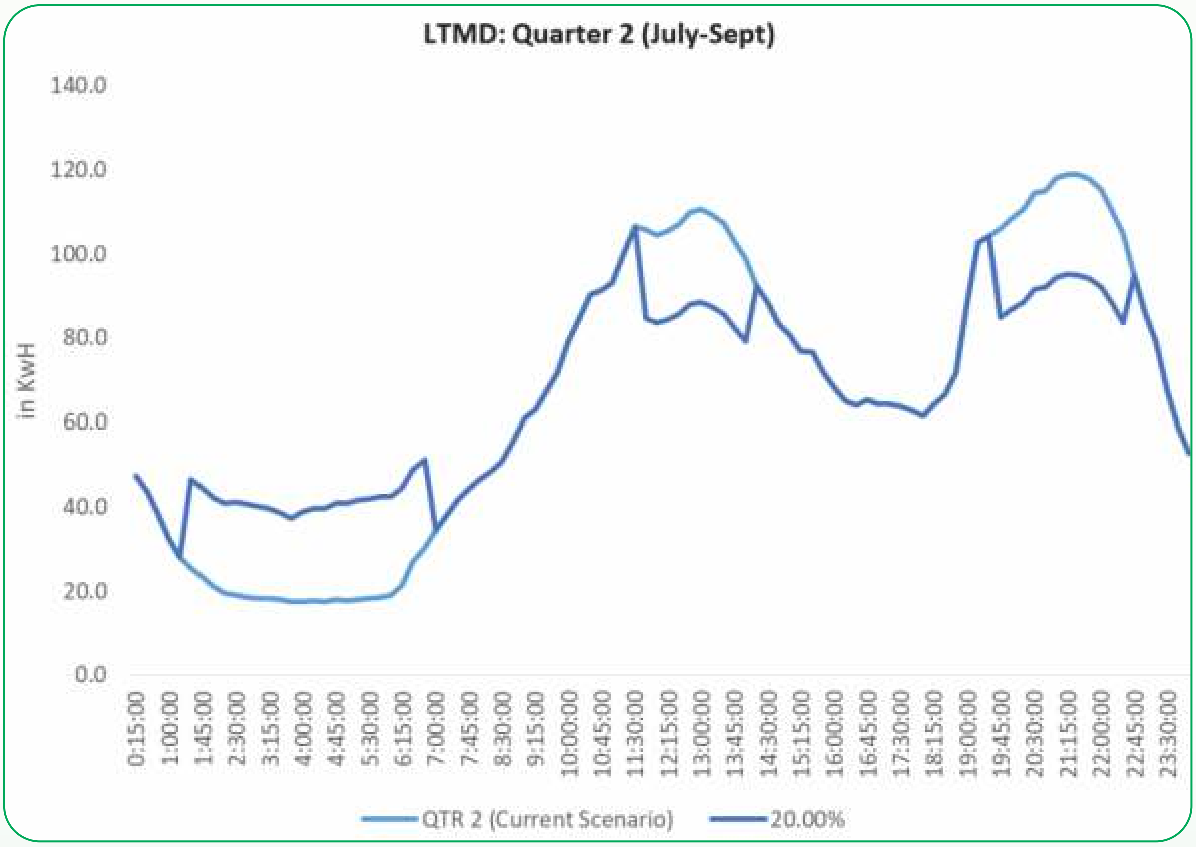


Figure 5-49: Change in LTMD night shift load curve in July-August-September due to 20% load shift

5.6.7 NRGP Night Shift Analysis

Similar to LTMD, we have taken into consideration the best-case scenarios for reducing load on the existing infrastructure, we have analysed shifts from the peak hours to late night hours. This will help to understand the impact of maximum possible reduction.

We observe that the load curve has shown a major change in terms of load reduction on one hand during peak hour and revision to a higher load level in the night-time. As compared to the ToU scenarios the peaks are much less intense which points towards comparatively low change in load, thereby proving beneficial in the long run.

NRGP night shift analysis peaks at two distinct time intervals (as shown in Figure 5-50) across the first quarter, namely April-May-June. We have proposed quarter-wise shifts of these two peaks at different scales (5%, 10%, 15% and 20%) as illustrated respectively in Figures 5-51, 5-52, 5-53 and 5-54.

Overall scenario

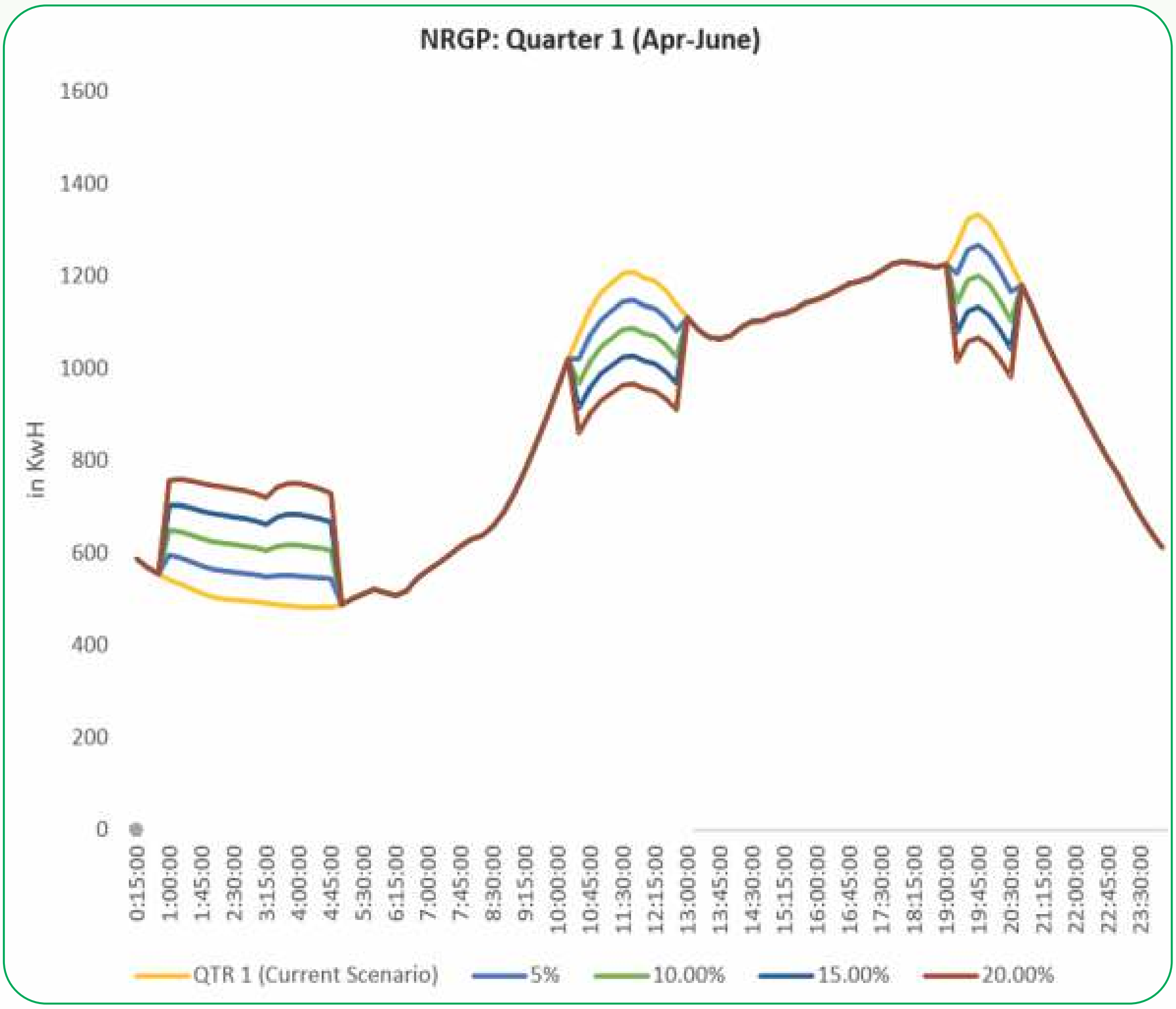


Figure 5-50: Load curve for NRGP night shift analysis consumers – First-quarter overall scenario

