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ACCELERATING USE OF RENEWABLE ENERGY BY GREEN TIME OF DAY TARRIF

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ACRONYMS

AERC	Assam Electricity Regulatory Commission
APDCL	Assam Power Distribution Company Limited
APEPDCL	Andhra Pradesh Eastern Power Distribution Company Limited
ARR	Aggregate Revenue Requirement
AT&C	Aggregate Technical and Commercial losses
BERC	Bihar State Electricity Regulatory Commission
CEA	Central Electricity Authority
C&I	Commercial and Industrial
CAPEX	Capital Expenditure
DGVCL	Dakshin Gujarat Vij Company Limited
DHBVNL	Dakshin Haryana Bijli Vitran Nigam Limited
DISCOMs	Distribution Companies
DPV	Distributed Solar Photo Voltaic Rooftop
EESL	Energy Efficiency Services Limited
EPC	Engineering, Procurement and Construction
FIT	Feed-in Tariff
GERC	Gujarat Electricity Regulatory Commission
GoI	Government of India
GW	Gigawatts
HERC	Haryana State Electricity Regulatory Commission
IEX	Power Exchange
INR	Indian Rupees
INR Cr	Indian Rupees Crore (10 million rupees)
JBVNL	Jharkhand Bijli Vitran Nigam Limited
JSERC	Jharkhand State Electricity Regulatory Commissions
KSEB	Kerala State Electricity Board Limited
kvAh	Kilovolt Ampere Hour
kWh	Kilowatt Hour
kWp	Kilowatt Peak
LED	Light Emitting Diode
LPC	Low-Paying Customer
LT	Low Tension

MGVCL	Madhya Gujarat Vij Company Limited
MUs	Million Units
MW	Megawatt
NBPDCL	North Bihar Power Distribution Company Limited
NDC	Nationally Determined Contribution
NSM	National Solar Mission
PACE-D	Partnership to Advance Clean Energy – Deployment
PACE-D 2.0 RE	Partnership to Advance Clean Energy – Deployment, Second phase
PFC	Power Finance Corporation
PGVCL	Paschim Gujarat Vij Company Limited
PLF	Plant Load Factors
PPA	Power Purchase Agreement
PPP	Public-Private Partnership
PV	Photo Voltaic
RE	Renewable Energy
RECs	Renewable Energy Certificates
RESCOs	Renewable Energy Service Companies
RPO	Renewable Power Purchase Obligation
SBPDCL	South Bihar Power Distribution Company Limited
SERCs	State Electricity Regulatory Commissions
SOURA	SOURA Natural Energy Solutions India
SPVRT	Solar Photo Voltic Rooftop
T&C	Technical and Commercial
T&D	Transmission and Distribution
TPL	Torrent Power Limited
UGVCL	Uttar Gujarat Vij Company Limited
UHBVNL	Uttar Haryana Bijli Vitran Nigam
UJALA	Unnat Jyoti by Affordable LEDs for All
USAID	United States International Development Agency
WBERC	West Bengal Electricity Regulatory Commission
WBSEDCL	West Bengal State Electricity Distribution Company Limited

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EXECUTIVE SUMMARY

As the penetration of low-cost renewable energy (RE) increases in India, most distribution companies (DISCOM) face surplus power during some period of the day. To cope, they operate thermal power plants at low plant load factors (PLF) and/or sell power to power exchanges (IEX) at minimal profit/loss. Several efforts are underway on the supply side to accommodate higher RE. Some of these include (1) thermal machines operating economically at low PLF, (2) faster ramping rates, and (3) decreasing storage costs. This paper suggests a novel demand-side approach that shifts existing demand and generates additional demand during the surplus power period due to RE.

DISCOMs should examine the period of the day when:

> Variable cost of the surplus thermal power/Surplus RE power + Transmission and distribution (T&D) losses < Normal tariff.

When this equation holds true, there is a good case for a green time-of-day (ToD) tariff. Accordingly, the green ToD tariff is the tariff that is lower than the normal tariff and applicable for additional demand that is generated in a specified period compared to previous year demand in the same period and helps in demand shift. The USAID PACE-D 2.0 RE program conducted this analysis for Assam Power Distribution Company Limited (APDCL) and Jharkhand Bijli Vitran Nigam Limited (JBVNL) and found that APDCL, by introducing the green ToD tariff of one Indian rupee/kilowatt hour (kWh) lower than the normal tariff, can make an annual profit of INR 29.71 crore with a modest additional demand generation of 6.6 percent from the previous year. Applying the same green ToD tariff, JBVNL can earn an annual profit of INR 42 crore by generating an additional demand of only 3.2 percent.

Encouraged by the results of the analysis of APDCL and JBVNL, the program attempted to examine the scenario at the national level. The above-mentioned equation cannot be used for national-level analysis because of different variable costs, tariffs, variations in T&D losses, and different time periods of surplus power across India. Therefore, to determine the demand shift, the program used India's past experience with ToD tariffs and price elasticity of electricity for demand generation. The team found that keeping green ToD tariffs ten percent lower than normal tariffs should shift the demand by 4 percent and generate an additional demand of 0.2 percent in the short term and 0.6 percent in the long term. The national analysis is more empirical, and there are not yet many published results available on ToD tariffs and price elasticity of electricity. The results will get refined and improved in the near future.

Each DISCOM should carry out an analysis on using surplus power to increase their business and contribute to the state economy by increasing per capita consumption of electricity. To facilitate the analysis, the PACE-D 2.0 RE program has developed the Excel-based Green ToD Tool and suggested a methodology for designing green ToD tariffs. However, determining green ToD should be dynamic process as it is sensitive to availability of the demand and supply. The green ToD should be reviewed every year.

The biggest challenge in the implementation of the green ToD tariff lies in identification of the base line, or previous year's consumption and deployment of ToD meters green ToD is recommended for additional demand only in the surplus period. To facilitate easy implementation, several examples for various situations with and without the availability of ToD meter and consumption data are provided. To further support the DISCOMs, the program organized a one-day capacity-building course on green ToD with the Indian Institute of technology (IIT) Roorkee in April 2021. More than one hundred professionals participated, and IIT Roorkee expressed interest in conducting a similar course sometime in the next six months.

1. INTRODUCTION

India has emerged as one of the leaders in the transition from fossil fuel–based energy sources to clean energy sources. The country has "enhanced its installed renewable capacity by 2.5 times and increased installed solar capacity by more than 13 times in the last six years,"[1] as mentioned by India's Prime Minister Narendra Modi.

India's nationally determined contributions (NDCs) under the Paris Agreement are to achieve a 40 percent share of non-fossil-fuel-based sources in its installed energy capacity by the year 2030. After the Paris commitment, India set the target of 175 gigawatts (GW) (primarily 100 GW solar and 60 GW of wind) of RE capacity by 2022.

Table 1 provides the existing generation capacity from various sources as of January 31, 2021, and the expected generation capacity in the target year.

Table 1.1 Existing and Upcoming Generation Sources

Source	January 31, 2021		Expected in FY 2021-2022	
	Installed Capacity (GW)	% of Total Installed Capacity	Installed Capacity (GW)	% of Total Installed Capacity
Thermal	231.87	61.46%	257.5	52.7%
Nuclear	6.78	1.80%	7.9	1.6%
Hydro	46.06	12.21%	59	12%
Renewable Energy Sources	92.55	24.53%	160	32.7%
Total	377.26		488.1	

Source: Central Electricity Authority. The data can be accessed at https://cea.nic.in/wp-ontent/uploads/installed/2021/01/installed_capacity.pdf

1.1. PROJECTED IMPACT OF RE TARGETS ON THE POWER SCENARIO

The demand curve in most states in India is flat during the day. Generally, it has two peaks, one in the morning and the other in the evening (Figure 1).

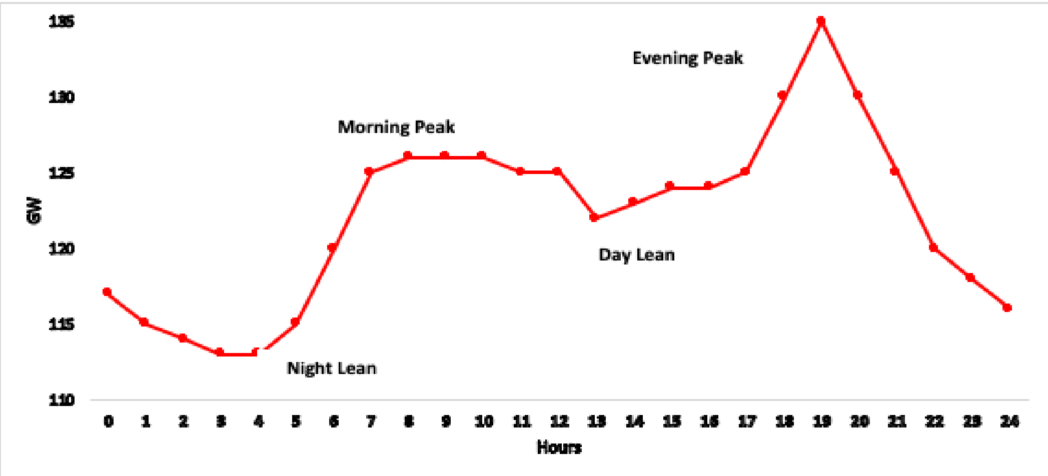
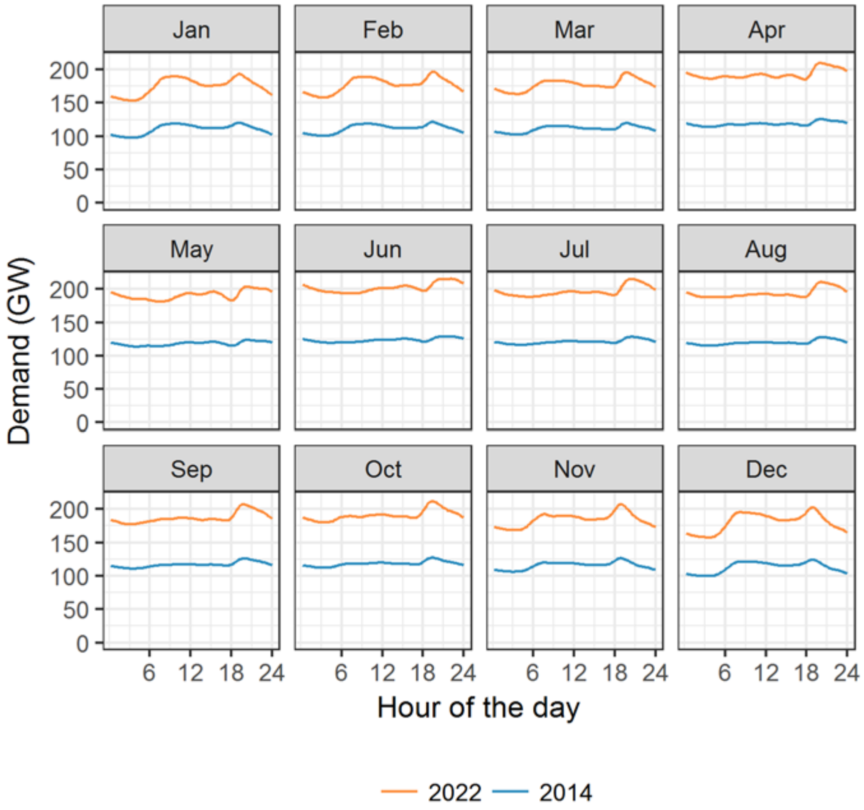


Figure 1.1 Typical Demand Curve for India

Source: NLDC, IEEFA

[1] PV Magazine, January 5, 2021

The national monthly load profile for 2014 and projected national monthly load profile for 2022[2] for all months are presented in Figure 2. The figure indicates that in 2022 the ratio between peak demand and average demand will be higher compared to the same ratio in 2014, and the higher RE generation (100 GW solar) will come during the daytime. The variability in demand, especially during the day, is largely met by coal-based power plants. To cater to the variability, thermal power plants operate at varying PLFs.

