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Demand Flexibility and Distributed Energy Resources

Examining Four Approaches for India's Power Distribution Sector to Become More Clean, Affordable and Reliable

Dheer Patel, Joni Sliger and Ranjit Bharvirkar[1]

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Introduction

The rise of low-cost renewable energy offers the promise of substantial benefits. Recognizing the potential of renewable energy to reduce greenhouse gas emissions and support rural electrification, the Government of India declared a target of installing 175 gigawatts of renewable energy capacity by 2022, including 40 gigawatts specifically from rooftop photovoltaic (PV) solar power. Since that announcement, the costs of grid-integrated wind and solar have fallen below the cost of coal power,[2] making these sources even more attractive to investors. However, affordably transitioning to clean energy is a daunting task for India's distribution companies (discoms), which are already reeling under heavy financial stress.[3]

This paper identifies two objectives that policymakers and discoms can pursue to facilitate an affordable transition, and then proposes four pathways for how these two objectives can be achieved. Our initial analyses of these pathways show they can each promote one or both objectives; different options, however, may serve local needs better than others. Our purpose is not to provide a conclusive analysis but instead to launch a discussion with stakeholders so as to achieve a more robust analysis based on the local context. Different avenues may be necessary in different areas and for different consumers whose interests and needs vary. In pursuing an affordable transition to low-cost renewable energy, policymakers may be wise to eschew a search for a one-size-fits-all solution for all states and regions in the country, and instead apply solutions that suit their local objectives and priorities best and learn from each other's experiences.

The Objectives

Demand flexibility and distributed generation are both essential to affordably transitioning India's power distribution system to clean energy.

Countries around the globe are experimenting with various policies, business models and market designs as they aim to provide affordable, reliable and clean power to all. We have observed that in their efforts to achieve this long-term goal, there are two common objectives that are generally followed, either explicitly or implicitly.

First, although electricity as a product is homogenous in nature, it is well established that both the economic and environmental cost of serving electricity varies.[4] The nature of electricity, as a commodity, is highly sensitive to time, weather and location, both on the supply side and demand side. However, utilities or system operators have generally

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[2] Both BloombergNEF and Wood Mackenzie report that renewables in India have achieved a levelized cost of energy below that of coal. See Jain, A. (2018). *Indian coal power faces long-term headwinds*. Powering Past Coal Alliance. https://poweringpastcoal.org/insights/energy-security/indian-coal-power-faces-long-term-headwinds (citing BloombergNEF data); Samanta, K. (2019, 19 July). *India's renewable energy cost lowest in Asia Pacific: WoodMac.* Reuters. https://www.reuters.com/article/us-india-renewables-woodmac/indias-renewable-energy-cost-lowest-in-asia-pacific-woodmac-idUSKCN1UO0L8

[3] Press Trust of India. (2019, 15 September). *Power gencos outstanding dues on discoms rises 57% to ₹73K cr in July.* Livemint. https://www.livemint.com/companies/news/power-gencos-outstanding-dues-on-discoms-rises-57-to-rs-73k-cr-in-july-1568554248005.html

[4] See Faruqui, A., Hledik, R., & Palmer, J. (2012). *Time-varying and dynamic rate design,* p. 32. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/time-varying-and-dynamic-rate-design

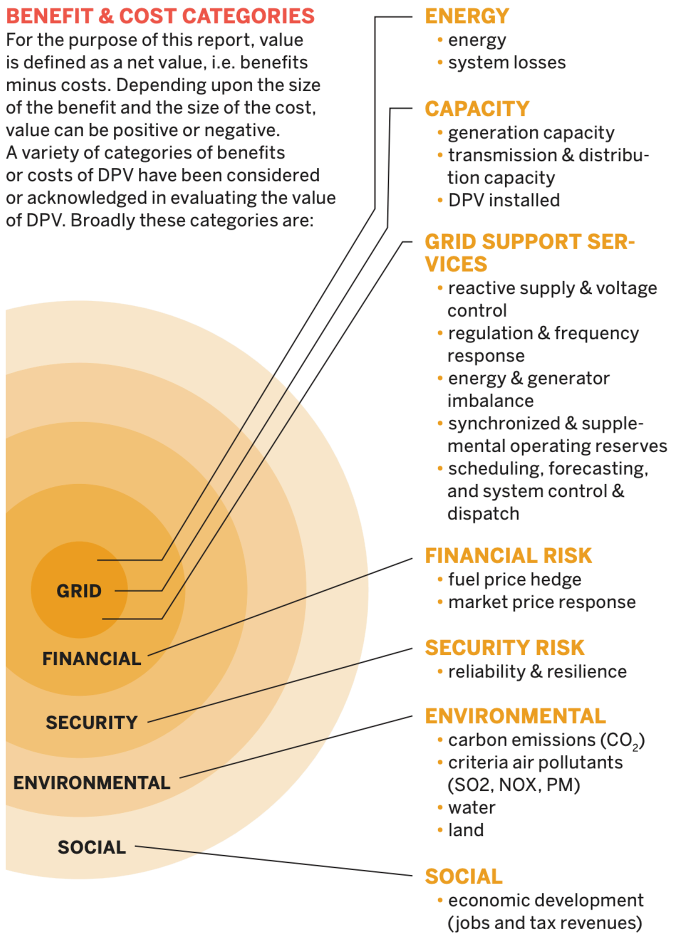
approached the demand-supply imbalance only from the supply side. This means that utilities and system operators always try to ensure that adequate generation is available to meet the demand at all times. The supply is increased during peak times and reduced during off-peak times. When it comes to balancing the grid through demand-side measures, the most common approach is load shedding. The cost of load shedding varies significantly among different markets, and, in India, there is no direct cost imposed upon the discoms for shedding load.

The future power system has to be managed differently with demand flexibility being as high as possible. The cleanest and possibly the cheapest sources of power available in India and the world are uncertain and variable in their availability. To take advantage of such power, it is important to consume power either directly when it is available or store it for future use at times when these sources are not generating in abundance. This will allow consumers to utilize power that is cheap and clean while ensuring that the grid operations are easily and affordably manageable. So, the first objective we identify is to *enable demand flexibility*.

Second, India has recognized the value that rooftop solar can bring to consumers as well as the grid and hence has targeted 40 gigawatts of rooftop solar installations by 2022. Rooftop solar is a type of distributed energy resource (DER). These are generally defined as small-scale generation units within the grid that are set up at the site of or very close to consumption. We focus here on renewable DERs, particularly rooftop solar. Renewable DERs bring several benefits to the table that align with the long-term goals of providing affordable, reliable and clean power. For instance, rooftop solar could provide consumers with higher reliability and reduce their dependency on the grid by partially or even fully meeting their energy needs. Subsequently, this also reduces or delays the need to make investments in transmission, generation and distribution capacity. Further, the grid can benefit from the range of services that a DER like rooftop solar could provide. DERs can bring complexity to the system, as they require better forecasting and management given their variable and distributed nature. However, as mentioned above and shown in Figure 1,[5] DERs can bring value to the grid and to consumers. So, the second objective we identify is to *compensate rooftop solar fairly to bring out its value to consumers*.

[5] Hansen, L., Lacy, V., & Glick, D. (2013). *A review of solar PV benefit & cost studies* (2nd ed.). Rocky Mountain Institute. https://pscdocs.utah.gov/electric/17docs/1703561/314699UCEExhibitC7-15-2020.pdf

Figure 1. Overview of the benefits and costs of distributed energy resources



Note: "DPV" in the figure refers to distributed solar PV.
Source: Hansen, L., Lacy, V., and Glick, D. (2013). *A Review of Solar PV Benefit & Cost Studies* (2nd ed.)

Before moving on, there is another important objective that should be placed higher in priority than the above two objectives, and that is energy efficiency. The cheapest and cleanest way to meet the long-term goal is to reduce the amount of electricity required to power something. This should be an integral part of the portfolio of objectives that India pursues. The above two objectives help us further optimize by incentivizing consumers to use electricity when and from where it's the cheapest and cleanest, and these are the focus of this paper. Keeping these objectives in mind, we first present the challenges faced by India's power sector. We then lay out different options that Indian policymakers, regulators and other stakeholders can explore to create a policy and regulatory framework that facilitates India's efforts to meet its clean energy goals.