Quarter 1 load night shift:

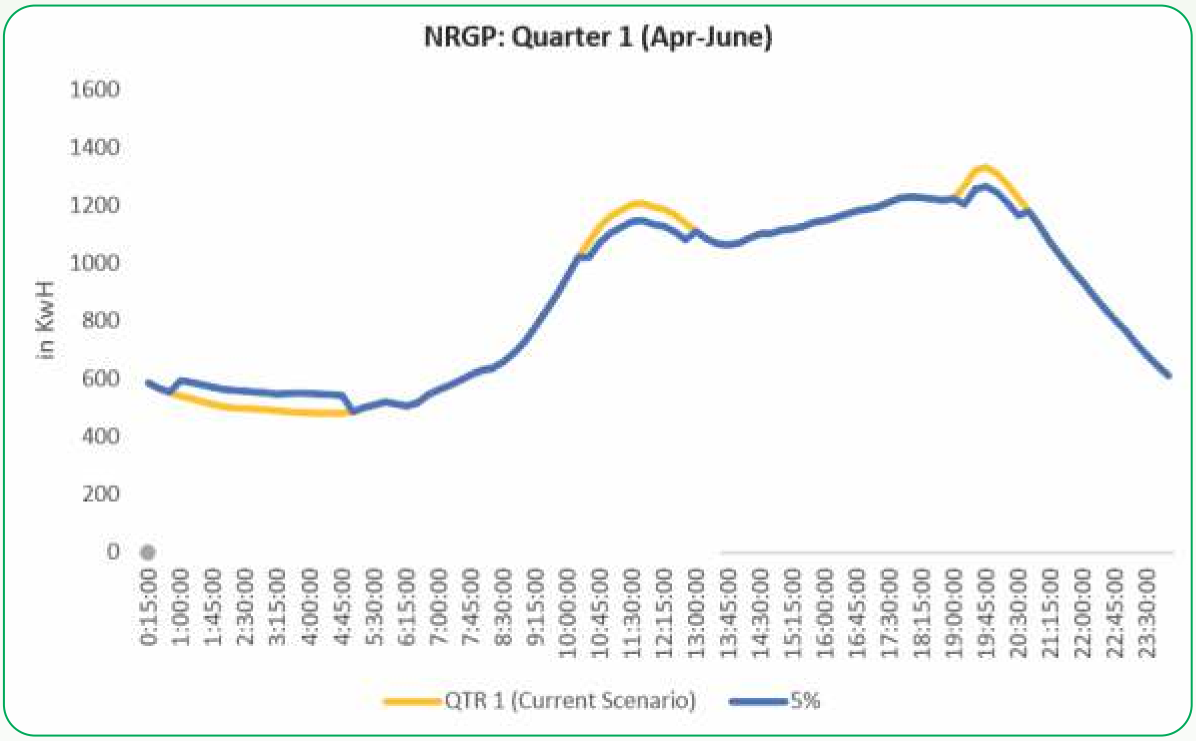


Figure 5-51: Change in NRGP night shift load curve in April-May-June due to 5% load shift

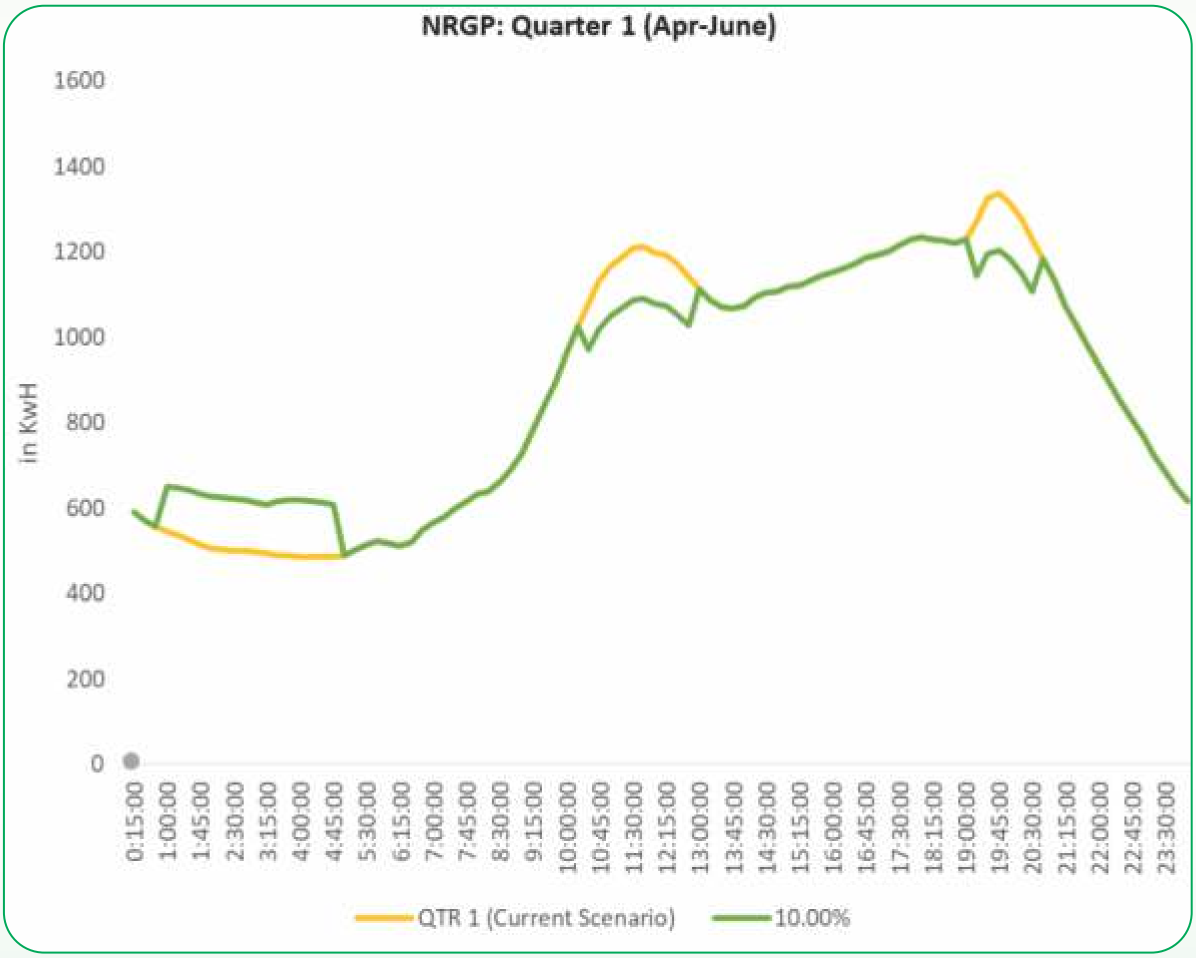


Figure 5-52: Change in NRGP night shift load curve in April-May-June due to 10% load shift