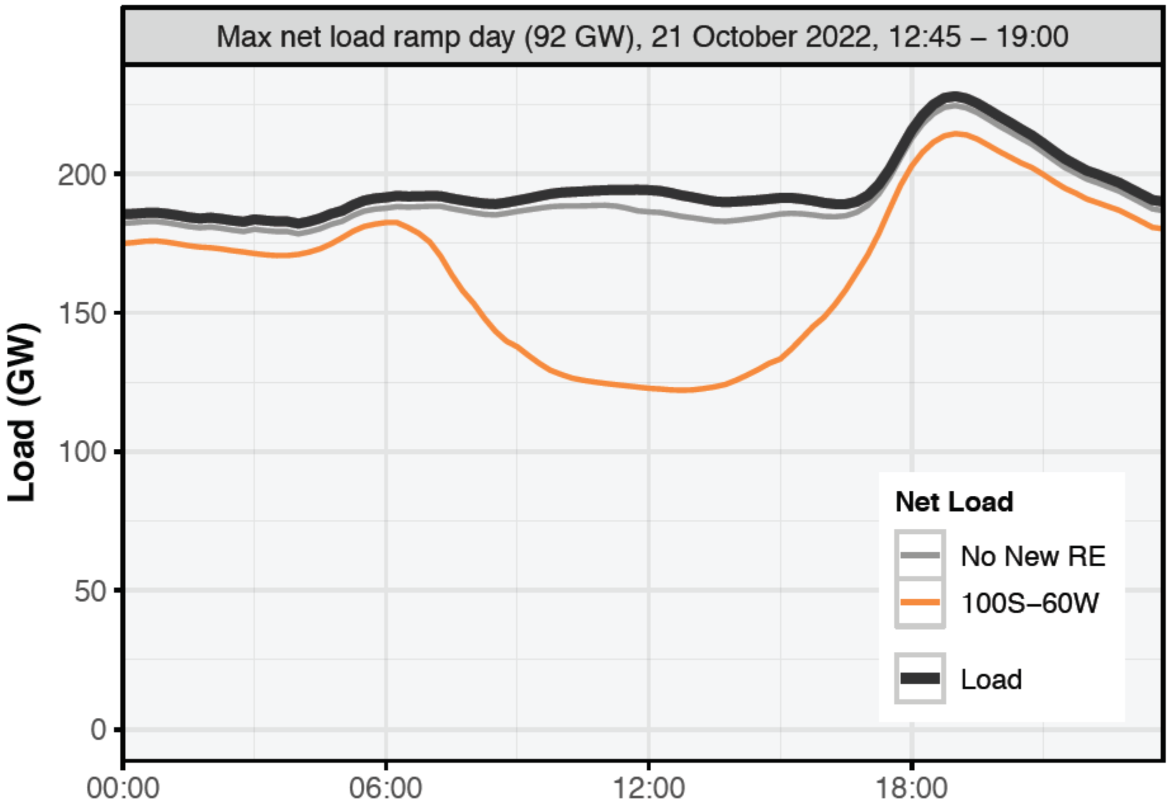


Source: www.greeningthegrid.org

Figure 1.2. National average daily load profiles for each month in 2014 and 2022

However, solar PV generation is available only during the day and follows a generation pattern that resembles a bell curve. Wind generation is available mostly at night. In India RE has a "must run" status, which means the generation from RE sources is used first to meet the load. Under USAID's Greening the Grid program, an analysis was conducted to evaluate the operation of India's power grid with 175 GW of RE. Figure 1.3 shows the net load curve, i.e., total load minus RE (100 GW solar and 60 GW wind), in 2020.

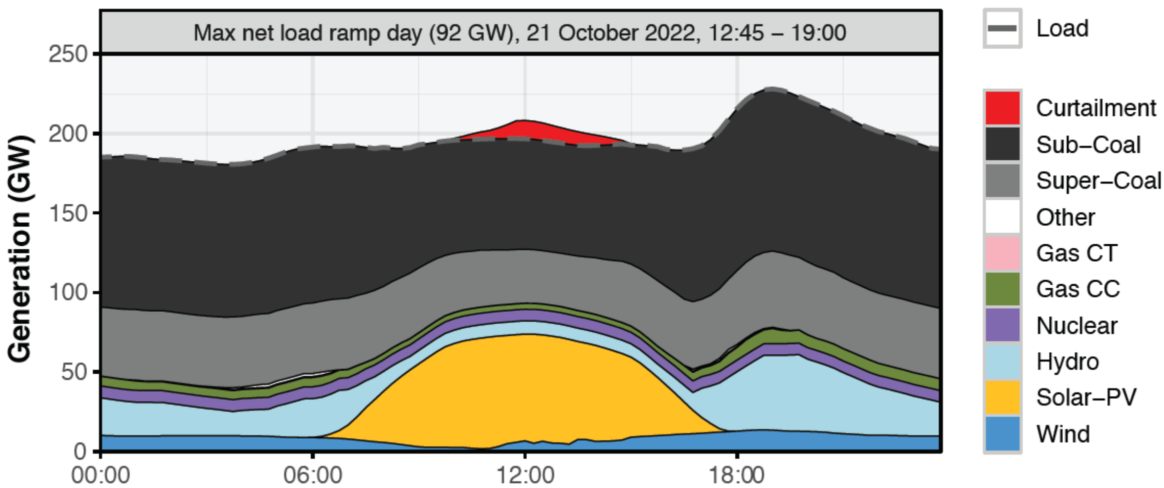
[2] Source: GTG Report



Source: www.greeningthegrid.org

Figure 1.3. Average hourly net load in 2022

The study further found that this load curve will require changing the minimum generation levels of all coal plants from 70 percent of their rated capacities to 55 percent.[3] Still, about 1.4 percent of RE generation will be curtailed (Figure 4).



Source: www.greeningthegrid.org

Figure 1.4. Simulated maximum net load for October 21, 2022

[3] CERC regulation specifies the minimum PLF for coal plants as 55 percent.

Increasing RE penetration affects the operations of thermal power plants, which in turn affects the finances of the DISCOMs and subsequently increases the cost of supply as shown in Table 2.

Table 1.2. Impact of higher RE on thermal power plant operations and DISCOM costs

Impact of increasing RE penetration on operations of thermal power plants	Impact on DISCOM costs
Decrease in thermal generation	Per unit cost of generation increases with decrease in the PLF of thermal plant. Thermal generators will recover this increased cost from DISCOMs
Meeting technical minimum generation from thermal power plants	DISCOMs would need to purchase surplus power from thermal power plants to meet technical minimum criterion and sell it to IEX at a lower price. [4]
Frequent reserve shut down	To balance the grid, thermal power plants would be shut down more frequently. Shutting down and restarting the thermal power plants involves cost and reduces the life of the power plant.
Fixed charges	

Several measures are being planned on the supply side to meet the variability and dispatchability of the 175 GW of RE. These measures include enhancing the flexibility of thermal machines; retiring inefficient thermal machines; increasing ramp-up and ramp-down rates, storage, and demand response; and enlarging geographical and electrical balancing areas.

However, the issue has been less analysed from the demand side of the equation. This paper analyses the scenario from the demand side and suggests measures to gainfully utilize RE generation that is likely to be curtailed and to run thermal power plants at a PLF greater than 55 percent. This approach has the inherent benefit of strengthening DISCOMs, which are in crisis due to poor financial health and the loss of their high-paying customers as a result of open access and captive generation.

The marginal generation cost of the plant operating at between 55 and 100 percent PLF and the curtailed RE cost are significantly lower than the average generation cost. This low-cost generation should be utilized by DISCOMs to increase sales, which is their core business. As more solar power is added to the grid, the day price on the Indian exchange will go down, which means DISCOMs will not have the option to sell excess power to the exchange. For example, in 2019-2020, Assam sold about 1,300 mega units (MU) of power to IEX at a loss of INR 0.06/kWh.

1.2. GREEN TIME OF DAY TARIFF

The PACE-D 2.0 RE program proposes the green time-of-day tariff as a demand-side solution for absorbing the higher RE penetration in a cost-effective manner. One of the merits of the proposed solution is a short gestation period for design and implementation. Under the green ToD tariff structure, DISCOMs will provide a rebate to customers for the incremental electricity consumption during the period with high RE generation or for shifting the demand from peak time to non-peak hours. Such rebates have the potential to increase demand, which will improve the utilization of thermal power plants and thus reduce the cost of generation by improving PLFs; reduce restarts of

[4] From GREENING THE GRID: Pathways to Integrate 175 Gigawatts of Renewable Energy into India's Electric Grid, Vol. I—National Study EXECUTIVE SUMMARY, "Changing minimum generation levels of all coal plants, from 70% today to 55% of rated capacity (consistent with the CERC regulations) reduces RE curtailment from 3.5% to 1.4% and annual operating cost by 0.9%, or INR 2000 crore. Reducing minimum generation levels further, to 40%, reduces RE curtailment to 0.76%, with negligible decreases to annual operating costs."

the plants; reduce need for running plants at technical minimum; and increased utilization of the fixed costs of the thermal plants.

Green ToD tariffs provide gains to all the stakeholders:

1. **Thermal Generators** – Increased daytime demand can improve the PLFs and reduce the variability in the generation pattern, which can increase the revenue from catering to increased demand and cost of generation.
2. **RE Generators** – Increased demand can provide enough capacity for the grid to absorb more RE and thus reduce the need for curtailment. A decrease in curtailment will increase the revenue of the RE generators.
3. **DISCOMs** – Increased daytime demand can help flatten the load profile, allowing DISCOMs to absorb more power at a lower cost. Adding new demand will increase the business and profitability of the DISCOM.
4. **Customers** – With the rebate for incremental consumption, customers can consume more electricity by adding new appliances and substituting other energy sources for electricity. This can reduce their average cost of energy.

The paper suggests several demand-side interventions such as demand generation, demand shift, electrical vehicle charging, storage before and after the meter, change in retail tariff design, and smart devices to remotely control the operation of electric home appliances, water pumps, etc. The focus will be on two main suggestions: demand shift and demand enhancement by the green ToD tariff. The paper commences with a brief overview of the green tariff, as originally conceptualized, and how a few states in India have adopted it in their tariff order as of March 2021. Subsequent chapters discuss case studies on designing and implementing green ToD for Assam and Jharkhand. There is also a brief description of various incentives provided by states such as Maharashtra, Madhya Pradesh, and Rajasthan to increase the demand. Finally, the paper lists the key steps DISCOMs should follow in designing and implementing green ToD tariffs.

2. GREEN TARIFF: AN OVERVIEW

Customers—from residential customers to large industrial ones—are increasingly procuring renewable energy in an effort to reduce their electricity bills and avoid fuel price unpredictability. Rising demand for RE is motivated by two factors—increasing pressure from customers, shareholders, and employees for companies to achieve their sustainability targets and falling RE prices, which enable customers to reduce their electricity costs and long-term electricity risks.[5] Globally, the following mechanisms have been adopted for RE procurement:

- **Renewable Energy Certificates (RECs)** – RECs are tradable certificates that represent the environmental attributes of energy generated from RE sources. In India, RECs are used to achieve the renewable purchase obligation (RPO) targets directed by various state electricity regulatory commissions to large electricity customers.
- **Power Purchase Agreements (PPAs)** – PPAs are agreements signed between two parties, in which one party purchases electricity produced by the second party at a specific tariff, subject to terms and conditions.
- **Virtual Power Purchase Agreements** – In these agreements, the RE generator sells electricity to the grid at a market price but passes on the RECs to the customer in exchange for the price differential between the market price and a prefixed hedge price.[6]

One of the emerging RE procurement options for commercial and industrial (C&I) customers is the green tariff. Under a green tariff arrangement, customers typically enter into a long-term agreement to purchase RE power provided by the utility and usually generated by a specific resource.[7] The large customer pays the utility and benefits from the cost savings that accumulate. The utility acts as an intermediary between the electricity customer and the RE generator. The arrangement involves the utility procuring RE from the RE generator on behalf of the customer, who in turn pays a utility green tariff rate for the RE service.[8]

Traditional utilities seeking to compete in the changing electricity marketplace are exploring green tariffs. Building on their longstanding capabilities, they may be able to offer many of the features customers are looking for in renewable energy, along with greater elasticity and lower transaction costs than those offered by third parties.