Objectives for a clean, affordable and reliable energy system:

1. Enable demand flexibility.
2. Compensate rooftop solar fairly to bring out its value to consumers.

In addition to the above objectives, policymakers should emphasize cost-effective energy efficiency measures.

Understanding the Status Quo

India's distribution sector is structured similarly across the country, with a minor exception in the city of Mumbai.[6] All states have distribution companies (mostly state-owned) which manage the distribution network and serve all consumers in their territory. All consumers fall under four broad categories: agricultural, residential, commercial and industrial. The distribution companies estimate their yearly revenue requirements and apportion them amongst these consumers based on various criteria. The tariffs determined for commercial, industrial and large residential (C&I) consumers are higher than the average cost of supply. This allows discoms to charge a tariff much lower than the average cost of supply to agricultural and small residential consumers, thereby creating a cross-subsidy.[7] In principle, this cost allocation model works in a similar way to a progressive taxation system as consumers who are economically better off shoulder the task of supporting poorer consumers.

The tariff design for different consumer categories varies, and there can be further differences between the states. Residential consumers are offered an increasing block-rate tariff as the default option with no other alternatives. The tariffs for lower consumption blocks are subsidized to provide affordable power to poor consumers. Agriculture consumers are generally offered either highly subsidized flat-rate tariffs or simply free power with unmetered connections.[8] For commercial and industrial consumers, almost all states have adopted some form of time-of-day tariffs with varying features and applicability. Figure 2 below shows the states that have adopted time-of-day tariffs and brief descriptions of the features of these tariffs in select states.[9] Large consumers[10] can also buy power from the wholesale market directly through various channels such as power exchange, bilaterally and through traders. This is known as open access and was implemented to allow large consumers to buy power at competitive rates as opposed to buying from the monopoly discom at higher rates.

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[6] Mumbai has four electricity companies that operate in different parts of the city. Brihanmumbai Electric Supply and Transport Undertaking serves most of the southern island city, whereas Maharashtra State Electricity Distribution Company Ltd. serves the eastern suburbs. There is a parallel licensee arrangement in the western and northern suburbs between Adani Electricity Mumbai Ltd. and Tata Power Company Ltd. where consumers can switch between these two retailers. All these electricity companies are regulated by the state electricity regulatory commission similarly to any other discom in India.

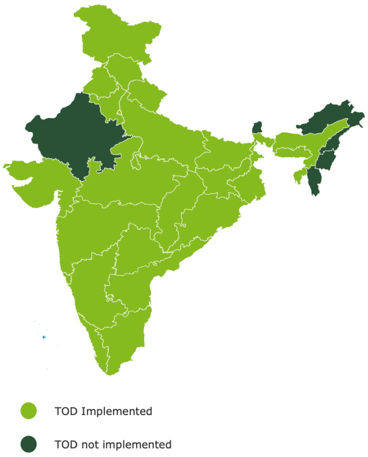
[7] Josey, A., Dixit, S., Chitnis, A., & Gambhir, A. (2018, May). *Electricity distribution companies in India: Preparing for an uncertain future.* Prayas (Energy Group). http://www.prayaspune.org/peg/publications/item/377

[8] Dharmadhikary, S., Bhalerao, R., Dabadge, A., & Nhalur, S. (2018). *Understanding the electricity, water and agriculture linkages: Vol. 1. Overview*. Prayas (Energy Group). http://www.prayaspune.org/peg/publications/item/395.html

[9] Mandal, A. (2019, 11-13 February). *Tariff principles and design with a focus on ToD tariff and market based dynamic ToD* [Presentation to the 12th Capacity Building Workshop for Officers of Electricity Regulatory Commissions at ITT Kanpur], p. 16. https://cer.iitk.ac.in/assets/downloads/FoR_CBP12/Day_1/Distribution_Tariff_and_TOD_Tariff_11_Feb_2019.pdf

[10] Typically, consumers who have a connected load of 1 megawatt or above.

Figure 2. Overview of time-of-day tariff features in selected states



Time of Day tariff in select states

Bihar	TOD tariff charges applicable to all HT consumers. Surcharge of 20%/ rebate of 15% applicable at peak and off peak periods on energy charges
Chhattisgarh	TOD tariff applicable to select HT consumers. Surcharge of 20%/ rebate of 25% applicable at peak and off peak periods on energy charges
Delhi	ToD tariff applicable on all consumers (other than Domestic) whose sanctioned load/MDI (whichever is higher) is 10kW/11kVA and above. Additionally, TOD optional for Domestic consumers. Surcharge/ Rebate applicable at 20% on Energy Charges
Gujarat	TOD tariff applicable to select HT consumers. Surcharge of 10%-20%/ during peak hours on energy charge. Night time concession available to consumers opting to use electricity exclusively during night time
Haryana	Optional TOD tariff applicable to HT Industrial customers from October to March. 19% surcharge and 15% rebate applicable on energy charges.
Jharkhand	TOD tariff applicable on HT consumers. 20% surcharge and 15% rebate applicable on energy charges.
Punjab	Additional charge of Rs. 2.00/kVAh during peak hours and rebate of Rs. 1.25/kVAh applicable during off peak hours for Medium and Large Industries, Non residential and bulk supply customers. Peak tariff is applicable only for months of June to September; off peak tariff is applicable for the rest of the year
Kerala	ToD Tariff applicable to EHT, HT and LT industrial consumers (with connected load of and above 20KW) Consumers. Surcharge of 50% and rebate of 25% applicable on energy charges during peak and off peak hours

Source: Mandal, A. (2019, 11-13 February). *Tariff Principles and Design With a Focus on ToD Tariff and Market Based Dynamic ToD*

Since 2010, different states in India have implemented various policies, initiated programs and experimented with business models to promote rooftop solar and bring out its value for consumers and discoms.[11] While these efforts have translated into success for C&I consumers, they do not show similar results for residential consumers. As of 2018, 70% of the rooftop solar installations were by C&I consumers, while government and residential consumers installed the remaining 30%.[12] There are several reasons why rooftop solar adoption by residential consumers remains low despite the high potential, including low financial viability despite capital subsidies of up to 30% from the government, high cost of financing and lack of support from the distribution companies.[13]

These trends lead us to the paramount challenge that discoms are facing with respect to C&I consumers: sales migration. The loss of large C&I consumer revenue due to distributed generation such as rooftop solar and battery storage, as well as other non-discom alternatives through open access, puts a lot of burden on the discoms to manage their cross-subsidies. In addition, the number of subsidized consumers entering the grid is increasing, requiring the discoms to collect *more* cross-subsidies to stay afloat. In the current framework, therefore, these large consumers play an important role, and if discoms cannot collect adequate revenue from C&I consumers, they may be unable to cover all their costs of service to remaining consumers. This is a vicious cycle. As large consumers shift to non-discom alternatives, the burden of bridging the subsidy gap eventually falls onto the remaining consumers in the form of higher tariffs, which leads to even more consumers shifting away from the discom due to higher arbitrage opportunities. The financial health of the discoms, as well as the continued viability of the cross-subsidy as a matter of public

[11] PricewaterhouseCoopers. (2018). *Rooftop solar in India: Looking back, looking ahead.* https://www.climateinvestmentfunds.org/sites/cif_enc/files/rooftop_solar_pv_in_india_ctf_pwc._v8pdf_0.pdf

[12] Garg, V., & Buckley, T. (2019, May). *Vast potential of solar rooftop in India.* Institute for Energy Economics and Financial Analysis. http://ieefa.org/wp-content/uploads/2019/05/IEEFA-India_Vast-Potential-of-Rooftop-Solar-In-India.pdf

[13] PricewaterhouseCoopers, 2018.

policy, is at stake — and the current approach may not be conducive to maintaining the health of the discoms.

Renewable energy, including distributed generation and demand-side interventions, has the potential to reduce discoms' costs of service, facilitating the continued provision of electricity to all consumers. Both demand flexibility and clean localized consumption will be essential to minimizing the costs of transitioning to an affordable, clean, reliable and resilient power sector.