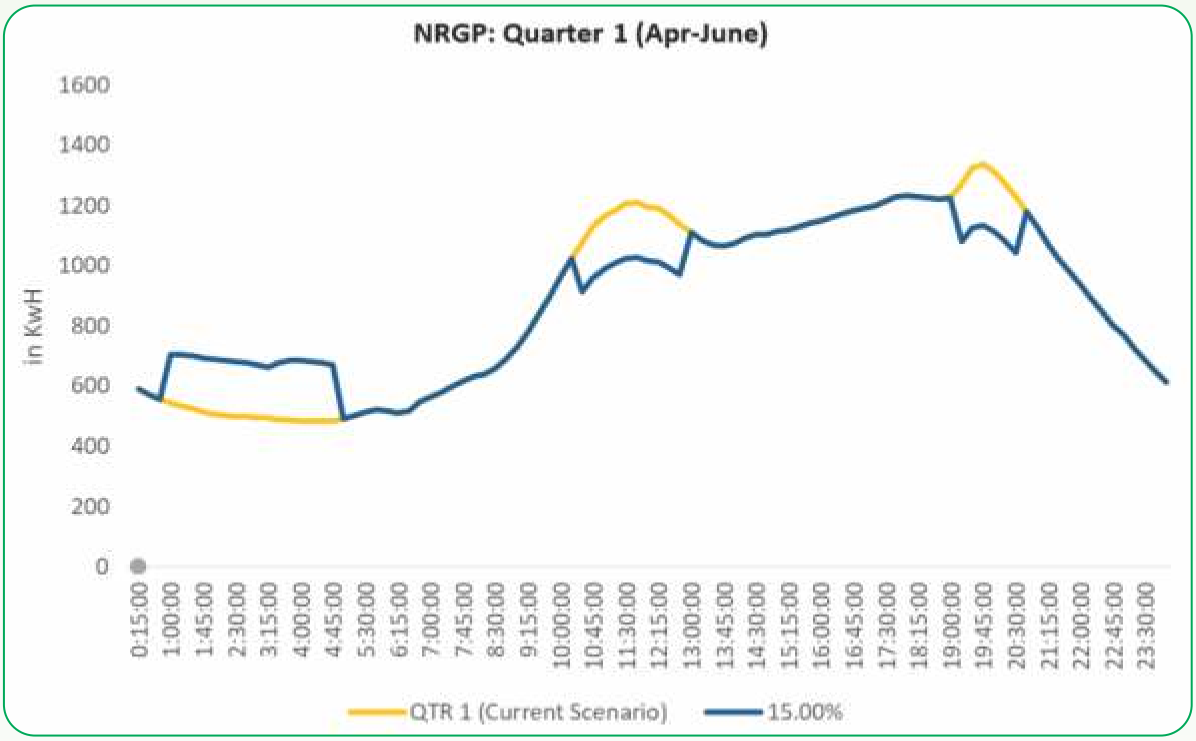


Figure 5-53: Change in NRGP night shift load curve in April-May-June due to 15% load shift

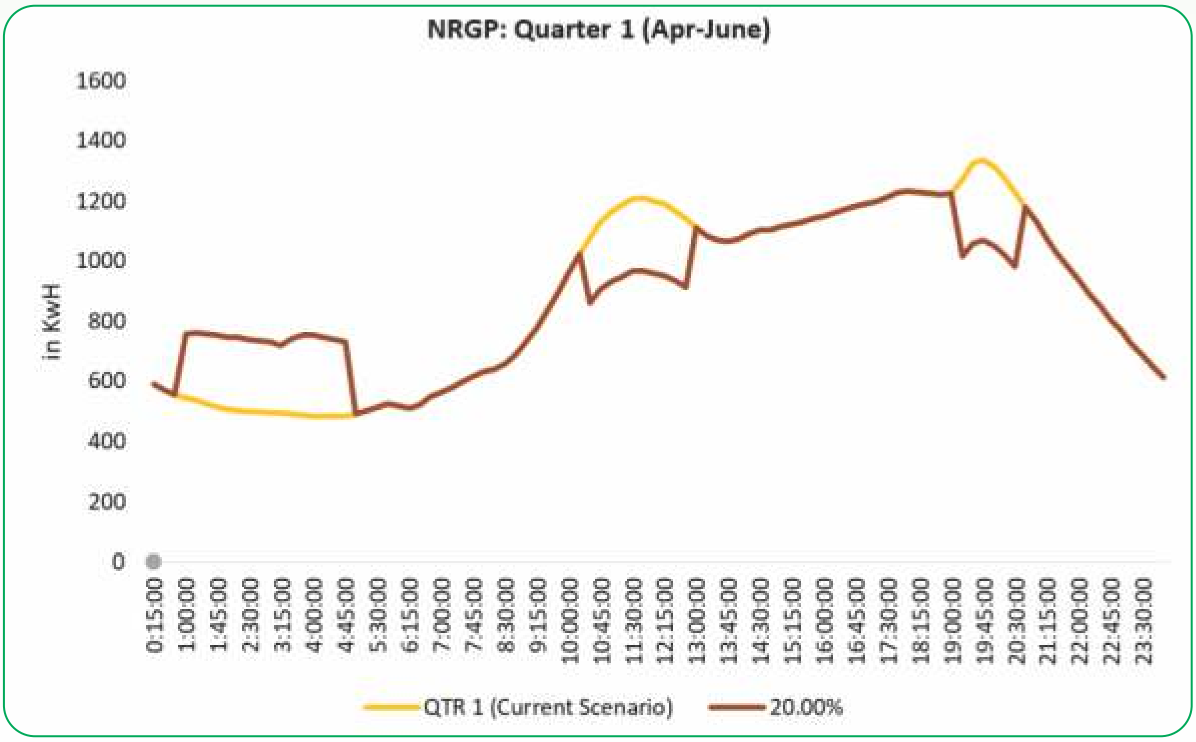


Figure 5-54: Change in NRGP night shift load curve in April-May-June due to 20% load shift

NRGP night shift analysis peaks at two distinct time intervals (as shown in Figure 5-55) across the second quarter, namely July-August-September. We have proposed quarter-wise shifts of these two peaks at different scales (5%, 10%, 15% and 20%) as illustrated respectively in Figures 5-56, 5-57, 5-58 and 5-59.

Overall scenario

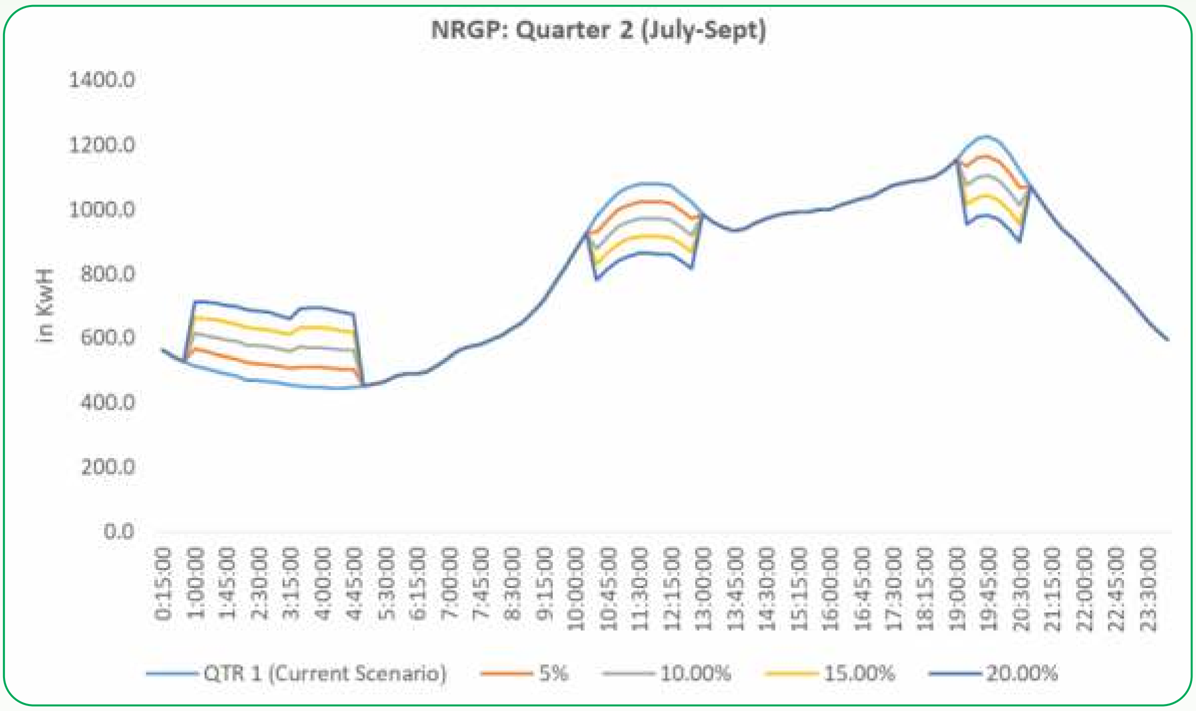


Figure 5-55: Load curve for NRGP consumers night shift analysis – Second quarter overall scenario

Quarter 2 load night shift:

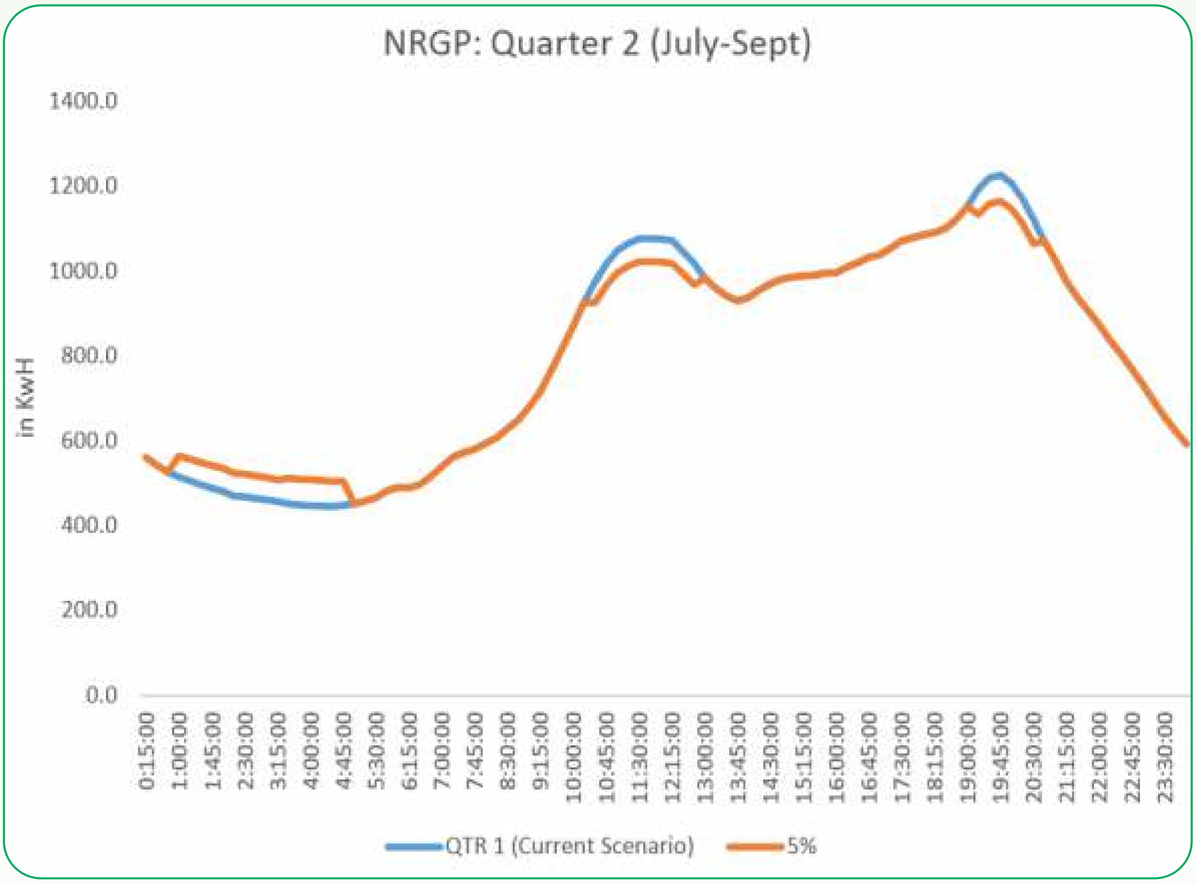


Figure 5-56: Change in NRGP night shift load curve in July-August-September due to 5% load shift

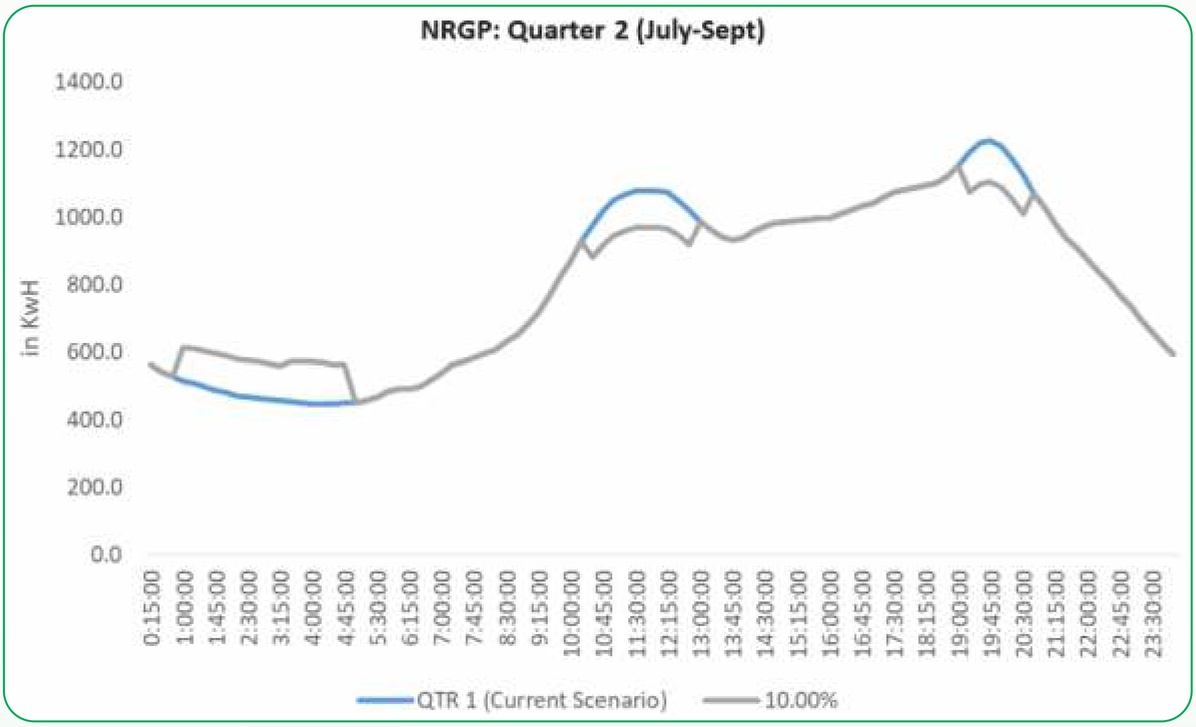


Figure 5-57: Change in NRGP night shift load curve in July-August-September due to 10% load shift