What Are Green Tariffs?

Green tariffs are tariff structures offered by utilities that allow large commercial and industrial customers to buy bundled renewable electricity from a specific project through a special utility tariff rate or a premium. This provides these larger energy customers an option to meet their sustainability and renewable energy goals, reduce long-term energy risks, and demonstrate commitment to the development of new renewable energy projects.

Making the green tariff voluntary gives customers the choice to opt for green energy. The extra charges for the procurement of renewable energy being charged to specific customers would not increase the cost borne by other customers. In addition, this would also reduce hesitation on the part of DISCOMs going for the high cost of power purchase from renewable sources, as it will not affect the general tariff.

Green tariffs have emerged globally as an attractive option for corporate sourcing for a wide variety of reasons. First, customers can source up to 100 percent of their electricity from renewable sources.[9] Second, customers can save on upfront capital investment, and subsequent operations and

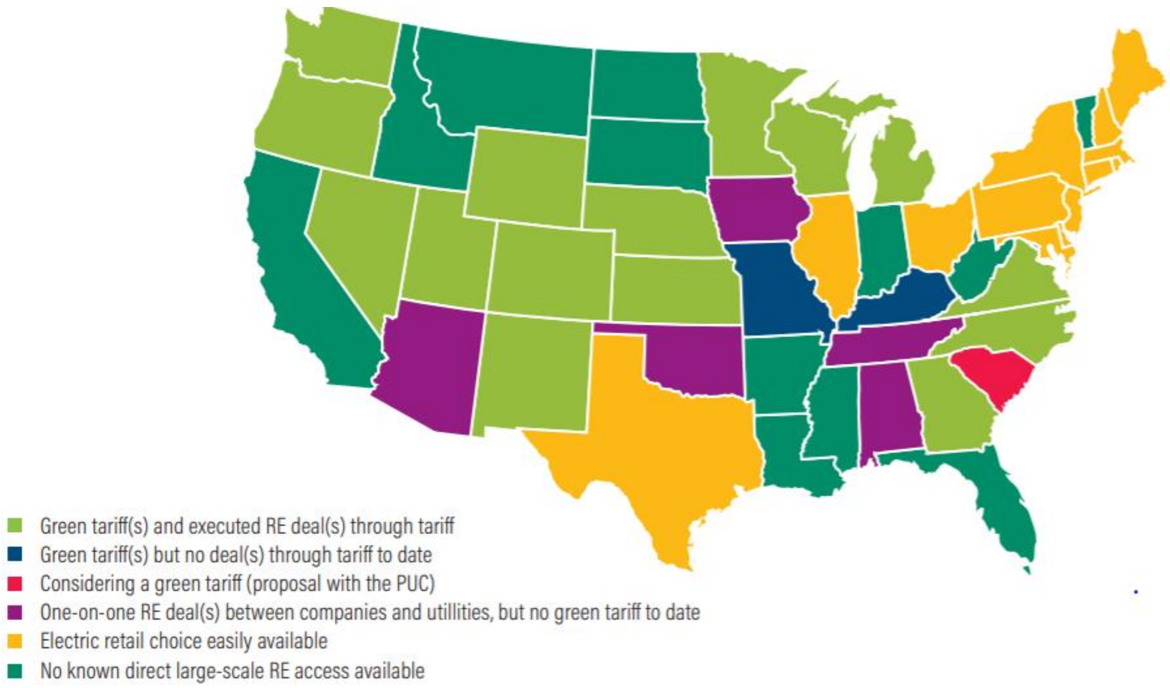
[5] Barua 2017; Dingenen et al. 2018.
[6] EPA 2016
[7] Barua 2017; IRENA 2018
[8] Bird et al. 2017

9 IRENA 2018

maintenance costs, through green tariffs. Through green tariffs, the customer can diversify its power sources without the costs associated with managing an RE project. The cost of identifying a third-party producer can also be mitigated by approaching the local utility to enter into a green tariff arrangement. Third, considering that both solar and wind energy are cost competitive, long-term contracting for purchasing RE at a fixed or predictable price, through green tariffs, is an attractive option. Last but not least, the green tariff is an opportunity for the utility to prevent the loss of large C&I customers to cheaper RE, aid in meeting regulatory targets for renewable energy supply, and attract new customers.

2.1. GREEN TOD-INTERNATIONAL EXPERIENCE

A review of the literature indicates that green tariffs are being used by large customers in Australia, China, the United States, United Kingdom, and many European countries. In the United States, as of November 2019, as many as 31 green tariffs were approved or awaiting approval in 18 U.S. states (Figure 5).



Source: Bonugli 2019.

Figure 2.1. Utility renewable energy deals in the United States

Across Europe, RE electricity sources are generally accessible to residential customers and small-scale commercial customers. As of 2018, C&I green tariff deals have been reported across the United Kingdom, Spain, Germany, Sweden, Italy, Switzerland, and the Netherlands.[10] In the United Kingdom, many retailers provide a green tariff option offering up to 100 percent of electricity from renewable generation.

In Australia, GreenPower is the Australian government's voluntary accredited program that enables customers to purchase RE in the retail electricity market. The program allows accredited energy providers to sell GreenPower products and thereby grant a customer large-scale generation certificates (LGCs) to ensure certain increments of RE in relation to a customer's monthly electricity consumption.

10 IRENA 2018

2.2. GREEN TOD APPLICATION IN INDIA

In India, DISCOMs have been mandated to meet RPOs under the Electricity Act 2003 and the National Tariff Policy of 2006. Although some Indian corporations are increasingly looking to set sustainability goals for their electricity procurement, India has seen limited experimentation with green tariffs, namely, in the states of Karnataka and Andhra Pradesh.

2.2.1. ANDHRA PRADESH

In 2008-2009, for the first time, Andhra Pradesh announced an optional green power tariff for C&I customers at a premium price of INR 6.7/kWh.[11] In their 2017-2018 tariff order, this category was detached by quoting the absence of sales since commencement. However, a petition was filed in 2016-17 by customers who had subscribed to this tariff category. In response, Andhra Pradesh Electricity Regulatory Commission (APERC) reintroduced the "HT Category VII-Green Power" tariff category in 2018-2019 for HT customers "who wish to avail power from Non-conventional sources of energy voluntarily and show their support to an environmental cause."[12] At INR 11.32 per kilovolt Ampere hour (kVAh), subscription to this tariff category is elective and entitles the subscribing HT customers to RECs as well. There is no constraint on the end use of this green energy, and no monthly minimum charges are imposed under this category. This has been sustained in the tariff order dated February 10, 2020.

2.2.2. KARNATAKA

Starting December 2010, HT customers of Karnataka could opt for green power directly from the utility by paying a premium of INR 1/kWh on their existing grid tariff (power thus procured would be over and above their RPO), which was called a green tariff.[13] In its petition requesting the green tariff, Bangalore Electricity Supply Company Ltd. (BESCOM) specified that "there is [a] group of customers who want to purchase power from green sources and would not mind paying more for such power." This tariff was changed to INR 0.50/kWh by Karnataka Electricity Regulatory Commission (KERC) in 2013 and was sustained in the most recent order on May 30, 2019.

2.2.3. MADHYA PRADESH

The Madhya Pradesh State Action Plan on Climate Change (MP SAPCC) states the intention to structure green tariffs to incentivize the production of clean energy, per a 2013 directive from the Government of Madhya Pradesh.

Andhra Pradesh and Karnataka both seem to have witnessed partial success in green tariff adoption.[14] In both states, the green tariffs are simple premium pricing models based on surplus RE with the utilities. Very low uptake of the green tariffs in these states may have prevented the evolution of more sophisticated green tariffs in India.

2.2.4. MAHARASHTRA

However, in a recent order in 2021, the Maharashtra Electricity Regulatory Commission (MERC) allowed a green power tariff for customers opting for 100 percent green energy. All customers including extra high voltage, high voltage, and low voltage, are eligible to choose 100 percent RE power with payment of the green power tariff. Per the order, the green power tariff of INR 0.66/kWh, which is higher than the normal tariff of the respective category for tariff orders, will be levied on such customers.

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[11] IDFC 2010

[12] APERC 2018

[13] KERC 2010

[14] Andhra Pradesh and Karnataka seem to have only one single consumer of green tariff. The experiments of two Indian states (Andhra Pradesh and Karnataka) with green tariffs have been largely ad hoc in nature than structured green tariffs involving a long-term contract. General perception as mentioned in sources states that the uptake has been poor in both states due to the premium charged on top of already high industrial/commercial tariffs.

The Tata Power Company Limited (Distribution) (TPC-D) filed a petition seeking approval for the green power tariff for supply of RE to customers to meet the requirement to utilize 100 percent green energy for their entire demand. MERC found the petition helpful to increase awareness amongst the customers about the use of renewable energy. The state regulator observed that computing the cost of the green power tariff based on the average cost of renewable energy sources was the correct approach. MERC ruled that the tariff would be uniform for all DISCOMs in the state.

Although some large customers are increasingly looking to set sustainability goals, India has seen limited experimentation with green tariffs. Creating the appropriate regulatory environment may incentivize the uptake of utility-based green tariffs. The industry needs best practices to foster a friendly environment, such as improved planning and forecasting mechanisms to better assess demand and supply; consideration of cross-subsidy structures when formulating new tariffs for customers; specification of electricity needs of large customer categories to produce exact tariffs; consultation with regulators to ensure that other customer categories are not unfairly burdened; and transparent promotion of relevant information. This report will inform future efforts to formulate green tariffs in India. A central, consultative approach is needed to ensure that these tariffs result in a win-win situation for all stakeholders.

3. ESTIMATING SHIFT IN DEMAND DUE TO GREEN TOD TARIFF

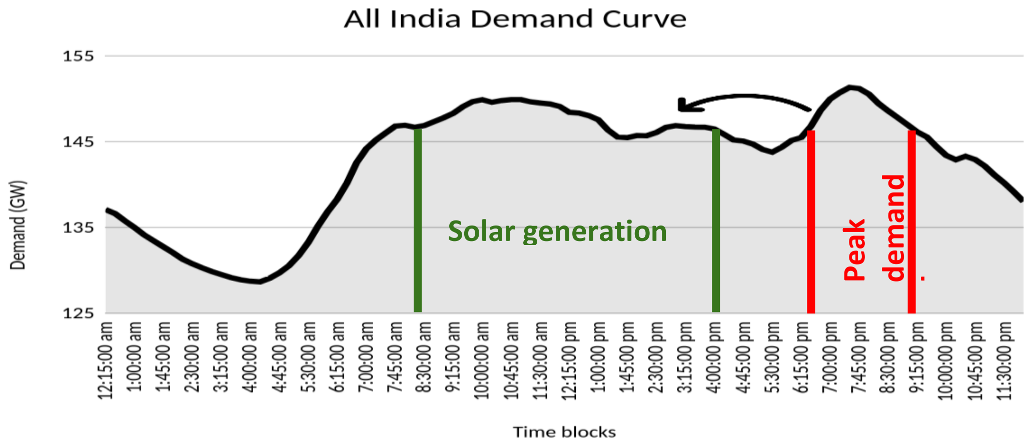
Adding 100 GW of solar to the grid by 2022 will lead to surplus power generation during the day (Figure 6), resulting in thermal backing,[15] because RE has a must-run status. Since most DISCOMs have long-term contracts with thermal generators, they will pay the fixed charges for the backed power. Therefore, it is beneficial for the DISCOM to sell this surplus power during the day at a rate higher than variable charges and losses due to transmission and distribution (T&D) of the thermal power generation. Many DISCOMs purchase power during the evening from the power exchange to meet their demand at a rate higher than the rate of thermal power generation (fixed plus variable). Therefore, shifting some demand from evening to daytime will

1. **Reduce costly purchases** from the IEX. Reduction in power purchase from IEX will make the DISCOM's power portfolio more stable in terms of price (IEX price volatility avoided) and secure.
2. DISCOMs will be able to **make a profit by selling power** at a rate much higher than the variable cost of thermal generation.
3. DISCOMs will be able to **draw higher power from thermal power plants,** eliminating the risk of paying the minimum commitment charges to thermal generators, provided the demand shifted is higher than the surplus RE power.
4. Thermal power plants will operate more economically at **higher PLF**.