This policy brief identifies four possible approaches and explores how well each might contribute, alone or in unison, to fostering demand flexibility and clean localized consumption in India.

The Four Approaches

Options for increasing demand flexibility and fostering localized consumption from distributed generation include:

- **Targeted programs**, such as community solar and energy efficiency.
- **Tariff design** for both consumption and distributed generation.
- **Alternate market structures**.
- **Peer-to-peer trading** through the use of distributed ledger technology (DLT) and Internet of Things.

These four approaches are not mutually exclusive but can be combined to suit the needs of different regions and consumers in India. One can think of these approaches as moving in a progression of consumer choices and interaction with the grid. We start with India's current framework of monopoly discoms offering only default flat tariffs (except to C&I consumers who are on some form of time-of-day rate) and move toward envisioning a power system with multiple generation resources and end uses that interact and trade with each other directly on sophisticated platforms.

The aim of this report is not to identify the optimal route but to facilitate a thoughtful conversation about how India's power sector can leverage new technologies. Different approaches will likely be necessary to reach and guide different consumer classes, and possibly even within consumer classes. Moreover, different approaches may be necessary for different parts of the country with differing resource mixes and power needs. Policymakers may find it difficult to find a one-size-fits-all solution for all states and regions but instead can apply solutions that suit their objectives and priorities best and learn from each other's experiences. Additionally, the report does not suggest that India or any other market must eventually move towards a particular system, for instance a peer-to-peer network, but should rather adopt approaches and create frameworks that promote activities suited to achieve India's long-term goal.

Each of the four approaches — targeted programs, alternative tariff designs, alternate market structures and peer-to-peer trading — is explored in depth below. This chapter provides an explanation of these options. The following chapter evaluates how well each might deliver the two desired objectives of increasing demand flexibility and compensating fairly for distributed generation, particularly rooftop solar.

1. Targeted Programs

Certain consumers, consumer loads or geographical areas may be less reachable by the other options or may hold particularly strong potential to deliver on the two objectives. Designing targeted programs that both deliver the objectives and distribute their benefits may be a foundational necessity. Notably, many of these targeted programs could be administered by a government agency, a discom or a third-party provider.

Here, we point to two areas in which targeted programs could deliver substantial benefits: energy efficiency and community solar. Others exist. However, this approach is intentionally illustrative rather than comprehensive.

Energy Efficiency

An efficient system will be easier and less costly to supply and serve than an inefficient one. The value of energy efficiency is well recognized.[14] It can benefit consumers, discoms and society. Yet many opportunities to pursue energy efficiency are hindered by barriers to entry.

One example of such a barrier is limited access to capital. Not all consumers — or all discoms — have adequate capital on hand to invest in energy efficiency, despite the immediate and long-term savings likely to benefit them. Nor are they able to secure the necessary loans from others, if their credit is similarly constrained.

Interventions through the use of targeted programs can effectively overcome these barriers and deliver energy efficiency that would otherwise be passed by. For instance, Energy Efficiency Services Ltd. — a state-owned energy service company — has delivered great benefits through its efforts, such as with the Unnat Jyoti by Affordable LEDs for All (UJALA) scheme to deliver efficient light-emitting diode (LED) lightbulbs to consumers across India.[15] A similar scheme could be designed and funded to promote and deliver other appliances, such as super-efficient air conditioners.[16] Alternatively, a targeted program could foster more energy-efficient building designs.[17] Many possibilities exist.

These programs can provide benefits not only to consumers but also to the system and to society at large. Program administrators would do well to recognize these broader benefits

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[14] Lazar, J., & Colburn, K. (2013, September). *Recognizing the full value of energy efficiency*. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/recognizing-the-full-value-of-energy-efficiency

[15] Energy Efficiency Services Ltd. (n.d.). *About EESL*. https://eeslindia.org/content/raj/eesl/en/About-Us/about-eesl/About-EESL.html

[16] See, e.g., Garg, A., Mohan, P., Shukla, S., Kankal, B., & Vishwanathan, S. S. (2017, July). *High impact opportunities for energy efficiency in India.* Copenhagen Centre on Energy Efficiency. https://smartnet.niua.org/sites/default/files/resources/india-hio-report_web.pdf

[17] See, e.g., Kumar, S., Singh, M., Chandiwala, S., Sneha, S., & George, G. (2018). Mainstreaming thermal comfort for all and resource efficiency in affordable housing: Status review of PMAY-U mission to understand barriers and drivers. Alliance for an Energy Efficient Economy. https://shaktifoundation.in/wp-content/uploads/2018/10/Mainstreaming-thermal-comfort-for-all-and-resource-efficiency-in-affordable-housing_1.pdf

in determining the value of funding such programs. By enabling consumers to partake in programs without the demand for upfront capital, targeted programs like UJALA could be adopted to aid the transition to an energy system that is both clean and efficient.

Community Solar

Rooftop solar need not be limited to consumers with enough rooftop space for the panels. Community solar is one form of solar program that invites participation from a broader set of consumers. A large array of solar panels can be installed, then consumers may receive or pay for a subscription in the output from one or more panels.

Many other opportunities exist to advance solar for all consumers. The Council on Energy, Environment and Water has developed an online interface aimed at discoms to help them identify feasible approaches for advancing rooftop solar in their territory.[18] Moreover, some states and discoms have already embarked on alternative approaches.[19]

2. Alternative Tariff Designs

Consumers respond, as much as they are able, to prices that they see and understand. This is as true in the power sector as in any other sector. As a result, sending consumers appropriate price signals that reflect system or societal values is crucial to driving consumer responses in consumption (i.e., demand flexibility) or production through distributed generation. Electricity tariffs need to be designed for these objectives.

The advantages of placing large consumers on time-of-day tariffs, specifically peak demand reductions and increased conservation measures, have already been recognized in both the National Tariff Policy and the National Electricity Policy.[20] However, little discussion has emerged about alternative tariff designs — either for consumption or for distributed generation — beyond time-of-day pricing or about whether such tariffs could serve small consumers as well.[21] This section provides an overview of the variety of tariff designs that could be offered. It does not seek to propose any design as optimal but simply explains the options. The chapter on projecting outcomes examines the advantages and disadvantages of various designs for different consumers.

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[18] Council on Energy, Environment and Water. (n.d.) *Rooftop solar business model decision-support tool for discoms.* http://cef.ceew.in/rooftop_solar

[19] For example, the Soura project, launched by the government of Kerala (http://sourakseb.in). See also Prateek, S. (2019, May). *Andhra Pradesh approves discom-driven rooftop solar program*. Mercom India. https://mercomindia.com/andhra-pradesh-discom-driven-rooftop-solar

[20] The Forum of Regulators notes this policy support and other regulatory actions in a commissioned report specifically on time-of-day pricing. See PricewaterhouseCoopers India Private Ltd. (2010). *Assignment on implementation & impact analysis of time of day (TOD) tariff in India*, p. 6. Forum of Regulators. http://www.forumofregulators.gov.in/Data/study/Implementation_Impact_Analysis_of_Time_of_Day_TOD_tariff_in_India.pdf

[21] Two exceptional reports that seek to further this discourse are Kumar, S., Sodha, N. S., & Wadhwa, K. (2013). *Dynamic tariff structures for demand side management and demand response: An approach paper from India.* ISGAN. http://indiasmartgrid.org/reports/Dynamic%20Tariffs%20White%20Paper.pdf; and Kulkarni, A., De, A., Gaba, V., & Bharath, V. (2014, April). *Smart grids: An approach to dynamic pricing in India.* U.S. Agency for International Development. http://www.indiasmartgrid.org/reports/Smart%20Grids,%20An%20Approach%20to%20Dynamic%20Pricing%20in%20India,%20USAID%20PACE-D%20TA%20Program.pdf

We make one initial observation: Adopting a new retail tariff design does not restrict regulators or discoms from continuing to impose a cross-subsidy for public policy reasons. Many reports on retail tariff design focus exclusively on the economic theory,[22] with little to no discussion of consciously adopted cross-subsidies. Mentions of "improper cost shifts" in the retail tariff design literature should be understood to refer specifically to cross-subsidies between consumers that might emerge without any direct intention from the regulator or discom for the cross-subsidy to serve an economic or public policy goal. The following discussion does not evaluate if or how a cross-subsidy should be imposed under the varying options; it simply accepts that a cross-subsidy will be imposed.