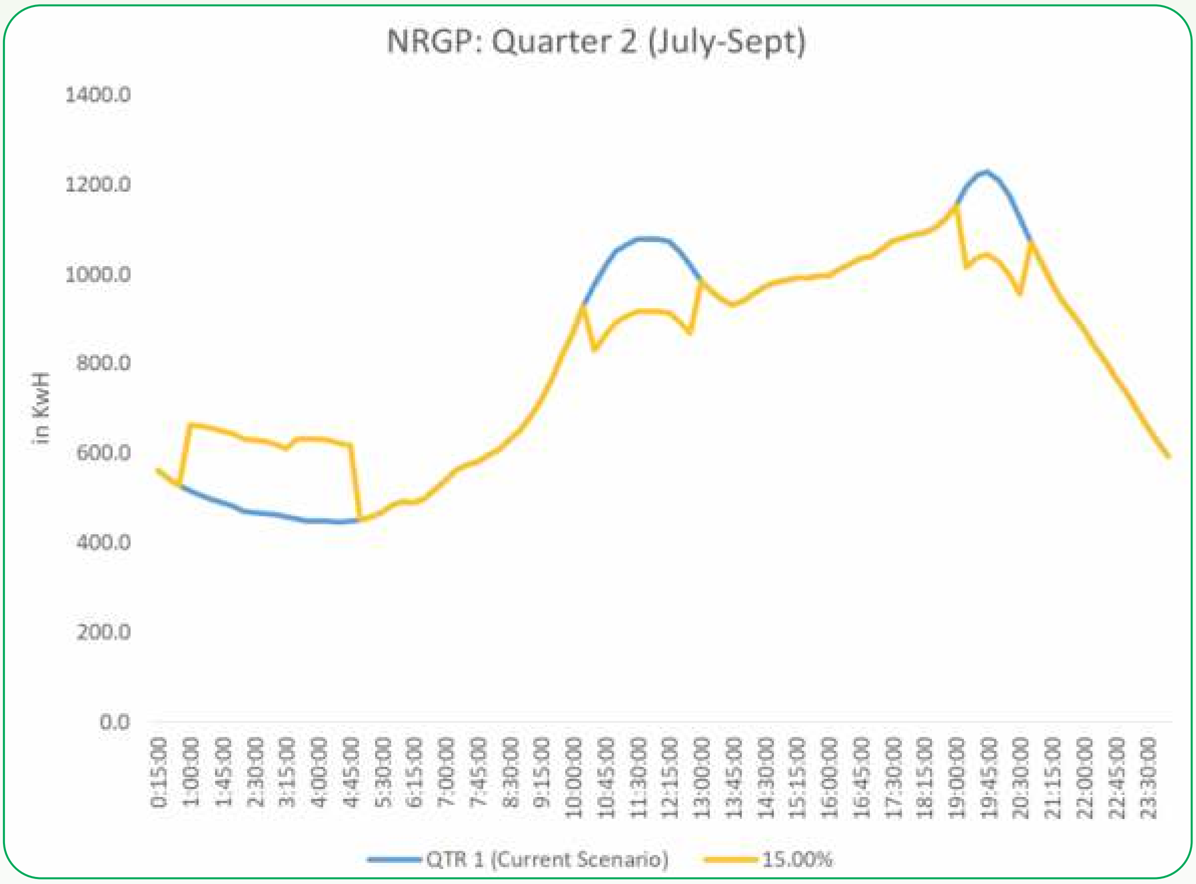


Figure 5-58: Change in NRGP night shift load curve in July-August-September due to 15% load shift

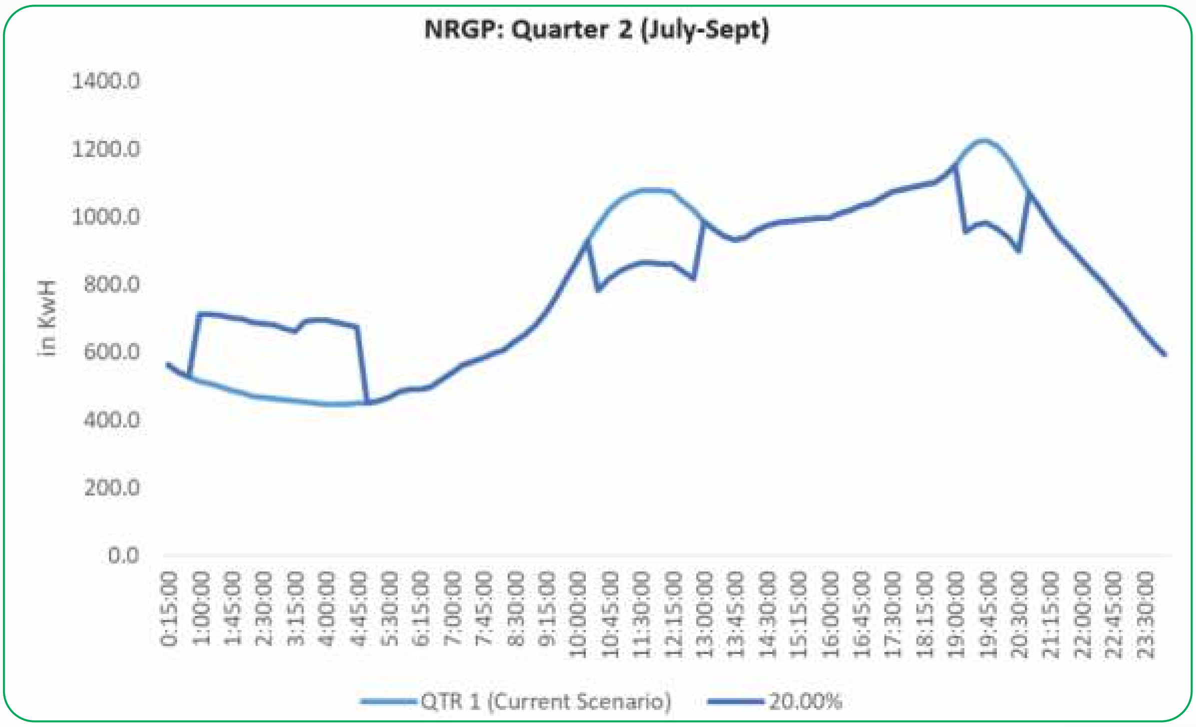


Figure 5-59: Change in NRGP night shift load curve in July-August-September due to 20% load shift

6. ToU TARIFF IMPLEMENTATION STRATEGY, ROADMAP AND RECOMMENDATIONS

Accurate consumption data in each time interval is required for implementing ToU tariff which the present metering regime cannot support. With a ToU tariff scheme, consumers can voluntarily (either by automation or manually) change their electricity usage to reduce their energy costs. The price signals are time-varying, calculated based on the equilibrium of the power system or short-term wholesale market price signals, as the name implies. Significantly, ToU tariffs unlock flexibility on the demand side and can thus help to increase renewable energy penetration. Examples demonstrate how the ToU tariffs have been implemented by different countries and regions and explain the effect of these tariffs on the electricity system's power system, such as aggregators.

6.1 Metering Scenario

An energy meter or watt-hour meter is an instrument used to measure the quantity of electricity or energy, over a time period. In the present days, different types of energy meter are used such as three phases, single-phase, high tension (HT), low tension (LT). Energy meters come with different accuracy classes as well.

In recent years, the metering industry has made giant leaps to enhance both, electric utility operations and quality of service to end-consumers. In this transformative journey, the industry has made impressive progress from electromechanical meters, electronic meters to Automated Meter Reading (AMR), prepaid meters and smart meters with two-way communication between the customer and the utility. Smart meters use communication network elements such as network interface cards (NIC), gateways, Data Concentrator Units (DCU) interfacing with numerous mesh nodes to enable last-mile connection and multi-way communication capability in real-time.

6.1.1 Electromechanical Induction Type Energy Meter

It is widely popular and the most common type of the age-old watt-hour meter and consists of rotating aluminium discs mounted on a spindle between two electromagnets.

Figure 6-1: Electromechanical Energy Meter

6.1.2 Electronic Energy Meters

The electronic energy meters are high procession, accurate and reliable measuring instruments as compared to the conventional mechanical meters as they consume less power and start measuring instantaneously when connected to the load. These meters can be analog or digital style. In the analog type meters, power is converted to a proportional frequency or pulse rate and is integrated by counters placed inside. In the digital electric meter, power is measured directly by the high-end processor. The power is integrated by logic circuits to get the energy, is used for testing and calibration purposes and is converted to a frequency or pulse rate for recording the consumption.

6.1.3 Analog Electronic Energy Meters

In analog type meters, voltage and current values of each phase are obtained by the voltage divider and current transformers respectively which are directly connected to the load.

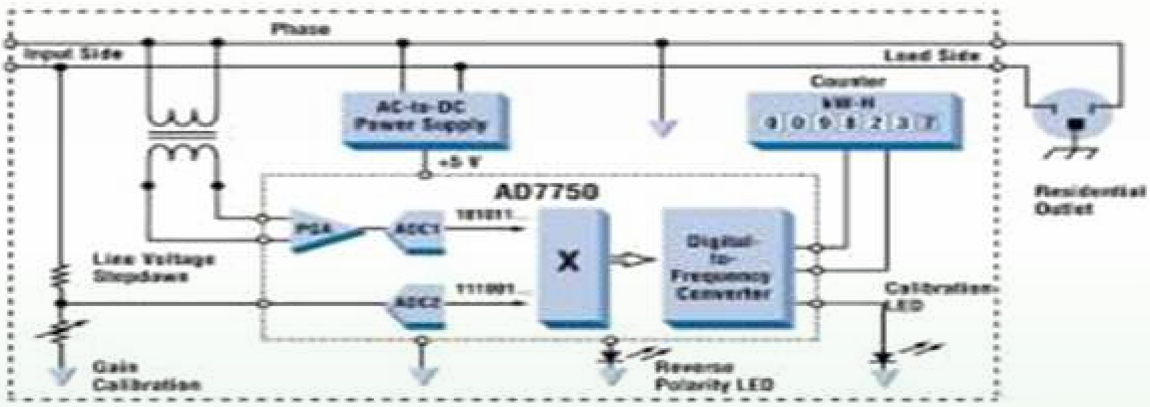


Figure 6-2: Analog Energy Meter

Analog to digital converter converts these analog values to digitized samples which are then converted to corresponding frequency signals by a frequency converter. These frequency pulses then drive a counter mechanism where these samples are integrated over time to measure electricity consumption.