The time-of-day tariff is an important tool for shifting demand from peak time to solar time (daytime) This tariff is already in use in most states of India for industrial and commercial customers, where it is used in the opposite way—the evening tariff is higher than the daytime tariff, which has a standard rate. The green TOD tariff the program proposes would reduce the standard tariff during the day since the DISCOMs' cost of power purchase is low.

Figure 6 represents the demand curve of India for FY 2018-2019. Demand for power is the lowest in the early morning hours and gradually increases as the day progresses, stabilizing in the 140 to 145 GW range during the day. Again, as evening approaches, it falls a little and then again picks up to reach its peak, at around 7:45 p.m. The daytime demand falls within the solar generation hours—8 a.m. to 4 p.m., and some of the evening load can be shifted to this time period. The difference in demand between the peak and valley times is about 8 to 10 GW. A reduced tariff in the form of a green ToD tariff can encourage customers to shift some of their electricity use to daytime hours when supply is greater, and the cost is cheaper.

[15] Thermal backing is exercised when the load of thermal power plants is reduced due to lower demand.



Source: Energy statistics 2019, Central Statistics Office, Ministry of Statistics and Programme Implementation, Government of India

Figure 3.1. Demand curve for all of India

3.1. EXPERIENCE WITH TOD

The ToD tariff is not a new concept and has been used in almost parts of India. A good summary presentation was made by Prof. Himanshu Jain from IIT Roorkee in a one-day capacity-building program on green ToD, conducted jointly by PACE-D 2.0 RE and IIT Roorkee. The full presentation is available at www.pace-d.com while the key lessons from the existing ToD programs are mentioned below:

1. Mainly industrial and commercial customers participate. Limited residential customers can be encouraged to participate by promoting smart devices to control their home appliances remotely.
2. Price differential has significant impact on demand shift.
3. Smart metering and advance metering infrastructure (AMI) are critical.
4. Understanding customer behavior, reaching out to them, engaging with them, and making the ToD program easier for them to understand are critical.
5. ToD tariffs have shown the potential for peak demand reduction but relatively modest energy and customer bill savings in developed countries.

3.2. DEMAND SHIFTING

To examine the possibility of demand shifting, the program needs to understand load requirements. For this, load can be classified into following three categories:

3.2.1. REGULATED LOAD

This load comprises a power supply that is regulated by the DISCOM to certain times of the day and for certain purposes, such as an agricultural load. Such loads can be easily shifted by the DISCOMs to the hours when there is surplus or low-cost power. Customers of these loads are accustomed to regulated electricity supply, so changing their usage patterns is expected to be smooth.

3.2.2. DEFERRABLE LOAD

A deferrable load is an electrical load that requires a certain amount of energy within a given time period, but the exact timing is not important; it can wait until power is available. Such loads just need to maintain their operating cycle and their starting time can be changed. Customers can shift their load easily to take advantage of the green ToD. One such example is a municipal water-pumping load.

3.2.3. ADAPTABLE LOADS

Certain customers, especially large industrial ones, can shift their operations, or some of their loads, to hours when the electricity tariff is lower. Such loads are called adaptable loads. Large industrial customers are already under existing ToD regimes and benefit by avoiding higher electricity tariffs in the evening. The green ToD tariff will further encourage them to examine and shift operations and/or load to take advantage of the lower tariff.

3.3. ESTIMATION OF DEMAND SHIFT

The electricity consumption of various categories of customers in FY 2017-2018 is provided in Table 3. Our observations and estimation of possible demand shift for each of the customer categories are discussed next.

Table 3.1. All-India Electricity Consumption for Various Customer Categories

Customer Categories	Consumption (GWh)	% Share of Consumption
Industry	468,825	41.48%
Agriculture	204,348	18.08%
Residential	273,519	24.20%
Commercial	96,184	8.51%
Traction & Railways	14,354	1.27%
Others	73,014	6.46%
Total	**1,130,244**	**100.00%**

Source: Energy statistics 2019, Central Statistics Office, Ministry of Statistics and Programme Implementation, Government of India

Estimating the shift in demand because of the tariff differential is a complex exercise and primarily depends on two fundamental parameters:

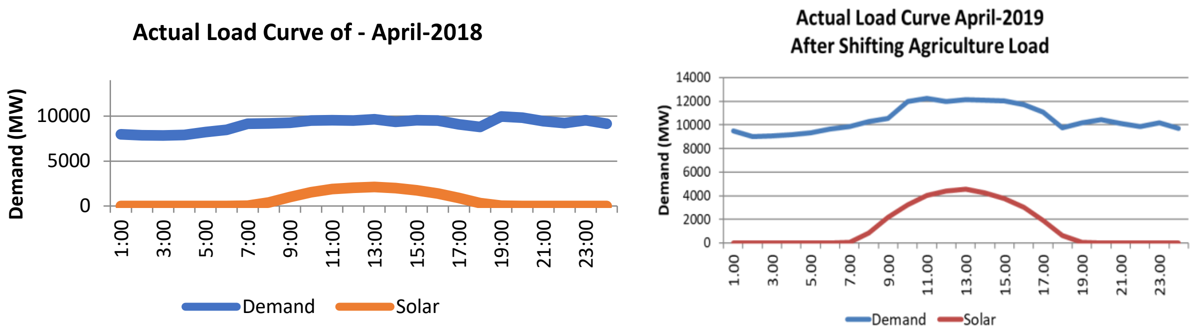
1) Price differential between current tariff and ToD tariff, and
2) Cost for shifting the load, which can be financial costs or intangible costs resulting from changes in behavior that occur to shift the load.

Other parameters involved in estimating demand shift are percentage of electricity expenditure in the total budget, whether household or commercial, publicity by the DISCOM, metering infrastructure, and simplicity of the procedure customer follows to opt in and opt out. Surveying each customer category and class can be helpful, but initial surveys may require refinement over a period of time to produce accurate results. Thus, conducting surveys was considered beyond the scope of this paper. Instead, the program calculated rough estimates for possible demand shifts for each customer category on an empirical basis, with an assumption of certain price differentials for each customer category. Our results are in the following subsections.

3.3.1. AGRICULTURAL LOAD

The electricity requirement for the agricultural load is typically 5 to 6 hours per day for about 250 to 300 days per year, depending on the crops and geographical location of the farm. Presently, most DISCOMs provide electricity to agricultural customers at night when there is a surplus. Though this helps the DISCOMs to smooth out the demand curve, it also creates a lot of problems for farmers who must brave the night to irrigate their fields, which raises safety concerns and increases the chance of animal attacks. To mitigate these risks, many farmers keep their pump sets switched on. Many times this leads to over-irrigation because anytime the power is available, the pumps start pumping water. This not only wastes groundwater but also electricity. Because electricity for agriculture is either free or heavily subsidized in most states, the wasted electricity does not affect the farmers much. Still, it wastes taxpayers' money and adversely affects the environment.

Karnataka is one state that has shifted 2,000 MW from the night-time agricultural load to solar generation hours. The total power demand for the state is around 15,000 MW of which the agricultural share is 34 percent.[16] Figure 7 presents the load curve before and after shifting the agricultural load in Karnataka.



Source: PACE-D presentation to Assam in August 2019

Figure 3.2. Load curve of Karnataka before and after shifting agricultural load

With separation of agricultural feeders being undertaken across the country, shifting of agricultural loads to solar generation hours can be an option that the DISCOMs should explore. Some DISCOMs already provide electricity for agricultural load for four hours during the day and four hours at night. Thus, out of a total of 18% of agriculture consumption, it will be possible to shift only about 5% to the daytime. Because agricultural load is regulated, it is not dependent on price differential and DISCOMs can affect the shift.

3.3.2. INDUSTRIAL LOADS

Electricity tariffs for industrial customers in India, compared on a purchasing power parity (PPP) basis, are among the highest in the world.[17] The overall demand in this sector is also the highest in the country, at about 41 percent (See Table 4). Various studies have highlighted that large industrial customers are the most sensitive to tariff changes and thus can be a potential target for green ToD tariffs, particularly the iron, steel, textile, cement, food processing, and chemicals industries, where power cost is a significant fraction (>25 percent) of the total production cost. Such industries can

[16] https://www.saurenergy.com/solar-energy-articles/pm-kusum-solar-saviour

[17] https://www.iea.org/data-and-statistics/charts/industrial-electricity-prices-in-india-and-selected-countries-2005-2019

easily shift load to green ToD time zones without compromising overall efficiency and production capacity for appliances and processes such as industrial washing machines, dryers, freezers, cutting and pressing water filtration, and reverse osmosis and desalination plants. These loads can take advantage of a green ToD tariff structure to reduce their electricity expenses by shifting to green ToD hours, when the DISCOM offers lower tariffs leading to cost savings for the industry.

In India, ToD tariffs for industrial customers started around early 2000 after establishment of regulatory commissions. Most states have observed a 5 percent to 7 percent shift in the industrial load. The program suggests that a modest additional 5 percent shift in industrial load will be possible with the green ToD tariff, provided the price differential between the green ToD tariff and standard normal tariff is above 10 percent.

3.3.3. COMMERCIAL, RAILWAY TRACTION, AND OTHER LOAD

Commercial activities are at their peak during the evening. In summers, weather is pleasant during the evening and hot during the day. Thus, it is difficult for commercial establishments to shift their load from the peak business time. Some shift is possible using storage, such as ice technology for air-conditioning, but customer adoption of these strategies will take some time. For the purpose of this study, the program assumes that no notable shift in commercial load will take place as a result of the green ToD tariff.

Similarly, the program does not expect any significant demand shift in the railway traction load and other categories (except the water-pumping load, which is described later in this section).

3.3.4. RESIDENTIAL LOAD

The shift in residential load is highly dependent on the price differential. In the residential category, there is a class of customers who will not mind paying more but will not want to change their lifestyle to shift demand. Lifestyle changes here mean shifting the water pumping, geyser, and washing and dishwasher machine load to the daytime and adjusting temperatures for air-conditioning. Different customer classes will have different tariff differential threshold levels for shifting load. Conversion of home appliances into smart home appliances, which can be operated remotely, will support shifting the load and will reduce the threshold tariff differential. The transition will take some time. Therefore, the program does not expect more than a 2 percent shift in demand for residential customers as a result of the green ToD tariff, only if the price differential is above 15 percent. This does not include the water-pumping load for residential multi-story apartment buildings, which is considered in the following subsection.

3.3.5. WATER-PUMPING LOAD

Urban local bodies (ULBs) are entrusted with supply of potable water to citizens. Pumping systems for water supply are generally operated in the early morning and/or evening hours. Water supply is the largest expenditure item among all municipal services of ULBs in India[18] and can be shifted to the solar generation hours, tapping the green ToD tariff, which will reduce the electricity bills of the ULBs. Typically, the water-pumping cost, i.e., the cost of the electricity, is 30 percent to 35 percent of the total cost that ULBs invest to supply water. Thus, a 10 percent to 15 percent reduction in electricity costs to pump water will be significant savings for ULBs and can be channelled toward improving other municipal services such as health, infrastructure development, and education.

With the rapid proliferation of multi-story apartments in metro and other big cities, water pumping has increased significantly. To a great extent, this load can also be shifted to daytime.

[18] Mukesh, Mathur. 2000. Municipal Finance and Municipal Services in India: Present Status and Future Prospects

The water-pumping load, as depicted in Table 4, is divided into two categories—residential and others. The program believes that the water-pumping load from ULBs and housing societies will be about 2 percent of the total electricity consumption. The program estimates 50 percent of the load can be shifted to green ToD time zones, provided the green ToD tariff is at least 10 percent lower than the normal tariff.

3.4. SUMMARY

Table 4 below provides a summary of the demand estimation for different customer categories at a certain tariff differential (normal tariff minus green ToD tariff).