A Key Concept: De-averaging Rates

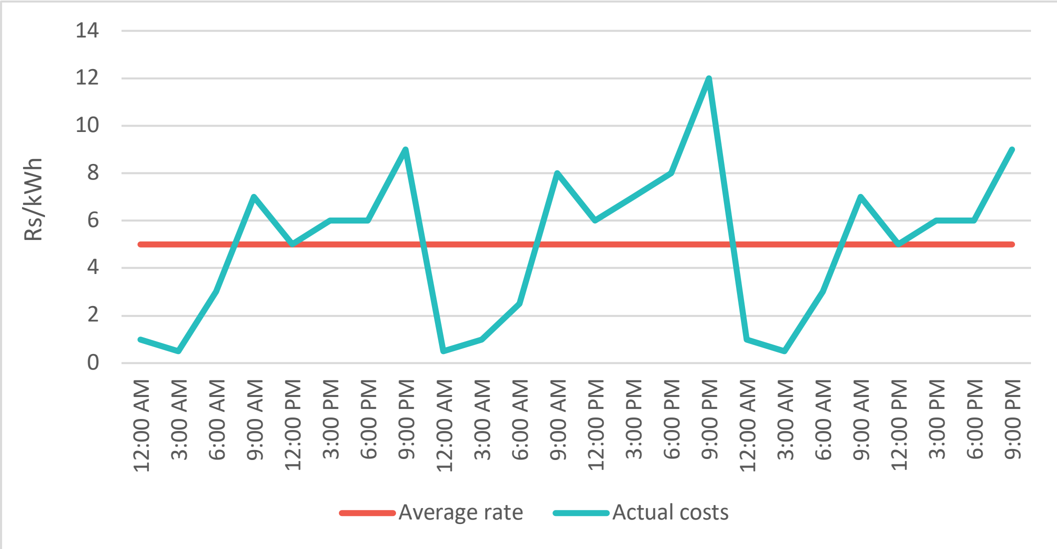
The long-run marginal costs for producing and delivering electricity vary with fluctuations in supply and demand. Time and location are two parameters that can serve as proxy factors to illustrate this variation.[23] Producing a kilowatt-hour (kWh) in late afternoon during the hottest day of the summer and delivering it to a congested area of the grid might incur a greater cost to a discom (or other retail provider[24]) than producing a kWh at midnight on a mild winter night and delivering it to an uncongested area. Discoms face these varying costs, yet few consumers see them. Figure 3 illustrates how an average rate (such as under a flat-rate tariff) remains static while a hypothetical discom's marginal costs might vary over the course of three days.

[22] For an introduction to the economic theory of tariff design, see "The Economics of Regulation," available as an appendix in Weston, F. (2000). *Charging for distribution utility services: Issues in rate design*. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/charging-for-distribution-utility-services-issues-in-rate-design

[23] Neither time nor location cause costs to be high or low. However, both are reasonable proxies for many causes; for instance, time can be used to reflect, for instance, increased consumer demand given established consumer behavior, such as turning the lights on at dusk. Similarly, location can be used to reflect, for instance, increased line losses in lightly or densely populated areas.

[24] See the other options discussed below, specifically on retail competition and peer-to-peer trading. For simplicity, in the remainder of this section, we refer only to discoms as the assumed provider, but that assumption could be changed.

Figure 3. Hypothetical average rate contrasted with hypothetical marginal costs of service



A spectrum of tariff design options exists to reveal these varying costs. On one end, a seasonal rate takes the first step in de-averaging flat-rate tariffs by providing at least two separate average rates. On the opposite extreme, locational real-time pricing offers price signals specific to a consumer's precise location and hour of consumption. Progressing along this spectrum — from whichever point a consumer class is at — may offer stronger price signals to consumers about their discom's long-run marginal costs. These price signals can encourage consumers to respond by choosing to either reduce their consumption or change the time of (i.e., "shift") their consumption from times when costs are high to times when the costs are lower. In short, de-averaging rates can encourage demand flexibility.

Similarly, few consumers who export power to the grid are compensated based on the value provided in their location or at the time of export according to a discom's avoided long-run marginal costs. The same spectrum of tariff design options exists for how consumers are compensated for exporting power as for how they are billed for consuming it. Progressing along this spectrum may offer stronger price signals to consumers about the value of an investment in distributed generation for their and the system's benefit. In short, de-averaging compensation rates can direct investments in distributed generation towards the forms (e.g., solar PV or storage) and the locations where the investment is likely to provide the highest value to the system. By aligning compensation with actual value, discoms can guide the market forces driving investments in distributed generation towards investments that benefit the grid as well as the investing consumers.

By aligning compensation with actual value, discoms can guide the market forces driving investments in distributed generation towards investments that benefit the grid as well as the investing consumers.

The following section describes this spectrum of tariff design options for de-averaged rates. First, it describes options for revealing locational marginal costs. Then, it describes options for revealing time-varying marginal costs. Several of these options may be combined. This spectrum of options is the focus of this report, although note that more tariff design options exist than are discussed here.[25] (Note that where the term "cost" is used to describe the economic impact of consumption, the term "value" should be implied to describe the economic benefit of exporting power.)

A central question to ponder is how de-averaged the rates need to be to deliver the desired benefits to consumers and to discoms. One important consideration is how different consumers may view and understand different tariff designs, as their understanding will shape their appetite for a new tariff and their responsiveness to the new price signals. The later chapter on projecting outcomes begins to examine this question.

Options for Revealing How the Cost of Electricity Varies With Location

Each consumer class tends to face the same delivery charge for electricity, but a discom faces different long-run marginal costs to deliver to different areas. The discom may need to install, replace or upgrade wires in different parts of the distribution and transmission system. In addition, congestion in the system can increase line losses, which increase costs. These varying costs are generally socialized across consumers, so they do not see the geographic variations. Yet revealing these cost differentials to consumers can encourage them to act in ways that reduce costs.

Different approaches have emerged for revealing the locational costs on the transmission system.[26] Rather than a single average rate, the locational costs can be revealed through zonal pricing or nodal pricing. Zonal pricing requires designating areas (zones) within which a uniform price is set; the price may vary between zones, but the cost within any one zone remains the same. The most granular approach is nodal pricing, which sets prices based on the cost data for every distinguishable point (node) of power import or export on the transmission system. However, applying these approaches to the distribution system may not be technically feasible or politically desirable.

An alternative approach is to identify high-cost areas on the distribution system and reward consumers for making delivery cost reductions in that area. Consumers could earn these rewards, or "distribution credits," through investing in distributed energy resources, including energy efficiency and solar PV.[27] This approach provides an incentive without

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[25] For instance, some tariffs may vary in terms of the quality of supply they promise. Such non-firm or interruptible tariffs are not discussed at length here but may be worth considering.

[26] See, e.g., Hogan. M., & Pandra, J. M. (2019, June). *Locational market in Poland: Security of supply, costs and the impact on the energy transition.* Forum Energii in partnership with the Regulatory Assistance Project. https://forum-energii.eu/en/analizy/rynek-lokalizacyjny. See also Hogan, M. (2018, September). *Locational pricing in Poland: Lessons from experience.* Regulatory Assistance Project. https://www.raponline.org/knowledge-center/locational-pricing-in-poland

[27] Moskovitz, D., Harrington, C., Cowart, R., Shirley, W., & Weston, F. (2000). *Profits and progress through distributed resources,* pp. 24-25. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/profits-and-progress-through-distributed-resources-2.
For more on this approach, see Moskovitz, D., Harrington, C., Cowart, R., Shirley, W., Sedano, R., & Weston, F. (2001). *Distributed resource distribution credit pilot programs: Revealing the value to consumers and vendors.* Regulatory Assistance Project. https://www.raponline.org/knowledge-center/distributed-resource-distribution-credit-pilot-programs-revealing-the-value-to-consumers-and-vendors

imposing higher costs, reducing the possibility that consumers in a high-cost area perceive the effort to de-average locational costs as imposing a penalty on them.