6.1.4 Digital Electronic Energy Meters

Digital signal processors or high-performance microprocessors are used in digital electronic meters. Similar to the analog meters, voltage and current transducers are connected to a high-resolution Analog to Digital Converter (ADC) which converts analog signals to digital samples. Further, voltage and current samples are multiplied and integrated by digital circuits to measure the energy consumed.

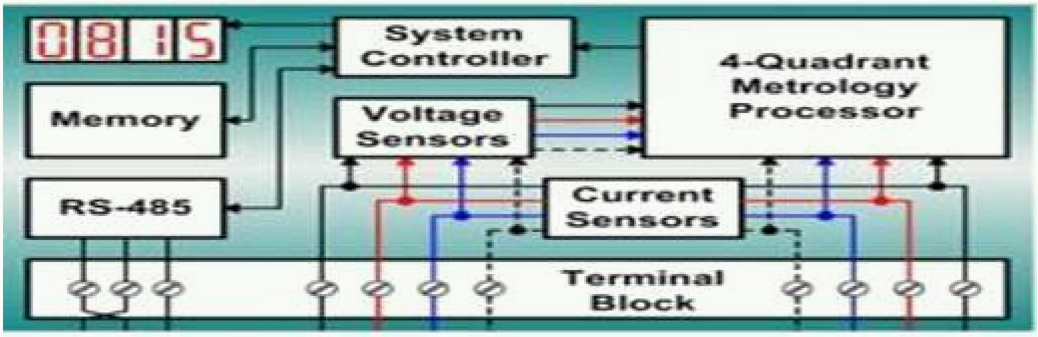
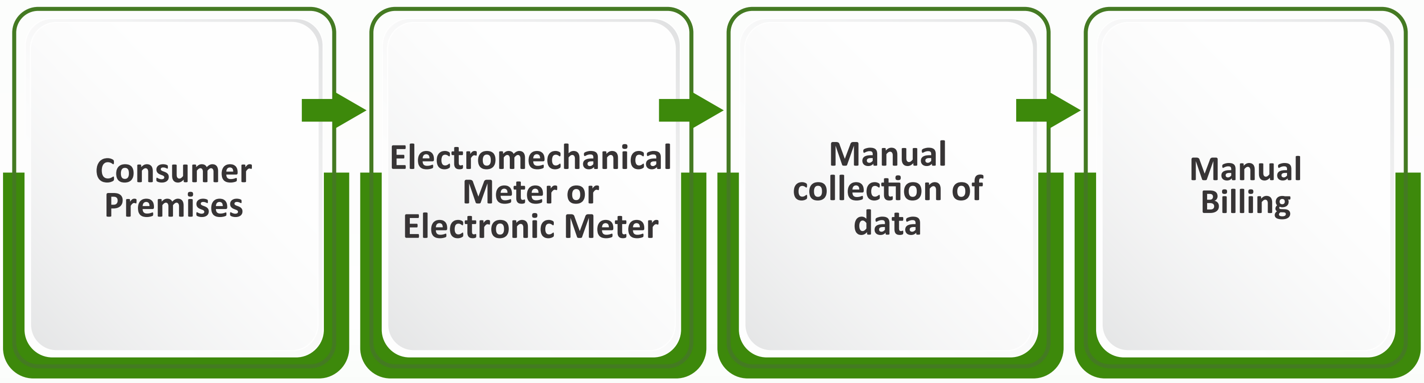


Figure 6-3: Digital energy meter

A microprocessor calculates phase angle between voltage and current, so the digital electronic meter can also measure and indicate reactive power consumption. It is programmed in such a way that it can calculate energy according to the tariff and various other parameters such as power factor, maximum demand, etc. It also stores these values in a non-volatile memory called EEPROM.

It contains a real-time clock (RTC) for calculating the time for power integration, maximum demand calculations and also date and time stamps of particular parameters. Furthermore, it interacts with liquid crystal display (LCD), communication devices and other meter outputs. A battery is provided for RTC and other significant peripherals for backup power.



Although most DISCOMs have digital meters, they are read manually; hence only few parameters are captured. These meters can store the 15-minute interval data for over 35 days and the data can be downloaded using a laptop (connected through LAN cable) or through a handheld device for meter reading.

6.2 Smart Metering

The Government of India has announced mandatory smart metering for all 250 million electricity customers in the country on a fast track. The DISCOMs in Gujarat are also expected to rollout smart meters for all customers in the next 2-3 years. Smart metering or Advanced Metering Infrastructure (AMI) offers multiple benefits to the DISCOMs, Customers, Generation and Transmission Utilities as well as to the Society at large which are summarized below:

For DISCOMs:

- **Reduced metering reading and data entry cost**

  Without smart meters, Utilities must send personnel to customer premises to manually read the meter. Implementation of AMI enables remote meter reading both regularly and on-demand. Data entry and processing is performed automatically. Overall, AMI should deliver greater convenience at reduced cost relative to traditional meter reading.

- **Reduction in time taken for meter reading and bill generation as well as reduction in errors**

  There are always chances of human errors when meters are read manually or even via automatic hand-held devices. In addition, the process is time consuming. By delivering meter data automatically over communication networks, AMI eliminates human error from the meter reading process as well as make the entire process faster.

- **Reduction in cost of disconnection and reconnection**

  It can be managed through remote operation of the AMI system.

- **Faster detection of dead meters**

  It will enhance enhanced revenue protection .

- **Real time energy auditing and accurate energy accounting from time-stamped meter data**

- **Enhanced Revenue per Month**

  Large shares of meters existing in DISCOMs are old and hence the readings are not very reliable. With new smart meters, the accurate energy consumption can be captured which will enhance the monthly revenue considerably. It is expected that the monthly payment to AMI Service Provider (AMISP) can be met from the increased revenue. This has been the experience in DISCOMs where AMI has been implemented (eg: Mysore, Indore, Gujarat and NDMC). With 10% of capex invested by the DISCOM and 15% grant from GoI, and the rest 75% paid monthly over 10 years from increased revenue on a monthly basis is a very attractive option for Utilities.

- **Reduction in Aggregate Technical & Commercial (AT&C) losses**

  AMI can remotely detect meter tampering and enable real time energy accounting. This reduces theft through by-passing the meter, thereby substantially reducing aggregate technical and commercial (AT&C) losses. AMI will also streamlined the billing, or meter-to-cash, process considerably by reducing the human errors in meter reading and billing.

- **Enabling faster outage detection and service restoration after faults**

  Traditionally utilities know about an outage when they receive complaints from affected customers. Service restoration requires utility crews to identify the area and rectify the fault - a time consuming and expensive process. The Bureau of Indian Standards requires all smart meters to be capable of sending 'last gasp' and 'first breath' messages, which informs the utilities when power has failed or resumed. This will reduce outage restoration times leading to financial savings and improved customer satisfaction.

- **Better load research and demand forecasting from AMI data can reduce power purchase cost**

  With meter data time stamped at 15-minute intervals, AMI enables near real-time estimation of customer demand and understands customer's power consumption in granular detail. This improves DISCOM's load forecasting and enhances the ability to procure the right volumes of power. Utility can also implement time-of-use (ToU) tariffs for different categories of customers and encourage load shifting with demand response programs. These measures could reduce peak load and hence reduce purchase of expensive power during the peak hours.

- **Power quality measurement and management**

  Smart meters are capable of measuring specific aspects in near real-time, such as power factor, over or under voltage, and over current. This helps DISCOM to enhance system power quality in conjunction with power quality data from other sources. Improved power quality also leads to lower power losses. Also, avoided costs associated with investigation of voltage complaints.