Table 3.2. Summary of Demand Shift by Green ToD

Customer Categories	Consumption		Estimated Demand Shift		Price Differential between Standard Tariff and Green ToD
	GWh	% Total of Consumption	GWh	% Total of Consumption	
Industry	4,68,825	41.48%	23441.25	5%	>=10%
Agriculture	2,04,348	18.08%	10217.4	5%	
Residential	2,73,519	24.20%	5470.38	2%	>=15%
Commercial	96,184	8.51%	0	NIL	
Traction & Railways	14,354	1.27%	0	NIL	
Water Pumping load	22,605	2.00%	11302.44	50%	>=10%
Others	50,409	4.46%	0	NIL	
Total	**11,30,244**	**100.00%**	50431.47	4%	

The load factor is generally used to determine the MW demand from MWh. The load factor varies between customer categories and DISCOMs. If a load factor of 0.5 is taken, the estimated demand shift of 50,431.47 GWh will be about 11.51 GW

4. ESTIMATING GENERATION OF ADDITIONAL DEMAND DUE TO GREEN TOD

The Central Electricity Authority (CEA) is responsible for projecting the future electricity demand of the country. CEA generally does this by taking an Electricity Power Survey (EPS). The most recent survey was the 19th EPS. CEA observes that in the business as usual (BAU) case, electricity demand will grow at a compound annual growth rate (CAGR) of 5.1 percent from 2021-2022 to 2026-2027, and at the rate of 4.66 percent from 2026-2027 to 2036-2037, assuming CAGR of gross domestic product (GDP) is 7.3 percent and using a partial end-use methodology. The report provides various other scenarios at different levels of GDP and using different methods. In this chapter, the program estimates the possibility of demand generation in addition to the demand projected by EPS in the BAU case as a result of 1) lowering the electricity tariff and 2) factors other than BAU. Prior to that, the program examined the possibility of reducing the electricity tariff and the potential for electricity demand generation.

4.1. REDUCTION OF ELECTRICITY TARIFF

4.1.1. LOWER COST ELECTRICITY GENERATED FROM RE SOURCES

The possibility of reduction in the electricity tariff has emerged mainly from the decreasing cost of electricity generation from RE sources. As of May 2021, the bids received in RE procurement tenders are about INR 2.5/kWh for solar generation, INR 2.75/kWh for wind generation, and INR 4/kWh for bundled power in round-the-clock mode with 80 percent RE. Although exact prices depend upon the procurement capacity, location, power evacuation, payment terms, etc., it is much cheaper than the current average power purchase cost of INR 3.80/kWh.[19] This benefit needs to be passed on to the customers through adjustments in tariffs.

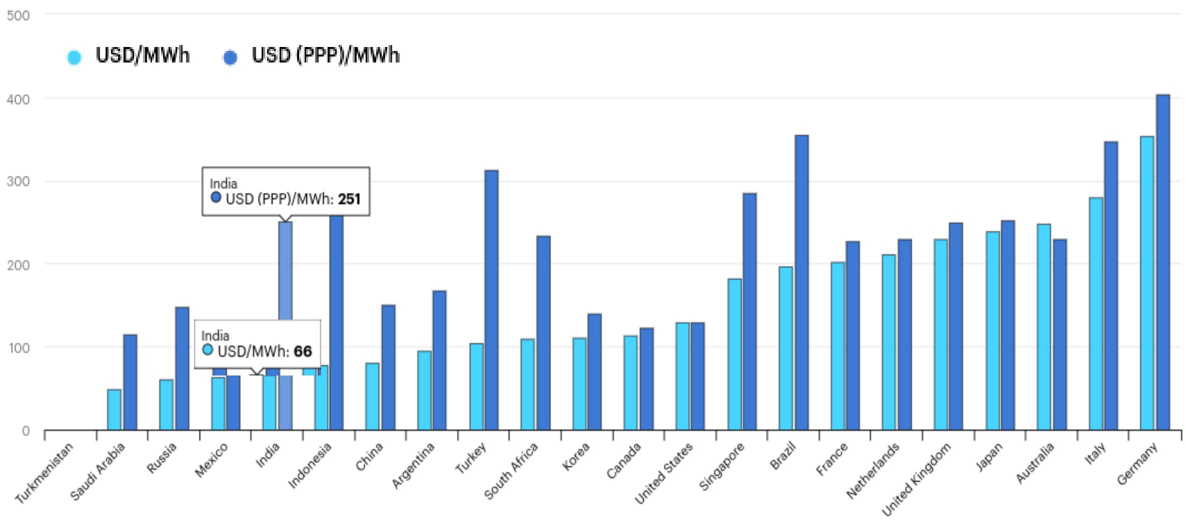
4.1.2. REDUCING T&D LOSSES

India has T&D losses of 20.66 percent,[20] while other countries with well-managed power systems have T&D losses in the single digits. High T&D losses result in higher tariffs for customers. However, T&D losses will slowly but surely come down as a result of the massive efforts and support of the Government of India and respective state governments. Technology such as advanced metering infrastructure, intelligent data analytics, and automatic faster communication will help in reducing the T&D losses by 50 percent. A few government and private DISCOMs, such as Madhya Gujarat Vij Company Limited (MGVCL), Andhra Pradesh Central Power Distribution Corporation Limited (APCPDCL), Tata Power Delhi Distribution Limited (TPDDL), Calcutta Electric Supply Corporation (CESC), and Torrent Power Limited, have been successful in achieving T&D losses in the single digits.

4.1.3. HIGH ELECTRICITY TARIFF

In absolute terms, the price of electricity in India is one of the lowest in the world. However, electricity prices, adjusted to the purchasing power parity (PPP) of the country, are among the highest in the world.[21] This is illustrated below in Figure 8.

[19] Executive Summary report of CEA for March 2021, page 11. For FY 2018-19 average cost of supply is INR5.99/kWh, 20.66% T&D losses and taking 20% other expenditures.
[20] CEA Monthly executive report
[21] https://www.iea.org/reports/energy-prices-2020



Source: https://www.iea.org/reports/energy-prices-2020

Figure 4.1. Residential electricity prices in selected economies, 2018

With the economy opening in all sectors, a reduction in electricity tariffs is inevitable for India to manage global price competition. The most classic example is the textile industry in Bangladesh. The low cost of energy in Bangladesh played an important role in making its textile industry globally successful.

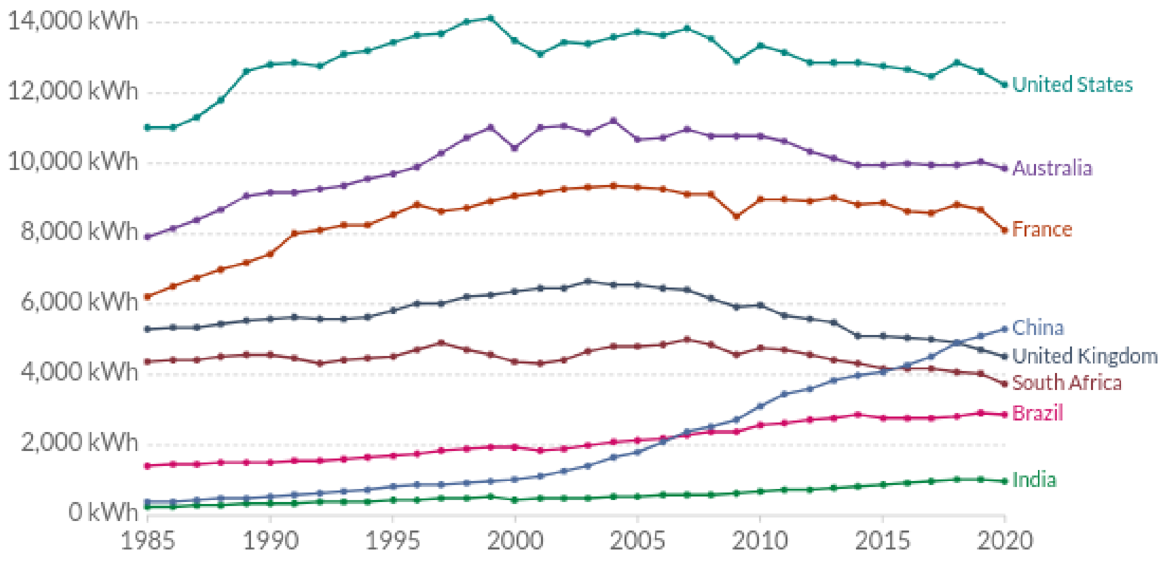
Electricity consumption in India is dominated by the industrial sector. The C&I sectors accounted for almost half of total electricity consumption in 2017-2018. The cost of supply to industrial customers is lower as it can be supplied at high voltages, but the C&I tariff is higher than the tariff for other customers. Globally, the trend is the opposite, with the industrial tariff being lower. Therefore, in order to keep Indian industries globally competitive, the industrial tariff needs to be reduced. The successive Electricity Tariff Policies issued by the Government of India also stated that the cross-subsidy by C&I customers to residential customers should be reduced over a period of time.

4.2. FACTORS OTHER THAN BAU

4.2.1. LOW PER CAPITA CONSUMPTION

Despite being one of the fastest growing economies in the world for the last couple of decades, the India's per capita electricity consumption (one of the indicators of socioeconomic development) is one of the lowest in the world. The per capita electricity consumption in India was 972 kWh in 2020 compared to 5,297 kWh in China and 12,235 kWh in the United States[22] (See Figure 9). With the second largest population in the world and a fast-growing economy, there is considerable scope to increase electricity consumption in India.

[22] https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html and https://ember-climate.org/data/



Source: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html and https://ember-climate.org/data/

Figure 4.2. Country-wide per capita electricity consumption

4.2.2. ELECTRIC VEHICLES

By 2030, about 50 million electric vehicles (EVs) will be deployed in India per the latest NITI Aayog report, "Mobilising Electric Vehicle Financing in India," released in March 2021. About 80 percent to 85 percent of these will be private vehicles, with two-wheelers making up almost 70 percent of the mix, that depend on slow-, medium-, and fast-charging technologies and various input powers required across different vehicles. According to the detailed study conducted by PACE-D 2.0 RE for Assam and Jharkhand, in 2030, about 18 percent and 16 percent, respectively, of the state's total electricity consumption will be from EVs. The study conducted by a private DISCOM in Delhi estimated this number as 13 percent for their area. This will be an entirely new demand for DISCOMs. Appropriate design of the green ToD tariff for EVs will determine the time of day when EV demand is added to the grid.

4.2.3. ENERGY SUBSTITUTION

Replacing an existing energy source with another is termed "energy substitution." The low electricity tariff will lead to the substitution of existing energy sources by electricity. Although EV is the best example, another key example is heating, whether for food or industrial products. In terms of economics, electricity consumption is still cheaper compared to fossil fuels such as high-speed diesel, kerosene, natural gas, liquefied petroleum gas (LPG), etc. Lower electricity tariffs will make electricity financially attractive as well. Financial gains will drive the substitution. Providing cheaper electricity during the solar generation hours with a green ToD tariff can result in major substitutions in the following end uses.

4.2.4. INDUSTRIAL CUSTOMER

Fossil fuels are used for essential processes like space and water heating and steam generation in various industries. These can be shifted to either electromagnetic or resistive technologies. Recent IEA estimates show industry market potential of 6.5 GW for concentrated solar thermal (CST) technologies out of a total of 13 GW thermal technical potential.

Two specific large-scale industries are worth mentioning—cement and steel. India is the world's second largest producer of cement and steel. In Sweden, cement producer Cementa (a subsidiary of

HeidelbergCement) and energy producer Vattenfall are working together on the CemZero project to electrify cement production.[23] The pilot project implementation is underway. Similarly, electromagnetic technologies for heating, hardening, and melting; running heat pumps and mechanical vapor recompression; and using inexpensive resistance heaters in boilers and furnaces powered by electricity are potential opportunities for use of cheaper solar energy through a green ToD tariff regime. A deeper analysis on the commercial viability of these options is needed to assess the market potential.

The low-cost electricity through a green ToD tariff structure can prompt automation of various industrial processes that previously have been manual or semi-automatic. This has long-term positive impacts on the growth of the industry, its efficiency of operations, productivity, and improvements in factory environments. Refrigeration is another end use where thermal energy storage and phase-changing materials can be used in green ToD tariff hours to provide for cooling during the rest of the hours.