Options for Revealing How the Cost of Electricity Varies With Time

At least five distinct options exist for tariff designs that reflect the time-varying cost of electricity.[28] These five options are:

- Seasonal rates.
- Time-of-day rates.
- Critical peak pricing and peak time rebates.
- Variable peak pricing.
- Real-time pricing.

Seasonally varying rates are the least de-averaged option, while real-time pricing is the most de-averaged option. Again, the central question of how de-averaged the rates need to be to deliver the desired benefits to consumers and to discoms is discussed later.

Seasonal Rates

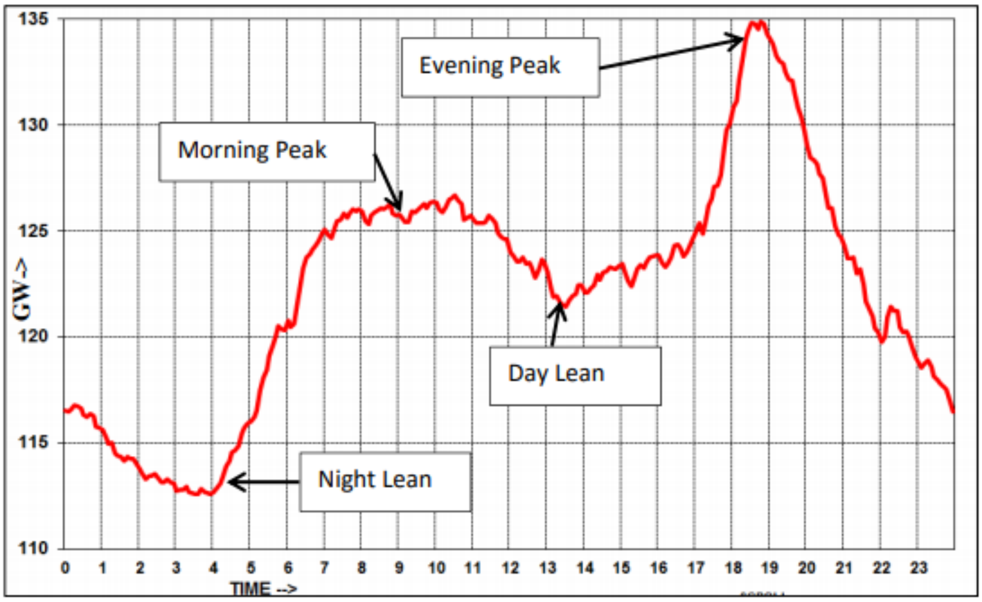
Discoms often face higher costs of service during one season (the "peak season"). These may be due to higher-cost generation or the cost of serving growing peak load reliably. Whereas a flat rate offers one averaged rate for all consumption, a seasonal rate typically offers two averaged rates: a higher rate for consumption during the peak season and a lower rate for consumption during all other seasons.

Time-of-Day Rates

Discoms also tend to face higher costs of service during certain hours of the day ("peak hours"). For instance, the typical daily curve in India shows two peak times, one in the morning and one in the evening. Figure 4 illustrates this.[29]

[28] Here, we use the term "time-varying pricing" to include dynamic pricing.
[29] Power System Operation Corporation Ltd. (2016). *Electricity demand pattern analysis* (Vol. 1). https://posoco.in/download/all-india/?wpdmdl=8873

Figure 4. Daily demand in India



Source: Power System Operation Corporation Ltd. (2016). *Electricity Demand Pattern Analysis* (Vol. 1)

Similar to a seasonal rate, a time-of-day rate typically offers two averaged rates, a higher rate for consumption during the peak hours and a lower rate for consumption during off-peak hours. Sometimes a third rate is offered for hours when the costs are moderate (a "shoulder" time period). Where multiple peak periods exist, the peak price may be the same or different for the multiple periods.

Seasonal rates and time-of-day rates can be offered together — a seasonal time-of-use rate. This combination could be particularly useful in regions where seasonal changes alter the daily peak periods on the system.

Critical Peak Pricing and Peak-Time Rebates

Discoms tend to face their highest costs during peak hours on a few days of the year. Critical peak pricing and peak-time rebates are similar offerings that try to address the higher costs to serve consumption during peak hours on, for instance, the hottest day of the summer.

Unlike peak seasons or peak hours, "critical peak" days typically cannot be accurately determined months or years in advance. Instead, under critical peak pricing, a discom obtains approval from regulators to declare a certain number of critical peak events over the course of the peak season and to charge a higher rate during peak hours on these critical peak days. The discom and regulator determine this rate in advance.

When a discom wants to declare a critical peak event, it must typically provide at least 24 hours' notice to consumers. This serves to inform consumers that prices will be higher during peak hours on the critical peak day and encourages them to adjust their consumption accordingly. For instance, a discom could encourage residential consumers to reduce consumption at their home by going out to see a movie. Critical peak pricing works best with customer outreach and communication of at least a year in advance, so customers are familiar with the pricing. And effective communication mechanisms immediately in advance of the critical peak event, such as social media, email, text messages and even dedicated devices, are critical to effectuating a customer response.

Critical peak costs can also be targeted through the use of a peak-time rebate offering. Rather than impose a higher rate during critical peak hours, a peak-time rebate effectively offers the chance of a bill discount with no risk of a bill increase. Consumers who successfully reduce their consumption during peak hours on a critical peak day receive the rebate. Consumers who cannot or do not reduce their consumption under a tariff with a peak-time rebate do not pay a higher amount than under their standard tariff.

Both seasonal rates and time-of-use rates can be offered together with either critical peak pricing or a peak-time rebate.

Variable Peak Pricing

Variable peak pricing is an adaptation of critical peak pricing. Under critical peak pricing, the discom charges a pre-determined rate during critical peak hours. However, this rate may not reflect the marginal costs that the discom incurs that day. Under variable peak pricing, the discom charges the marginal cost to serve during critical peak times. The variable peak prices may reflect the discom's actual marginal generation cost during critical peak hours or may be tied to wholesale market prices if they are available.

Both seasonal rates and time-of-use rates can be offered together with variable peak pricing.

Real-Time Pricing

Under real-time pricing, a discom charges consumers for the marginal costs of service for consumption on a (typically) hourly basis. This option reflects the most de-averaged tariff design possible.

Real-time pricing cannot be offered together with any other time-varying rate. Note, however, that any of the above tariffs could be offered as an alternative to any other tariff.

Comparison of the Five Time-Varying Options

Each of the five options described above could enable discoms to better align the rates that consumers see with the discoms' costs of service. Table 1 summarizes these options.