- **Asset optimization**

  AMI data supports granular monitoring of power flows on the distribution network which can help DISCOM identify segments of over- and under-loading. This is valuable information for system planning and optimizing network upgrades. AMI data can also help balance load, which reduces power losses. Better visibility of loading on the power system will help faster/delayed capacity enhancement and prevention of failure/under-utilization of equipment. Furthermore, network monitoring can decrease equipment failure rate by identifying phase imbalances and overloading in advance which can be corrected.

- **Ability to operate in prepaid and postpaid modes**

- **Remote operations**

  Smart meters typically include remote switching, which allows utilities to remotely disconnect or reconnect where necessary, such as when load is exceeded, for predetermined events, in the case of non-payment, or when a customer moves. Additionally, Utility can monitor the health of the meter and dispatch maintenance only where necessary.

- **Improvement in reliability indices and its accurate measurement**

  Enhanced monitoring of the distribution network operations would significantly improve the reliability indices like CAIDI/CAIFI, SAIDI/SAIFI as well as help measure these indices accurately.

- **Reduced Load on call centres, customer care centres and billing centres**

- **Smart meters act as feedback points**

  It helps to understand the behavioral interpretations of energy demand as consumption which can be modified.

For Transmission and Generation Utilities:

- **Deferred or avoided transmission capacity investments**
- **Deferred or avoided generation capacity investments on peak load plants and spinning reserves**

For Customers:

- **Error-free bills and no need for visiting billing centres**
- **Innovative tariff schemes**
- **Faster restoration in case of outages**
- **Ability to remotely manage and control appliances**
- **Potential to save money**
- **Remote control of loads in customer premises**

For Society

- Reduction in carbon footprint
- Better customer engagement on energy conservation and demand side management initiatives
- Enhanced customer satisfaction
- Energy efficiency and energy conservation: meta-analysis from the AMI programs in European countries indicate that on an average, consumers who actively use a smart meter can reduce their consumption of electricity by 5% to 8%

6.3 Metering Status in Gujarat DISCOMs

All DISCOMs in Gujarat have digital meters for all categories of customers, but smart meters have been installed only for the 22,000 customers in Naroda under the smart grid project.

As mentioned above, the Government of India has announced mandatory smart metering for all 250 million electricity customers in the country on a fast track. This may be completed in the next 3-5 years. Gujarat DISCOMs also will have 100% smart meters by 2024-25.

As part of R-APDRP, feeder metering was undertaken with Automated Meter Reading (AMR) systems. These AMR meters communicate the 15-minute interval data to the DISCOMs computers. This is very valuable information that DISCOMs can analyse to understand which feeders have the congestion during peak hours and can plan DSM and ToU programs to target customers on such feeders. Once smart metering is completed for all customers, DISCOMs will have full visibility of power consumption in real time.

6.4 Metering, Billing and Other Infrastructure Requirements for ToU Implementation

In order to run an effective ToU program, smart metering is required. Today, most customers pay a fixed tariff irrespective of what time of the day or what day of the week they consume electricity. Under the ToU regime, the tariff will be different for different time blocks in a day depending on the supply-demand situation on the grid. Without time-stamped consumption data it will not be feasible to implement ToU billing. Besides smart metering, other requirements include:

01

Web portal for enrolling customers under ToU plan: It is recommended to introduce ToU on a voluntary basis in the initial phase (6 months to 1 year). There should be provision for customers to opt-in for and opt-out of the ToU plan. This should be integrated with the billing systems.

02

Billing system modifications: Time stamped consumption data captured by smart meters (96 readings per day) to be processed appropriately to determine the total consumption over the billing period during regular tariff time, peak time and off- peak time blocks. This needs reconfiguration of the meter data management system (MDMS) and the billing software.

Figure 6-4: NEST Smart Switch

03

Communicating price signals to customers: In a real-time pricing regime, hour-ahead price signals need to be communicated to the customers covered in the ToU scheme. This could be made possible through messages on email, mobile phones or through direct phone calls in certain cases. SMS or WhatsApp messages can be sent to the ToU customers about the price signals.

04

Remote load control devices: Many customers enrolling for ToU may not have sophisticated automation systems to remotely control (switch-on and switch-off) their machinery or appliances. They can install smart plugs which are not expensive. These smart plugs that are connected to the WiFi in the buildings can be monitored and controlled from the mobile phone or computer.

6.5 Customer Engagement for ToU Implementation

For any new programs to be successful in an electric utility, it requires the support and active participation of the customers. Customers need to be explained the benefits to them and the society at large by implementing the new program. Several of them also need to be trained on how to make best advantage of the ToU tariff regime.

6.5.1 ToU Tariff Benefits to Customers

(a). Lower Electricity Bills for ALL

ToU gives customers options to save by conserving and shifting energy use to the time of the day when tariff is lower. By paying more attention to the timing of energy use, customers could have a new means of lowering energy bills and reducing the use of costly, polluting peak power plants. Since peaking power plants are operated only during peak hours of the day during the summer months, their overall usage is typically 10-20%; and hence the power from the peaking power plants is very high (3-5 times from base load plants) and this cost is adjusted in the overall tariff. In fact, all customers are paying for this expensive power. If peak load can be reduced (or shifted) that could avoid the use of peaking power plants, overall savings for the customers will be significant. There are many use cases in the USA and Europe to prove this fact.

(b). Freedom of Choice

Voluntary participation in ToU with the option to opt-in or opt-out, offers greater freedom to customers in choosing how they want to use and pay for electricity. Again, there are several examples of customers expressing their satisfaction with ToU in many geographies.

(c). Environmental Impacts

Primary objective of the ToU tariff is to reduce peak load that could avoid running peak power plants. Generally, all peaking plants are run on gas or oil which emits pollutants. ToU will contribute to reduction in emissions. This aspect also needs to be explained to customers that their choice to shift loads from peak hours to non-peak hours not only save money for them, but also save the planet.

6.6 Customer Impact

ToU implementation will impact a range of customers i.e., Large Commercial, Industrial, Schools/Colleges, Institutes, Utilities (WTP, STP, Municipal Board, Jal Board), Residential and Agricultural customers. Customer's participation in demand-side response will make a substantial contribution to utility load management and will improve operational efficiency of the DISCOM. It will help in future operational planning and infrastructure augmentation.

Customers' participation in ToU will have a different tariff structure and it will lead to a shift in electricity usage pattern. ToU will enable demand response, which can be defined as the capacity of end-use customers to change their electricity usage from their normal or current consumption patterns in response to market signals. This will encourage consumers to participate in the ToU, the dynamic tariff structures will flatten demand profiles and will help power distribution utility to reduce expenditure on capacity addition and efficiently plan electricity distribution.

6.7 Implementation Strategy and Roadmap

ToU tariff may be implemented on pilot basis in Naroda area in UGVCL in 2021. In the initial phase (6 months to 1 year) there should not be any financial implications of ToU – the customers opting for ToU may be presented two bills – one regular bill that they will pay; and another bill which will show the charges if they had opted for ToU regime and shifted part of their load. These Shadow Bills should show how much they would have saved if they shifted their load by 10%, 15%, 20%, 25% etc during peak hours during the billing cycle. This experiment will give enough time for DISCOMs to fine-tune their billing system for ToU regime.

Naroda area is recommended for the pilot implementation because the customers there have smart meters and are now familiar with the smart technologies. With the experiment in Naroda, the ToU regulations may be finalized for Gujarat.

While waiting for the smart metering rollout in the state, high value customers (say those with 100kW or above) may be enrolled in ToU. These customers can be provided smart meters on priority with GPRS connectivity and their time-stamped meter data can be downloaded remotely to prepare ToU bills. Every time a new customer is enrolled in ToU scheme, offer them a trial period of 3 months with shadow billing.

The steps to implement ToU are explained below:

Step 1

Selection of the Target ToU Customers

DISCOM should identify the customers with significant load (say 20 kW and above) who could shift part (or full) loads by a few hours – either prepone or postpone. It is also important to know the loading on the feeders. Should select ToU customers on feeders with maximum congestion during peak hours.