4.2.5. ELECTRIC COOKING

Although solar-powered cooking in the form of solar cookers has been promoted by MNRE for more than three decades, success has been limited due to mismatches between the technology and cooking practices. With 100 percent village electrification through the Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) and 100 percent household electrification through the Saubhagya scheme, it is only logical that electricity-based cooking will pick up in the country. GoI's ambition to provide all households with 24x7 power by 2022[24] will be instrumental in unlocking the potential of electricity-based cooking in rural areas too. According to a NITI Aayog study, the consumption of 8 to 10 LPG cylinders (14.2 kg each) per year is equivalent to electricity consumption of nearly four units per day. With more than 25 crore active LPG customers, India imports 50 percent of its LPG requirement. The Ministry of Petroleum and Natural Gas (MoPNG) estimates that with the renewed focus on LPG use under the Ujjwala scheme, the demand for LPG is likely to go up by an additional 34 percent by 2025, raising import bills and putting more pressure on the national treasury. In addition, getting cylinders refilled is a challenge for rural and poor customers. Against this background, large-scale adoption of electricity-powered cooking can be beneficial for all stakeholders and the environment. Brookings India estimates that electricity cooking energy demand may add 48 to 72 billion units of consumption by 2030.[25] This demand can be encouraged by cheaper green ToD tariffs during solar generation hours.

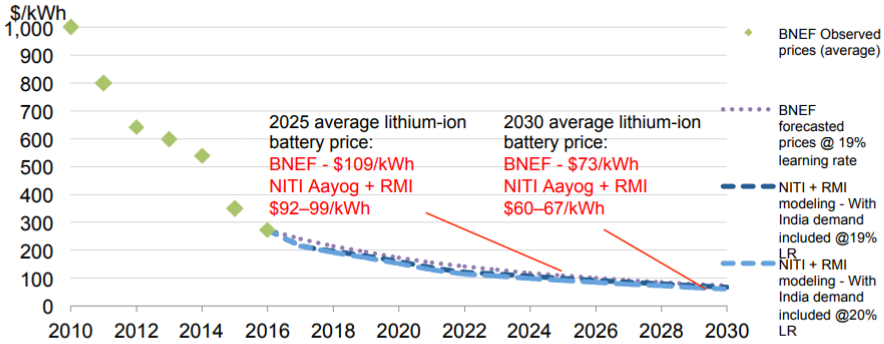
4.2.6. ENERGY STORAGE SYSTEMS (ESS)

Currently, ESS are prohibitively expensive. At many locations, full RE generation is either not utilized or thermal generation is backed down. ESS prices are dropping at a faster pace. As the price of ESS becomes more viable, load will come from ESS for charging and will need a reduced green ToD tariff. The decrease in prices of lithium-ion batteries (the most widely used for storage), as estimated by Niti Aayog, is presented in Figure 10.

[23] https://www.iea.org/reports/cement

[24] https://www.thehindubusinessline.com/opinion/bringing-24x7-power-to-all-by-2022/article22136414.ece1

[25] https://www.financialexpress.com/economy/after-completion-of-100-electrification-govt-keen-to-promote-power-as-cooking-fuel/1558263/



Source: Niti Ayuog report on "India's Energy Storage Mission: A make-in-India Opportunity for Globally Competitive Battery Manufacturing

Figure 4.3. Projected decline in lithium-ion battery cost

In addition,, ESS will be required for balancing the grid as more and more RE is added to the grid. The 2013 "Green Corridor Report" by POWERGRID recommended 500 MWh of energy storage for integration of 31 GW of renewable energy. Energy Storage Association In India (IESA) estimates ESS for EHV grid support in 2032 at 142 GW. At the MV level, which is under the purview of DISCOMs, IESA estimates ESS support of 84 GW. The input for this entire capacity will come from solar energy and from implementing a green ToD tariff structure, improving the economics of ESS integration into the grid[26].

4.3. DEMAND GENERATION VERSUS TARIFF

Theoretically, it should be possible to determine accurately from the price elasticity of electricity how much demand will be generated by an "X" percent decrease in the tariff. However, it is more complex in the case of electricity. Linearity between demand generation and price elasticity is limited and different for different customer categories. In this paper, PACE-D 2.0 RE has estimated demand generation by using the price elasticity of electricity in the narrow band of linearity.

In India, the long-term price elasticity is 0.06 percent, which is three times the short-term elasticity at 0.02 percent. This means that a 1 percent increase in the real electricity price will result in about a 0.06 percent decrease in electricity consumption in the long term and a 0.02 percent decrease in the short term.[27] The opposite can also happen, i.e., a 1 percent decrease in electricity price will result in a 0.06 percent and 0.02 percent increase in electricity consumption in the long and short term, respectively. Thus, a 1 percent reduction in tariff during the solar generation hours, in the form of a green ToD tariff, can potentially shift more than 670 GWh in the long term and more than 220 GWh in the short term. (The total electricity consumption in 2017-2018 was 11,30,244 GWh (Table 4). It is estimated that green ToD will be about 15 percent lower than the normal tariff. Thus, it can be expected that 15 percent lower green ToD will generate demand of 0.3 percent in the short term and 0.9 percent in the long term, as presented in Table 6.

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[26] (ISGF 2019).
[27] CEA. 2019. "Long_Term_Electricity_Demand_Forecasting_Report.pdf." https://cea.nic.in/old/reports/others/planning/pslf/Long_Term_Electricity_Demand_Forecasting_Report.pdf.

Table 4.1 Potential of Demand Generation

	Elasticity	Potential of Demand Generation (GWh) at 1% Lower Tariff	Potential of Demand Generation (GWh) at 15% Lower Tariff
Short term	0.02%	22.6	3390.7
Long term	0.06%	67.8	10172.2

As the demand for agriculture and residential—the major customers apart from industry—is inelastic in nature, it can be assumed that there will be little change in consumption patterns and tariffs. On the other hand, electricity consumption for industrial loads is elastic in nature. The elasticity is higher in the long term compared to the short term because industry needs to make investments, either capital investments in equipment or investment in processes, to alter its consumption patterns. Also, changes in demand curves will kick in only after a tariff change of say 5 percent; below that, the demand will be inelastic.

5. CASE STUDIES

This chapter presents the case studies of Assam, Jharkhand, Madhya Pradesh, Rajasthan, and Maharashtra. The case studies of Assam and Jharkhand cover largely the analysis conducted to determine the green tariff ToD under the PACE-D 2.0 RE program, while the case studies of the remaining three states only describe the various features of the incentives provided by the states to generate the demand. Since the concept is in its nascent stage, understanding the impact of the green ToD tariff is difficult; however, Madhya Pradesh provides a fairly good example of the incentive versus demand generation scenarios.

5.1. CASE STUDY – ASSAM

5.1.1. DEMAND SUPPLY SCENARIO IN ASSAM

In FY 2019-2020, the average hourly demand varied between 878 MW and 1,497 MW (Figure 11). Higher demand is witnessed during the evening between 5:00 p.m. and 12:00 midnight, with a peak between 7:00 p.m. and 8:00 p.m.. Demand is lowest between 3:00 a.m. and 7:00 a.m. Demand during the rest of the hours is found to be flat.

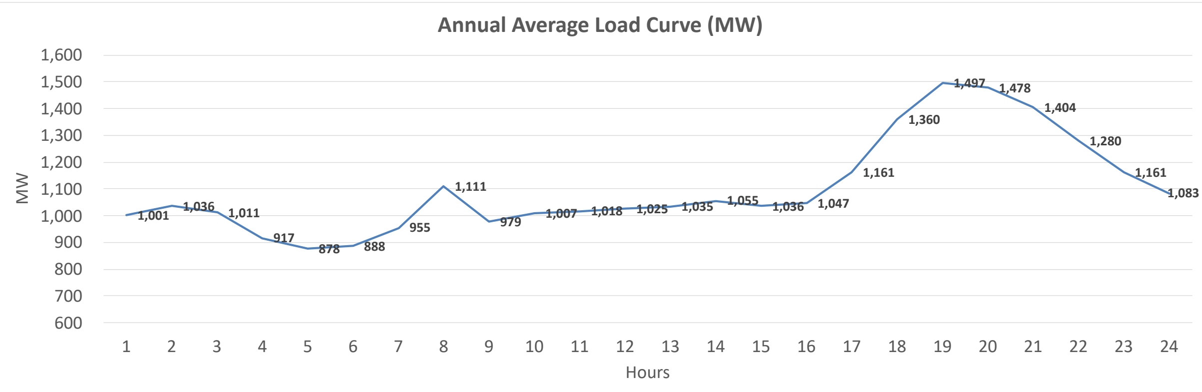

Figure 5.1. Annual average hourly load curve, 2019

APDCL has tied up 1,949 MW of generation capacity. It procures from a wide range of technologies and generators. Assam Power Generation Corporation Ltd (APGCL), North Eastern Electric Power Corporation Ltd (NEEPCO), and National Thermal Power Corporation Limited (NTPC) are the major suppliers of electricity to APDCL. Hydro, gas, and coal are the major sources, contributing almost equally to the capacity in MW. However, supply in kWh from hydro capacities is only 19 percent.

Table 5.1. Sources of Electricity for APDCL

Source	Capacity (MW)	Supply (in million units)	Share in Total Supply (%)	Variable Tariff in INR/kWh
Hydro				
State Sector	114	425		1.28
Central (NER) Sector	435	1,453		1.48
Others	114	207		4.67
Sub-total	*663*	*2,086*	*19%*	*1.75*
Gas				

State Sector	211	1,073		2.55
Central (NER) Sector	455	2,528		1.94
Sub-total	*666*	*3,600*	*33%*	*2.13*
Coal				
Central (NER) Sector	430	2,692		3.20
Central Sector	190	1,019		2.23
Sub-total	*620*	*3,711*	*34%*	*2.93*
Renewables				
Solar		52		7.41
Wind		163		3.15
Sub-total		*215*	*2%*	*4.19*
Short term		627	6%	4.24
IEX		505	5%	4.10
Others		197	2%	4.71
Total	**1,949**	**10,941**		**2.63**

5.1.2. POWER SURPLUS IN ASSAM

In FY 2019-2020, APDCL sold 1,477 MUs on the IEX, which is about 13.8 percent of total energy procured from all sources. Out of 1,477 MUs, 88 percent, i.e., 1,303 MUs was exported between 12 midnight and 5:00 p.m. to the IEX at an average realized price of about INR 2.49/kWh. Considering the must-run status of RE and default must-run status of hydro due to water levels, the surplus can be reduced only by reducing the procurement from gas- and coal-based power plants. Average variable cost of electricity from gas and thermal is about INR 2.55/kWh. APDCL lost INR 0.06/kWh on average for the surplus power.

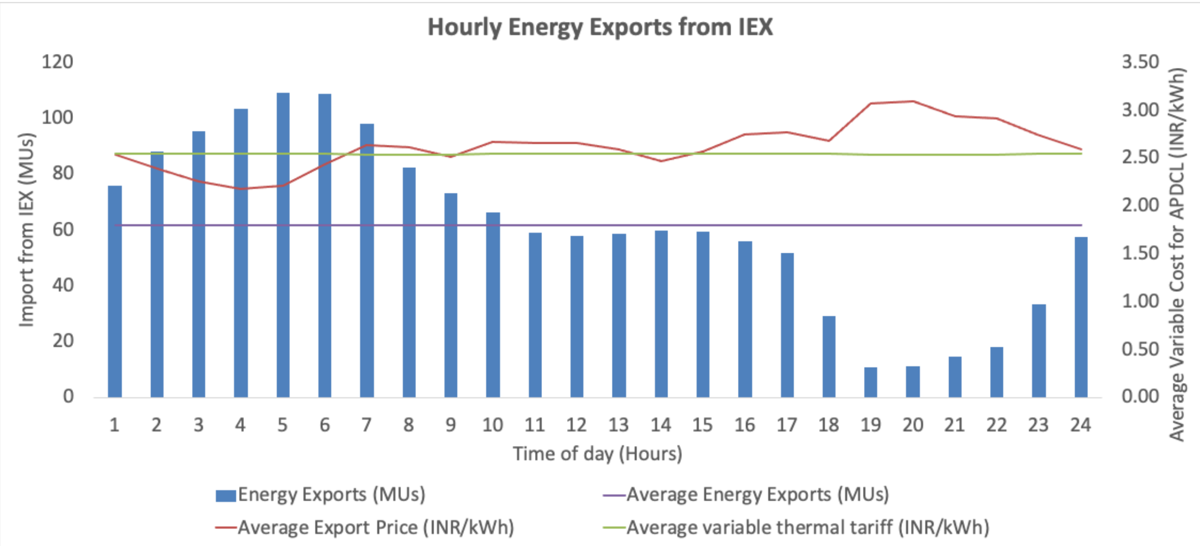

Figure 5.2. Hourly exports to IEX

APDCL is expected to add 100 MW solar in FY 2020-2021 and have plans for another 100 MW in the future. Considering the current surplus position, most of the solar generation would add to the surplus. Thus, it is imperative to address the current surplus situation for APDCL. To this end, the PACE-D 2.0 RE team has carried out a study on the surplus and proposed a green ToD solution for APDCL.