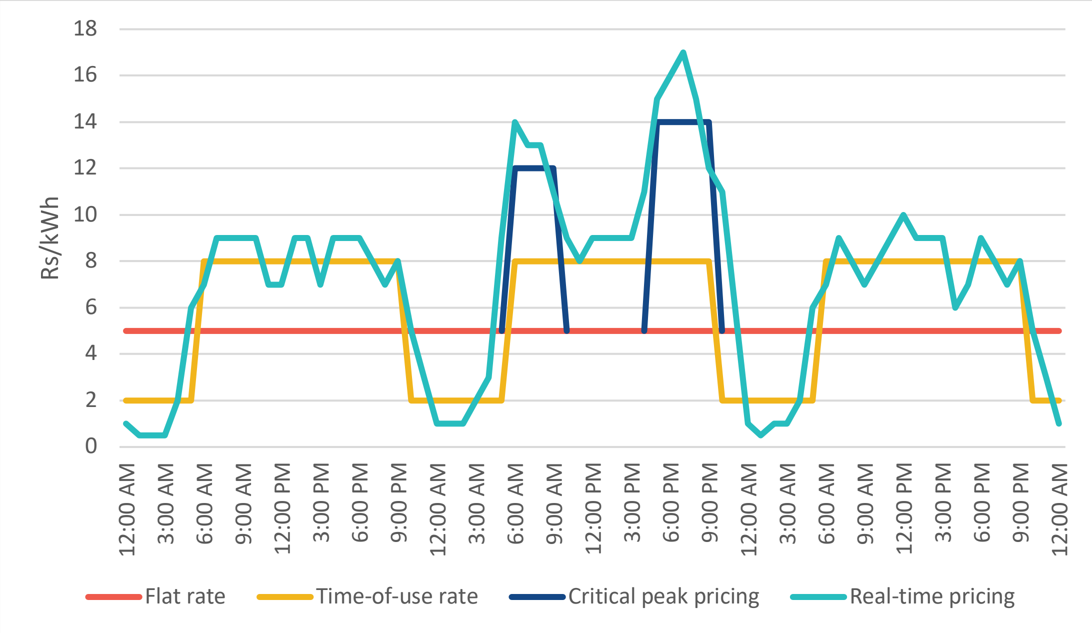
Table 1. Ability of tariff design options to align customers' rates with discoms' costs of service

Aligns rates with costs during:	Seasonal rate	Time-of-day rate	Critical peak pricing/peak time rebate	Variable peak pricing	Real-time pricing
Peak season	✓	✓*	✓	✓	✓
Peak hours		✓	✓	✓	✓
Peak days			✓	✓	✓
All hours					✓

* A time-of-day rate may include seasonally varying rates, but it does not have to.

Figure 5 illustrates the de-averaging of these different options.[30] This is a hypothetical example intended for illustration; the numbers used are not intended to reflect real-world conditions except in a general sense.

Figure 5. Options as applied to hypothetical three-day period, with one critical peak day



These options vary in how much they de-average the rate that consumers see by time. A flat rate averages the costs of service over a year (or longer) into a single averaged rate. A seasonal rate de-averages the flat rate into two averaged rates, one for peak season and one for the rest of the year. Time-of-day pricing, critical peak pricing and variable peak pricing further de-average the flat rate. The most de-averaged option is real-time pricing. Under real-time pricing, consumers face up to 8,760 different hourly rates for the 8,760 hours of the year rather than one rate for the whole year (or more, if sub-hourly rates are used).

De-averaging rates provides stronger price signals, but the most de-averaged rate may not be the one with the greatest consumer response. A discom might need to study its consumers' behavior in a pilot study to understand what tariff designs are most likely to be effective in facilitating demand flexibility, eliciting customer responses and gaining customer acceptance, and meeting other policy goals. The subsequent chapter on assessing the options explores further how any of the above options may be implemented.

Tariff Design for Different Sources of Electricity

Most consumers see electricity rates that reflect the overall average system supply sources. However, different fuel sources have different characteristics. Recognizing or revealing these varying characteristics to consumers may give rise to different retail and compensation tariffs.

For instance, consumers may show interest in an optional retail tariff that offers a higher

[30] Variable peak pricing is not illustrated, as it would simply overlap with the real-time pricing options shown during critical peak periods.

portion of electricity from renewable energy sources. The retail rate would need to reflect the costs of procuring a greater portion of renewable energy (or of renewable energy credits).[31] This design has been referred to as green pricing.[32]

Similarly, a compensation rate could incorporate the values of the particular distributed energy resource(s) that is exporting power to the grid. For instance, a compensation rate may recognize the value of ancillary services provided to the grid as well as the value of electricity provided. Tariffs that offer such a compensation rate have been referred to as value of solar tariffs or value of distributed energy resource tariffs.[33] There is as yet no consensus on what values ought to be incorporated. Some jurisdictions are evaluating more attributes than others (such as benefits from reduced greenhouse gas emissions). Others are assigning greater value to certain attributes (such as avoided transmission and distribution losses).[34] Any valuation of a particular form of distributed generation should necessarily reflect the costs and benefits within the local context.

Additional Considerations for Distributed Generation Tariffs

Both the retail rate and compensation rate are important factors in how prosumers — consumers who also produce — will perceive the cost of consumption or the value of production. As noted above, any of the options we have identified could be used as a retail rate or a compensation rate. These two rates provide information to a prosumer about the value of their production. The retail rate defines what savings a consumer may achieve through consuming distributed generation and thereby avoiding consumption from the grid.[35] The compensation rate defines what a prosumer is paid for exporting electricity to the grid.

The retail rate and compensation rate could be symmetrically equivalent; alternatively, they could be separately determined. If they are symmetrical, then any deficiency in a retail rate relative to a discom's marginal costs of service (implicit or explicit)[36] will also be present in the compensation rate, and vice versa. This may work in the discom's favor, if the compensation provides less than the actual value. Or it may work in the (individual) prosumer's favor, if the compensation provides more than the actual value. Choosing whether to have symmetrical retail and compensation rates or how to set the two separately are important to conveying the value of distributed generation to prosumers and to guiding

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[31] If such sources are procured through fixed-price long-term contracts, the retail rate may end up being more stable than a typical rate, which some consumers may find particularly appealing.

[32] For more on green pricing, see Regulatory Assistance Project. (1995, October). *Green Pricing Newsletter, No. 1.* https://www.raponline.org/knowledge-center/green-pricing-newsletter-issue-1

[33] For more information, see Lazar, J., & Vitolo, T. (2016, 22 September).*The value of solar: Assessing the benefits, the costs, and what it may mean for net energy metering* [Webinar]. Regulatory Assistance Project. https://www.raponline.org/event/the-value-of-solar-assessing-the-benefits-the-costs-and-what-it-may-mean-for-net-energy-metering. See also Shenot, J., Linvill, C., Dupuy, M., & Brutkoski, D. (2019). *Capturing more value from combinations of PV and other distributed energy resources*. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/capturing-more-value-from-combinations-of-pv-and-other-distributed-energy-resources

[34] Locational pricing could be relevant to the design of a compensation rate. See the discussion of options for revealing locational costs on Page 12.

[35] This could be done directly, such as from solar PV, or indirectly through the use of battery storage. Both are considered distributed generation for the purpose of this report.

[36] If a discom does not pay for externalities, then neither will a prosumer be compensated if they reduce those externalities.

their investment and prosumption behavior (production and consumption).

However, several other factors also affect how a prosumer might view the value of distributed generation to them versus to the system. First, there may be eligibility requirements, such as whether a given tariff is applicable to all prosumers or only a certain subset. Any limitation could be defined in terms of the size of an installation. Second, there are crediting terms that need to be set, such as whether consumers receive a cash payment or an on-bill credit for the compensation earned. If a bill credit, the expiration date, if any, for that credit must be determined. Third, there are various contractual terms to set. Determining how long a given approach (and, if applicable, a given compensation rate) will be in effect for a consumer — and what approach and compensation rate may follow — will be influential in how consumers view the likelihood of long-term benefits from a potential investment in distributed generation.

Finally, a metering and billing arrangement must be chosen.[37] The metering and billing arrangements determine how the flows to and from the grid are measured and accounted for. The metering and billing arrangement chosen may influence how consumers see the price signals from retail and compensation rates. There are at least three options for metering and billing arrangements: net metering, gross metering and net billing.[38] Details on the existing solar policies of each state for each consumer category are available online.[39] These include compensation methods such as net metering, financing support through subsidies or accelerated depreciation as well the ownership models in different states.

Net Metering

Net metering can be implemented with a single bidirectional meter. When a prosumer is importing power from the grid, the meter adds the consumption to the total. When a prosumer is exporting power to the grid, the meter subtracts the production from the total. For a single billing period, the prosumer pays their retail tariff rate for the net amount of energy consumed, if any. Any distributed generation that is self-consumed is effectively paid a compensation rate equal to the avoided retail rate.

A prosumer could export more than they produce. Often, the exported units are "banked" in the prosumer's bill as credits that will apply against consumption during the next billing period. Because this could conceivably occur over several billing periods, one decision to make is how long banked units can be on the bill before the credits expire. If units are not allowed to be banked, the prosumer is effectively not compensated for them.