Step 2

Customer Engagement and Education

Since utilities view ToU tariff rates as a tool to help control the electric grid, the survey indicates that consumer education could be a barrier to rolling out successful programs. The survey results are indicating that the majority of the customers don't understand how their electric bills work. There is a widespread lack of awareness, and customers cannot even understand their electricity bills easily. That could be a challenge as utilities introduce more complicated rate structures that charge different prices at different times of the day. One bright spot from the survey, most of the customers said they are open to trying ToU rates, especially if they offered potential to save money. The first step toward raising awareness is for regulators to encourage programs with utilities to make customers aware of a fast-track mode. To reach customers more effectively, it's important for utilities to know their customers and communicate how new rate structures can benefit them.

With usage data analytics utilities can determine from an individual customer's electricity usage patterns create an alternative bill and the same can be shown to the customer on their bill, a strategy known as shadow billing. It is one of the best tools that utilities have, because it gives the information based on their usage.

Step 3

Enrolment of Customers through Web Portal

It is recommended to educate all ToU tariff consumers to enrol for the ToU program through the DISCOM's web portal. A mobile friendly web portal helps provide better services to customers and offers a number of advantages by providing numerous online services which customers can avail using their unique id. The web portal will enable consumers to register them online and track the following key functionalities:

- Application for new connection
- Status of application
- Online bill payment
- Online pricing signals
- Online complaint registrations
- Tariff change

Step 4

Metering Upgrades by DISCOMs

DISCOMs should have a proper plan for the rollout of smart meters and related IT systems to implement ToU. Once consumers are registered in ToU scheme, and they do not have smart meters, DISCOMs should attempt to provide smart meters on priority. Such smart meters may be connected through GPRS communication. Once regular smart metering is rolled out, these meters can be replaced.

Step 5

Installation of Load Control Devices at Customer Premises

Customers opting for ToU tariff may be educated on various devices and automation schemes for remote control of their loads. While large factories with SCADA systems can be programmed to respond to DISCOM price signals, in medium and small industries, businesses and residential customer premises load control may be undertaken manually or remotely through smart plugs. Customers may be given demos and training in use of such devices. DISCOMs can promote smart plugs and other load control devices.

Step 6

Integration with Billing System

The smart meter data collected from the ToU customers need to be integrated with the billing system to prepare the bills according to ToU tariff. The new ToU billing can work either in isolation till it gets scaled up or can be integrated with existing billing systems with proper provisions.

Step 7

Go live

After setting up the right infrastructure at customer premise and integrating it with back end for billing, the ToU program can be made live.

Step 8

Feedback

There should be provision of a 24X7 helpline to collect the feedback from the customers. A better ToU feedback will help DISCOMs to scale up the implementation across the utility.

6.8 Recommendation for ToU Implementation

The recommendations to implement ToU are summarized here:

- GERC in consultation with the Energy Department, GUVNL and the DISCOMs may finalize a ToU Tariff regime. Our recommendation is to keep it simple in the beginning - just 3 part tariff – Regular, Peak and Off Peak. For the Peak, a surcharge may be added to the regular tariff, and a rebate on the regular tariff may be given for off peak rates. Exact numbers for different categories of customers may be analysed and finalized. Consultations with target ToU customers may also be conducted.
- Phase-1: GERC may approve pilot rollout of ToU in Naroda area where smart meters are already implemented. They may be given shadow billing showing the savings in the initial few months if they have opted for the ToU tariff; and allow them to opt-in for the ToU tariff.
- Phase-2: Once the ToU billing system integration is completed for the Naroda area customers, UGVCL should explore the feasibility of ToU rollout to HT and other high value customers (say with load above 100kW). These customers may be given smart meters with GPRS communication.
- Customer feedback and analysis systems should be monitored by GERC for appropriate modifications in the ToU framework.
- The savings in power purchase cost for the DISCOM, the peak load reduced and the consequent reduction in AT&C losses and emissions avoided must be calculated by the DISCOM and monitored by GERC. DISCOM should also assess their revenue impact (both positive and negative) from the ToU customers and overall revenue impact from the scheme and may make appropriate recommendations to GERC for changes in the ToU tariff framework.
- Smart metering rollout (as part of 100% smart metering scheme of GoI) may be designed so that the meter data management systems and its integration with billing system should have the features to capture and aggregate the meter reads in specified time blocks with different tariffs in separate buckets and apply relevant tariffs to prepare the ToU bills for the billing cycle.
- Phase-3: Once smart metering is completed in urban areas in Gujarat by all DISCOMs, ToU tariff may be offered to customers with load above 20kW across all DISCOMs in Gujarat.
- Phase-4: ToU tariff may be offered to all the customers in Gujarat on voluntary basis while it is mandatory for customers with load above 20kW.
- The ToU Analytical Tool (EXCEL File submitted along with this report) may be updated regularly with actual consumption data. The instructions to use the Tool are given in the EXCEL File. Training sessions for the officials of DISCOMs and GERC being arranged by ISGF.

ANNEXURE I: Survey Questionnaire

Consumer Profile: (To be filled in by the Interviewer)

1. Name: ....

2. Contact: ....

3. Address: ....

4. Consumer No.: ....

5. Applicable Tariff: ....

6. Survey Date: ....

Introduction:

Introduce Self. (Name and stating a current student of Gujarat University, if required, otherwise avoid). We are calling on behalf of the Government about a potential new electricity consumption management program (the way Consumers use electricity for their premises) that you could be eligible for. We would like to ask you a few questions about your Premise (Residence, Office, Shop, Farm or Factory), energy using equipment, and interest in this potential new electricity consumption management program. This survey will take about 10-15 minutes to complete. Also, emphasize confidentiality. Explain it is for our analysis only.

Ask Permission to Record. (Optional)

1. What is your sanctioned Load (kW)?

2. Is there any machinery/appliance that needs to be run 24x7 all seven days a week? If so, what is that Load?

3. Do you face frequent power fluctuations/ interruptions?

a) Yes
b) No

4. Does the connected load/appliances* have the flexibility to shift their operations during the day/night?
(*Connected Load / Appliances like Air Conditioner, Electric Geyser, Electric Pump, Production Line etc.)

a) Yes
b) No

5. Are you under the ToD Tariff?

6. Are you aware that there are different tariff schemes such as real-time or time of use/ critical peak pricing etc., in other countries?

a) Yes
b) No

7. Do you believe that the Changing (Dynamic) electricity rate determined by the market conditions would make a difference to you in saving money?

a) Yes
b) No

8. Are you looking forward to installing rooftop solar PV in the next two years?

a) Yes
b) No

If YES – what capacity (kW) of PV and how much energy storage system (kWh)?

9. Are you planning to buy Electric Vehicle in the next two years?

a) Yes
b) No

10. Do you have a smartphone and use different Apps?

a) Yes
b) No

11. Would you use an App for saving on electricity bills?

a) Yes
b) No

12. Would you be prepared to change your electricity consumption pattern (times) if lower rates are offered at different time slots?

a) Yes
b) No

13. Out of your total Load, how many loads you can shift to different time slots in a day?

a) 100%
b) 75%
c) 50%
d) 25%
e) Less than 10%
f) None

14. Which alternate Electricity Rate Design do you recommend?

a) Block (Time block of 3-4 hrs)
b) Hourly prices in real-time (2 hrs. before
c) Block / Hourly prices on a day-ahead basis
d) Block / Hourly prices every week
e) Block / Hourly prices every month
f) Other, Specify ....

15. Would receive subsidized Smart Switches (programmable thermostat) for heavy appliances installed for you be sufficient incentive to sign up for such a program?

a) Yes
b) No
c) Don't know

(Note: If possible, the current cost of installation of smart switches can be shared)

16. If your existing appliances are near completion of their useful life, do you believe that replacing the existing appliances with smart appliances (including smart switching features) would optimize operational cost?

a) Yes
b) No

17: Do you believe the Electricity Bill should also show what the customer would have paid for the same electricity usage under a different rate structure based on time of electricity consumption and the money that the consumer would have saved (Shadow Billing) before actual implementation of the Electricity Consumption Management Program?

a) Yes
b) No

An initiative supported by

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