5.1.3. GREEN TOD FOR APDCL

The recommended green ToD solution for APDCL includes providing a rebate of INR1/kWh between 12 midnight and 5:00 p.m. on incremental consumption. It is recommended to provide this rebate to all customer categories. For details, refer to the "Report on Optimal and Market-Based Utilization of Electricity Supply Resources of Assam" developed under the PACE-D 2.0 RE program and available at its website. (www.pace-d.com)

5.1.4. GAINS FROM GREEN TOD FOR APDCL

With an assumption of 25 percent T&D losses, APDCL can gain from selling the surplus energy to its own customers at a tariff higher than INR 3.40/kWh.[28] Low Tension A customers are those with the lowest tariff, i.e., INR 5.10/kWh. A rebate of INR 1.0 kWh for this customer category would yield a net tariff of INR 4.10/kWh, which is INR 0.70/kWh higher than the cost of delivery for surplus power. APDCL can gain about INR 0.70/kWh against the current loss of INR 0.06/kWh. The gains for APDCL will only increase when other higher tariff customer categories are considered.

5.2. JHARKHAND

5.2.1. DEMAND AND SUPPLY SCENARIO

Jharkhand Bijli Vitran Nigam Limited (JBVNL) is the largest among the four DISCOMs in Jharkhand, meeting about 50 percent of total power requirements of the state. The team used data from one day of each month of 2019 to study the demand and supply of JBVNL. The data was collected from JBVNL and Eastern Load Dispatch Centre. JBVNL demand varied between 775 MW and 1,250 MW in 2019. Daily high demand occurs between 6 p.m. and midnight. Demand is observed to be fairly low around 5 p.m. during the day.

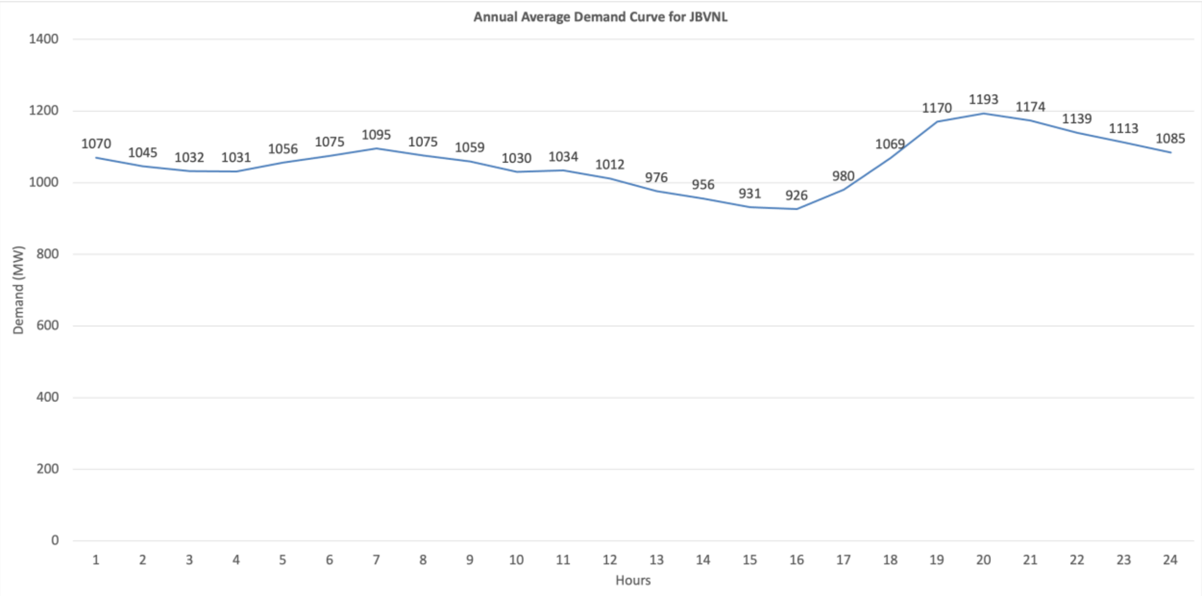

Figure 5.3. Average diurnal variation of JBVNL demand

JBVNL is a net exporter of energy to the IEX during most of the day, highlighting the power surplus scenario. However, it is a net importer of energy during the period from 6:00 p.m. to midnight (Figure

[28] The figure is calculated by taking average generation price as INR2.55/kWh and 25 percent T&D losses (2.55/0.75)

14). The export is due to the minimum commitment charges in long-term thermal contracts, low demand, and the must-run status of the RE generation.

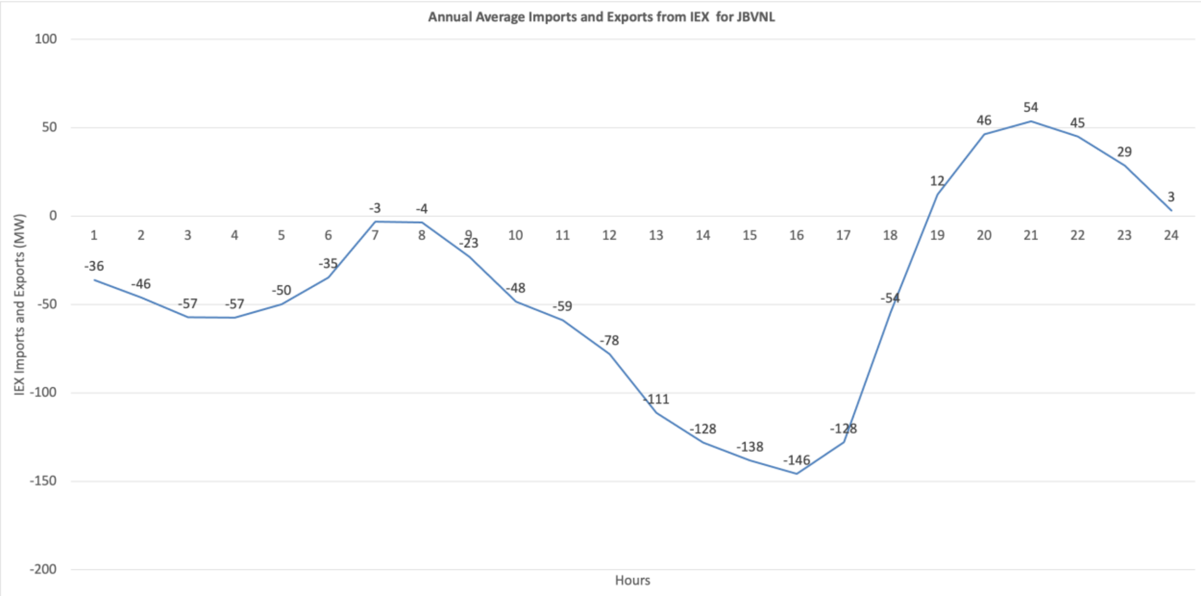

Figure 5.4. Average hourly export/import in 2019

5.2.2. IMPACT OF SOLAR AND INCREASE IN DAYTIME DEMAND ON THE COST OF PROCUREMENT

JBVNL signed a PPA for 700 MW solar with the Solar Energy Corporation of India (SECI). The supply is expected to commence in this year. This supply from solar will displace the procurement from current thermal sources during the daytime. To understand the impact of adding 700 MW of solar, the team carried out a simulation study using the 2019 supply data to understand the impact on supply from various sources and on the cost of procurement. The cost of power purchase decreases marginally due to reduction in the draw from expensive thermal power and reduction in imports from the IEX. See Table 7 for the results of the study.

The simulation was also carried out to understand the impact of increase in demand by 10% between 10 a.m. and 4 p.m. and shift of 5% demand from period between 6 p.m. and 10 p.m. to period between 10 a.m. and 4 p.m.. Table 5.2 also provides the impact on the cost for JBVNL. The average cost for JBVNL gets further reduced from INR 4.42/kWh to INR 4.36/kWh due to lower marginal cost.

Table 5.2. Existing and Upcoming Supply Sources with Costs

	Current Scenario	**After 700 MW Solar**	**After Increase in Demand and Demand Shift**
Total Energy Supply	**7,892 Mus**	**7,892 MUs**	**8,084 MUs**
Supply Sources			
Current PPAs	8,241 Mus	7,127 MUs	7,250 MUs
IEX Imports	286 Mus	204 MUs	204 MUs
Solar	--	1,196 MUs	1,196 MUs
IEX Exports	634 Mus	634 MUs	527 MUs
Total Cost	**INR 3,524 Crore**	**INR 3,485 Crore**	**INR 3,525**

	Current Scenario	After 700 MW Solar	After Increase in Demand and Demand Shift
Fixed Cost of Existing PPAs	INR 1,621 Crore	INR 1,621 Crore	INR 1,621 Crore
Variable Cost of Existing PPAs	INR 1,965 Crore	INR 1,655 Crore	INR 1,680 Crore
Solar		INR 299 Crore	INR 299 Crore
Net IEX Purchases	(INR 62 Crore)	(INR 89 Crore)	(INR 75 Crore)
Average Cost of Energy	INR 4.46/kWh	INR 4.42/kWh	INR 4.36/kWh

5.2.3. IMPACT OF GREEN TOD ON THE REVENUE AND NET GAINS

Current tariffs for industrial customers between 10 a.m. and 6 p.m. is INR 6.47/kWh.[29] The tariff during the peak period, i.e., between 6 p.m. and 10 p.m. is 120 percent of the tariff for the normal period, i.e., INR 7.76/kWh. Providing a rebate of INR1/kWh on incremental consumption between 10 a.m. and 4 p.m., would result in a tariff of INR 5.47/kWh. JBVNL can gain almost INR 42 crore from the rebate and the demand increase and shift. See Table 8 for the net gains from the rebate.

Table 5.3. Profit to JBVNL with Ten Percent Demand Increase and Five Percent Demand Shift

Current Customer Tariff	
Between 10 a.m. and 6 p.m.	INR 6.47/kWh
Between 6 p.m. and 10 p.m.	INR 7.76/kWh
Tariff on incremental consumption after rebate between 10 a.m. and 4 p.m.	INR 5.47/kWh
Increase in Consumption Between 10 a.m. and 4 p.m.	**254 MUs**
Due to new demand addition	181 MUs
Due to demand shift	74 MUs
Net Increase in Revenue	**INR 82 Crore**
Increase in revenue due to the increase in consumption	INR 139 Crore
Decrease in revenue due to demand shift	INR 57 crore
Increase in cost of procurement	INR 40 Crore
Net Gains	**INR 42 Crore**

At a green ToD rebate of INR 1/kWh and assuming a ten percent increase in demand and five percent demand shift, JBVNL will make an annual profit of INR 42 crore.

5.3. EXPERIENCE OF MAHARASHTRA, RAJASTHAN, AND MADHYA PRADESH FOR DEMAND GENERATION BY TARIFF INCENTIVE

The concept of decreasing tariffs for generating demand is not new. Currently, three states in India i.e., Madhya Pradesh, Maharashtra, and Rajasthan are providing incentives to generate demand. The incentive is only for incremental consumption over the previous year. However, these incentives are not ToD based. Still, they help in understanding the relationship between demand generation and incentive. Table 9 highlights the targeted customers of these incentive schemes.