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[37] This discussion draws from an explanatory report. See Zinaman, O., Aznar, A., Linvill, C., Darghouth, N., Dubbeling, T., & Bianco, E. (2017, October). *Grid-connected distributed generation: Compensation mechanism basics*. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy18osti/68469.pdf. There may be additional components, such as a state rebate for the equipment. Here, we focus on items that discoms and regulators can themselves choose from to adapt to the changing power sector and growing adoption of distributed generation.

[38] Some jurisdictions have continued to use this term to describe what is classified as net billing below. This description therefore is of what some may call traditional net energy metering.

[39] MySun. (n.d.). *State-wise solar policies in India*. https://www.itsmysun.com/solar-state-wise-policy

Gross Metering

Gross metering tracks consumption and production separately through the use of a second meter or other means.[40] Consumption is charged at the retail rate; production is paid at a compensation rate known as a feed-in tariff. Either or both rates could be time-varying, but they need not be.

Net Billing

Net billing also separately tracks consumption and production. However, unlike gross metering, it nets the consumption and production over separate time blocks. It may use a structure similar to a time-of-day approach or use shorter time periods, such as hourly or sub-hourly periods. This approach is most useful when either the retail rate and compensation rate are different or when time-varying rates are used. Under net billing, prosumers pay for consumption at the retail rate in every time period in which they consume more than they produce, and they are paid for production at the compensation rate in every time period in which they produce more than they consume.

Feed-in tariff: A gross metering arrangement or a net billing arrangement?

The term "feed-in tariff" has been used differently in different places. Generally, a feed-in tariff offers prosumers a certain compensation rate for their production for some period of time. The chosen compensation rate may apply to all production (under gross metering) or to only some portion of production (under net billing). A feed-in tariff requires a metering and billing arrangement, but it is not itself a metering and billing arrangement. A feed-in tariff may be used as part of the metering and billing arrangements described above.

Comparison of the Three Metering and Billing Arrangement Options

These three options primarily vary in two ways: whether they consider any differential between production and consumption and whether they can support the use of time-varying rates. In short, net metering looks at the overall differential for the entire billing period; it cannot support the use of time-varying rates if the retail rate and the compensation rate are different or if the time periods are different for consumption or production. Gross metering does not consider the differential but instead looks at the total production and total consumption; gross metering can support the use of a time-varying retail rate or time-varying compensation rate, but neither is required. Under net billing, the relevant rate applies to the differential prosumption for each designated time period (e.g., hourly) shorter than the billing period. Like gross metering, net billing can support the use of time-varying rates but does not require them. Table 2 summarizes these differences.

[40] In some jurisdictions, this arrangement is known as a "buy-all, sell-all" arrangement.

Table 2. Comparison of metering and billing arrangements

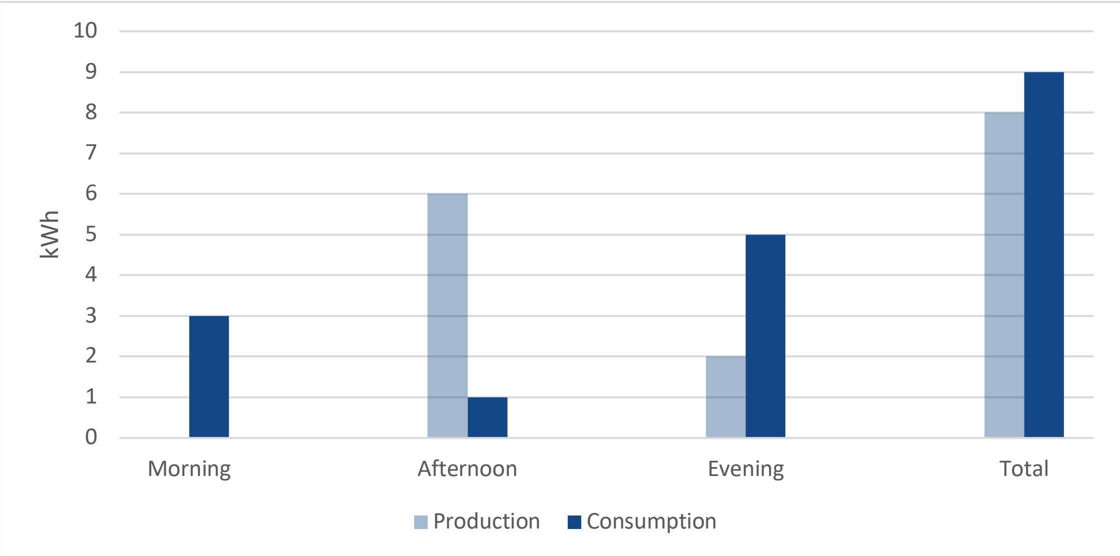
Arrangement	Considers differential between production and consumption?	Can support use of time-varying rates?
Net metering	Yes — single differential	No
Gross metering	No	Yes — possible but not required
Net billing	Yes — many differentials	Yes — possible but not required

Because of these differences, different metering and billing arrangements can result in significantly different electricity bills, even under the same retail and compensation rates.

Illustrative Example

The following example illustrates how the three billing and metering arrangements could be implemented. Imagine a prosumer whose production and consumption varies over the course of a day. In the morning, the prosumer produces no power but consumes 3 kWh. In the afternoon, the prosumer produces 6 kWh but consumes 1 kWh. In the evening, the prosumer produces 2 kWh but consumes 5 kWh. Figure 6 illustrates this hypothetical prosumer's production and consumption.

Figure 6. Hypothetical prosumer's consumption and production over a day



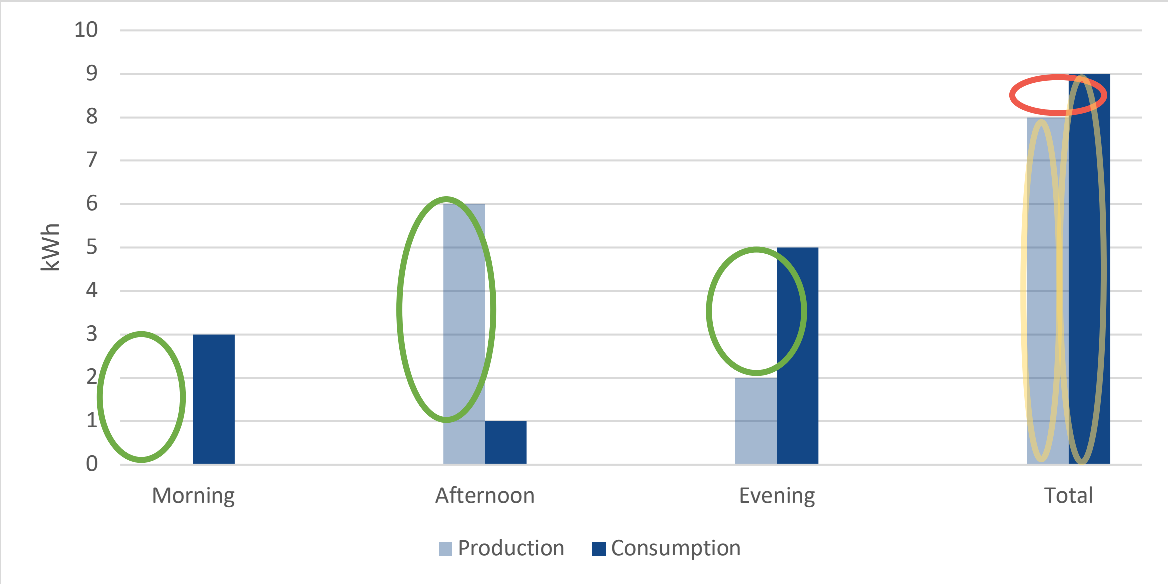
Under net metering, the prosumer would pay the retail rate for 1 kWh. Over the entire day, the prosumer produces 8 kWh (0 plus 6 plus 2) and consumes 9 kWh (3 plus 1 plus 5). The net difference is 1 kWh consumed (9 kWh consumed minus 8 kWh produced).