[29] Tariff is about INR 5.5/kVA. Assuming a power factor of 0.85, tariff would be INR 6.47/kWh

Table 5.4. Applicability, Eligibility, and Incentives for Demand Generation

Parameters	Madhya Pradesh[30]	Rajasthan[31]	Maharashtra[32]
Applicable Incentive	INR 1/kWh rebate on tariff	• INR 0.55/kWh for Medium Industrial (HT) customers • INR 0.85/kWh for Large Industrial customers	INR 0.75/kVAh
Eligible Customers	• Industrial (HT) • Non-industrial (HT) • Shopping Malls (HT)	• Medium Industrial (HT) customers • Large Industrial customers	• HT industries • HT commercial • HT public services • HT-PWW • HT - Railways/Metro/Mono • HT - Group Housing Society
Incentive for Existing HT Customer	Applicable	Applicable	Applicable
Incentive for new HT Customer*	Applicable	Applicable	NA
Incentive for Captive Power plant Customer*	Applicable	NA	Applicable
Incentive for Open Access Customer*	Applicable	NA	Applicable

*The incentive is different. The details are provided in Annex 1.

5.3.1. IMPACT OF INCENTIVE SCHEMES

The incentive scheme for Madhya Pradesh was implemented in FY 2016-2017. The consumption of the HT industrial and non-industrial customer category, for which the rebate scheme is applicable, has increased. This increase can be partly attributed to the incentive scheme. Between FY 2011-2012 and FY 2014-2015, the consumption of the HT customer category increased from 6,670 MUs to 7,938 Mus, i.e., at a CAGR of 5.97 percent. After implementation of the incentive scheme, the consumption increased from 8,140 MUs in FY 2016-2017 to 10,796 Mus, i.e., at a CAGR of 9.87 percent. No detailed study is available crediting the exact contribution of the incentive scheme with increasing the CAGR, but the incentive scheme might have contributed significantly toward the increase of the CAGR from 5.97 percent to 9.87 percent.

For Maharashtra and Rajasthan, the schemes were implemented recently, and adequate data are not available for assessing the impact of this incentive due to COVID.

30 ARR and Retail Supply Tariff Order for FY 2016-17 and subsequent tariff orders
31 ARR and Tariff Petition of JVVNL, AVVNL and JdVVNL for FY 2019-20 and subsequent tariff orders
32 Truing-up of ARR of FY 2017-18 and FY 2018-19, Provisional Truing-up of ARR of FY 2019-20 and Projections of ARR and determination for the 4th Multi Year Tariff Control Period FY 2020-21 to FY 2024-25

6. DESIGN AND IMPLEMENTATION OF GREEN TOD

6.1. DESIGN OF GREEN TOD

The PACE-D 2.0 RE team developed an Excel-based tool/model to design Green ToD. The tool is available at the PACE-D website (www.pace-d.com). Here, only the key steps involved in the design of the green ToD tariff are provided.

1. Prepare a table, (for instance, refer to it as table-1), for all the generation resources with their fixed and variable charges, and minimum commitment values.
2. Develop the average annual hourly curve (refer to as curve-1) with the help of last year's data on demand, supply-side resources, and import/export from the IEX or any other sources.
3. From curve-1, identify the period for which supply is more than the demand or power is exported to the IEX.
4. From table-1, find the variable cost of the surplus power identified in step-3. If there is more than one plant, take the weighted average.
5. To the variable cost, add T&D losses to determine the cost of power supply during the identified period. Refer it as "A."
6. Check the delta between A and the existing tariff of the customer category targeted for green ToD. If green ToD is for all customer categories, calculate the delta with the customer category of lowest tariff.
7. If delta is negative (A< customer tariff) and is sufficient (at least 20 percent[33] of the targeted customer tariff), there is a case for green ToD.
8. The value of green ToD should be determined based on the 1) delta, 2) the profit DISCOM wants to earn, 3) price elasticity of the customer category, and 4) financial value of the discomfort customer will have for shifting demand. There is not just one formula that can be applied to all the DISCOMs. Each DISCOM needs to determine the green ToD tariff based on its experience, customer profile, and target for demand generation and demand shift.
9. The analysis should be carried out each year and the green ToD adjusted accordingly.

6.2. IMPLEMENTATION

The green ToD is recommended for only incremental consumption during the identified period and not for the entire consumption. To determine incremental consumption during a certain period of the day, the current consumption and the consumption of the previous year in the same month and time. The previous year consumption is as a base line consumption also. Determining present consumption will not be difficult as ToD meters will be installed for all those customers who opt for the green ToD tariff. The challenge will be in ascertaining the daytime consumption of the customers from the previous year in the same month (base line). Based on the methodologies adopted by other states (Annex 1), the following methodology is suggested to determine the base line. Several examples are provided in Annex 2 to further clarify the methodology for determining consumption in the previous year during the same month.

A. Customers have ToD meters and their consumption during the green ToD is available for the base line

B. Customers do not have ToD meters and/or their consumption during the green ToD period is not available for the base line.

[33] The 20 percent value is based on the assumption that 10 percent will be the profit of the DISCOM and that any demand shift or demand generation requires a minimum incentive of 10 percent.

The base line consumption will be determined by:

(Monthly consumption in the previous year) Period of Green ToD/(24x30)

This method is not very accurate and has the following two shortcomings:

1. Every year there is natural growth in consumption. The Green ToD will get implemented on this consumption, which might not be the new demand. This can be addressed, but it will make the calculation more complicated. The base line can be increased by the CAGR.
2. This drawback will occur only in those cases where the ToD meter was absent and actual consumption of the previous year is not available. Customer's demand varies across the day depending upon their lifestyle. Therefore, assuming uniform consumption throughout the day is not appropriate.

The program hopes that as more DISCOMs start designing and implementing green ToD tariffs, new experiences and solutions will emerge, further improving this methodology.

ANNEXURE-1 INCENTIVE TO GENERATE DEMAND IN MADHYA PRADESH, RAJASTHAN, AND MAHARASHTRA

This annex provides details of the incentives provided by Madhya Pradesh, Rajasthan, and Maharashtra for their exiting, new, captive, and open access customers.

Existing Consumers			
	Madhya Pradesh	**Rajasthan**	**Maharashtra**
Incentives	INR 1/kWh rebate on tariff	• INR 0.55/kWh for Medium Industrial (HT) consumers • INR 0.85/kWh for Large Industrial consumers	INR 0.75/kVAh
Eligible Consumers	• Industrial (HT) • Non-industrial (HT) • Shopping Malls (HT)	• Medium Industrial (HT) consumers • Large Industrial consumers	• HT industries • HT commercial • HT public services • HT-PWW • HT - Railways/Metro/Mono • HT - Group Housing Society

Following tables summarize the rebate schemes for each targeted consumer category

Existing Consumers			
	Madhya Pradesh	**Rajasthan**	**Maharashtra**
Applicable Consumption	Incremental consumption over baseline only	Incremental consumption over baseline only	Incremental consumption over baseline only
Baseline	FY 2015-16 consumption	FY 2018-19 consumption	3-year average monthly consumption by consumer from FY 201718 to FY 2019-20
Others	For new connections after FY 2015-16, baseline would be consumption during first 12 months of operations	For new connections sanctioned in between FY 2018-19, baseline would be consumption during first 12 months of operations	• For consumers connected between FY 2017-18 and FY 2019-20, rebate shall be applicable after completion of 3 years • Rebate shall be applicable for 3 years and to be reviewed during mid term review

New Consumers			
	Madhya Pradesh	**Rajasthan**	**Maharashtra**
Incentives	INR 1/kWh rebate on tariff or 20% of applicable tariff whichever is lower	• INR 0.55/kWh for Medium Industrial (HT) consumers • INR 0.85/kWh for Large Industrial consumers	NA
Eligible Consumers	• Industrial (HT) • Non-industrial (HT) • Shopping Malls (HT)	• Medium Industrial (HT) consumers • Large Industrial consumers	NA
Applicable Consumption	Entire consumption	Entire consumption	NA
Baseline	NA	NA	NA
Others	• Rebate on entire consumption is applicable upto FY 2021-22 • Rebate on incremental consumption is not applicable	• Rebate on entire consumption is applicable until further notice • Rebate on incremental consumption is not applicable	NA

Captive Consumers			
	Madhya Pradesh	**Rajasthan**	**Maharashtra**
Incentives	INR 2/kWh rebate on tariff	NA	NA
Eligible Consumers	• Industrial (HT) • Non-industrial (HT) • Shopping Malls (HT) • Meeting energy demand fully or partially through CPPs between FY 2016-17 to FY 2018-19	NA	NA
Applicable Consumption	Incremental purchases from DISCOM subject to reduction in captive generation	NA	NA
Baseline	Consumption of Preceding financial year	NA	NA
Others	Rebate shall be applicable upto FY 2021-22	NA	NA

Open Access Consumers			
	Madhya Pradesh	**Rajasthan**	**Maharashtra**
Incentives	INR 2/kWh rebate on tariff	NA	INR 0.75/kVAh

Eligible Consumers	• Industrial (HT) • Non-industrial (HT) • Shopping Malls (HT) • Meeting energy demand fully or partially through open access during FY 2018-19	NA	• HT industries • HT commercial • HT public services • HT-PWW • HT Railways/Metro/Mono • HT- Group Housing Society
Applicable Consumption	Incremental purchases from DISCOM subject to reduction in captive generation	NA	Incremental consumption from DISCOM over baseline only
Baseline	Consumption of FY 2018-19	NA	3-year average monthly consumption by consumer from DISCOM from FY 2017-18 to FY 2019-20
Others	NA	NA	• For consumers connected between FY 2017-18 and FY 2019-20, rebate shall be applicable after completion of 3 years • Rebate shall be applicable for 3 years
Open Access Consumers			
	Madhya Pradesh	**Rajasthan**	**Maharashtra**
			and to be reviewed during mid term review

ANNEXURE-2 EXAMPLES TO EXPLAIN THE PROPOSED METHODOLOGY TO DETERMINE THHE PREVIOUS YEAR CONSUMPTION

A. For Existing ToD consumers whose ToD consumption for the baseline year is known

Example 1: A consumer consumed 800 kWh is between 12:00 mid night and 5:00 PM in current month against total consumption of 1600kWh. In previous year during the same month, the consumption was 600kWh 12:00 mid night and 5:00 PM and the total consumption was 1600kWh.

Incentive = (800 - 600) x 1=INR 200

Example 2: A consumer consumed 800 kWh is between 12:00 mid night and 5:00 PM in current month against total consumption of 1600kWh. In previous year during the same month, the consumption was 900kWh 12:00 mid night and 5:00 PM and the total consumption was 1600kWh.

Incentive = (800 - 900) x 1=INR 0

Example 3: A consumer consumed 800 kWh is between 12:00 mid night and 5:00 PM in current month against total consumption of 2000kWh. In previous year during the same month, the consumption was 800kWh 12:00 mid night and 5:00 PM and total consumption was 1600kWh.

Incentive = (800 - 800) x 1=INR 0

B. For Non-ToD consumers whose consumption in the baseline year is not known

Example 4: A consumer consumed 800 kWh is between 12:00 mid night and 5:00 PM in current month against total consumption of 1600kWh. In previous year during the same month, the total consumption was 1600kWh.

Incentive = (800 - 1600 x 0.708) x 1 =INR 0

Example 5: A consumer consumed 1200 kWh is between 12:00 mid night and 5:00 PM in current month against total consumption of 1600kWh. In previous year during the same month, the total consumption was 1600kWh.

Incentive = (1200 - 1600 x 0.708) x 1 =INR 66.67

Example 6: A consumer consumed 800 kWh is between 12:00 mid night and 5:00 PM in current month against total consumption of 2000kWh. In previous year during the same month, the total consumption was 1600kWh.

Incentive = (800 - 1600 x 0.708) x 1 =INR 0

Example 7: A consumer consumed 1200 kWh is between 12:00 mid night and 5:00 PM in current month against total consumption of 2400kWh. In previous year during the same month, the total consumption was 1600kWh.

Incentive = (1200 - 1600 x 0.708) x 1 =INR 66.67

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