Under gross metering, the prosumer would pay the retail rate for 9 kWh and the compensation rate for 8 kWh. These are the total amounts; no differential is considered. If a time-varying rate applies, the prosumer would receive the appropriate time-varying rate for consumption or production at the different times.

Under net billing, the prosumer would pay the retail rate for 3 kWh (3 minus 0) in the morning and 3 kWh (5 minus 2) in the evening. In addition, the prosumer would receive the compensation rate for the 5 kWh (6 minus 1) in the afternoon. Under a time-varying rate, the prosumer could receive different rates at different times.

These three results are illustrated in Figure 7, with the different circles indicating the relevant measurements. Net metering is in red, gross metering in yellow and net billing in green.

Figure 7. Compensation for hypothetical prosumer under the three options



Each approach to tariff design for retail or compensation rates and to metering and billing arrangements has advantages and disadvantages. The chapter on assessing the options examines how these approaches might fare in India.

3. Alternate Market Structures

In the previous chapter, we discussed various tariff designs that could incentivize demand flexibility among consumers and compensate distributed resources fairly. These tariffs can be adopted by the monopoly discoms through the regulatory process, which would go a long way in incentivizing consumers to respond to the prices by flexing their consumption. Consumers could also explore additional ways to reduce their electricity consumption itself through energy efficiency measures and realize permanent savings on their electricity bills.

In this chapter, we discuss alternative market structures that are followed in many markets and how they could help policymakers achieve their objectives. India has been discussing a reform plan to restructure the retail market for a very long time.

India's retail market reforms are aimed at bringing competition to the distribution sector. India's vision for a competitive retail power market goes back to the Electricity Act 2003, which created provisions for open access and parallel distribution licensees. Although both open access and parallel distribution licensees struggled to gain the desired popularity, the vision for bringing in more competition to retail power supply is still strong. Over the years, the government has been continuously deliberating the separation of the distribution business from the supply business to facilitate retail competition in a more transparent and efficient manner. The motivation behind introducing competition is to modernize the supply sector and offer consumers the choice to select their electricity supplier. Competition, like in any other industry, is expected to drive market participants to improve their operational efficiency and offer better quality products at competitive rates. All these potential outcomes give the government hope that competition could be one of the ways to address some of the big challenges that the power sector faces today.

Retail competition itself can have varying designs, and the Forum of Regulators devised a roll-out plan with PricewaterhouseCoopers for introducing competition in India's retail power market.[41] The common proposal in India is to allow the distribution business, also known as the "wires" business, to be operated by the existing discom, while the supply of power can be undertaken by several competitive retail electricity suppliers. This approach is commonly known as "carriage" and "content" separation in the Indian parlance, where carriage refers to the wires business and content is the power supply business. Table 3 summarizes the important objectives that such a reform is expected to achieve.[42]

Table 3. Objectives of India's move toward retail competition

Objective	Benefits derived from retail supply competition
Improvement in efficiency and loss reduction	The licensees can focus on their respective responsibilities. distribution company would focus entirely on technical and operational efficiency, while the retail supplier would focus entirely on power procurement and consumer interface
To give choice to consumers	Choice allows consumers to differentiate between suppliers on the parameters like quality of supply, supply tariffs and customer service. This in turn would put pressure on supply companies to provide better services.
Improved access and availability of power	Owing to focused investments of distribution in network upgradation and increased efficiencies in power procurement by retail supply companies, in the long run power availability to consumers will improve.
Efficient power procurement	In order to capture a greater market share in their supply area, the retail supply companies would work towards improving efficiency in power procurement.

Source: Forum of Regulators and PricewaterhouseCoopers Private Ltd. (2015). *Roll Out Plan for Introduction of Competition in Retail Sale of Electricity*

Currently, there is a lot of discussion regarding the potential introduction of retail competition to India's power markets and the way it should happen. The separation of carriage and content directly is one of the options. Recently, however, the current power minister has floated an idea of mandating the utilities to adopt a franchising model in their service territory to introduce retail suppliers.[43] A discom could have several distribution licensees and franchisees operating in one area using the existing distribution

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[41] Forum of Regulators and PricewaterhouseCoopers Private Ltd. (2015). *Roll out plan for introduction of competition in retail sale of electricity*. http://www.forumofregulators.gov.in/Data/study/Retail.pdf

[42] Forum of Regulators and PricewaterhouseCoopers Private Ltd., 2015.

[43] Singh, S. (2019, August). Discoms will have to supply power through franchisees: RK Singh. *The Economic Times.* https://economictimes.indiatimes.com/industry/energy/power/discoms-will-have-to-supply-power-through-franchisees/articleshow/70834891.cms

infrastructure and regulated rates. The idea is to bring in retail competition without necessarily going through with complete carriage and content separation.

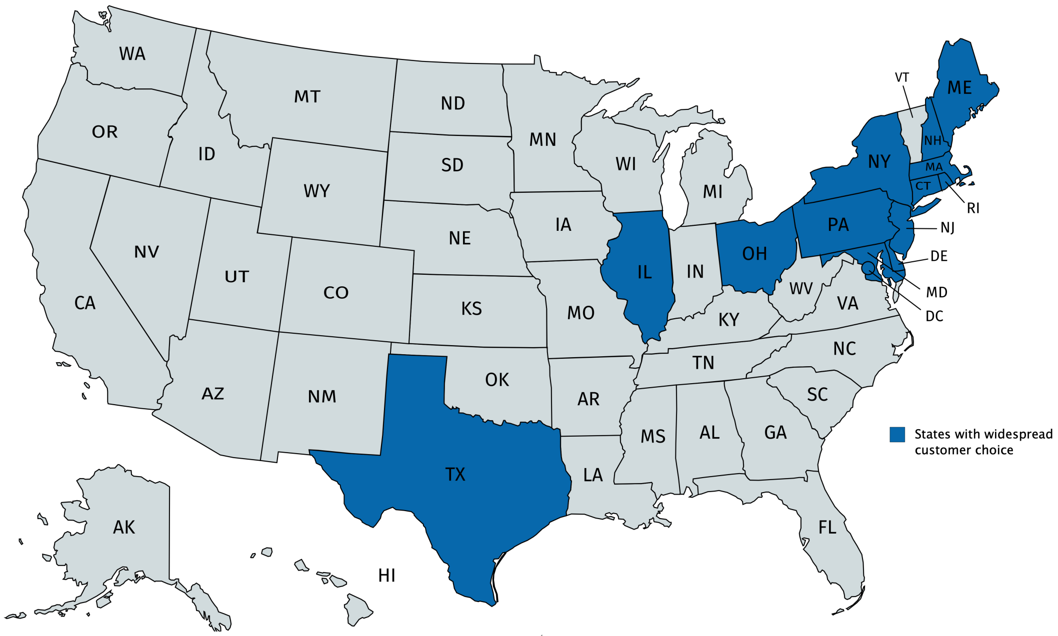
As noted in the previous chapter, a monopoly discom can encourage demand flexibility by changing the pricing structure. Under retail competition, any provider may offer a time-varying or dynamic tariff. To consumers, this affords the choice of an optional time-varying or dynamic tariff, rather than the discom's default tariff, which may continue to be a flat-rate tariff. However, does retail competition really enable better demand flexibility through these tariffs than a monopoly discom? Is the restructured market being designed keeping the objective of better demand flexibility and higher promotion of distributed energy resources in mind? Will more choices necessarily be beneficial to consumers? Some of these questions are explored below.

Retail Choice in International Markets

Electric Reliability Council of Texas

In the United States, 13 states and the District of Columbia allow consumers to choose their competitive electricity supplier over the utility's standard service offer and switch between these retailers easily (see Figure 8).[44] These markets combined make up one-third of the total electricity generation and consumption in the United States.[45] The participation of consumers in retail choice programs varies from 10% to 50% in these jurisdictions, with the exception of the state of Texas.

Figure 8. Retail competition in the United States



Data source: 21st Century Power Partnership. (2017, August). *An Introduction to Retail Electricity Choice in the United States*

[44] 21st Century Power Partnership. (2017, August). *An introduction to retail electricity choice in the United States.* https://www.nrel.gov/docs/fy18osti/68993.pdf

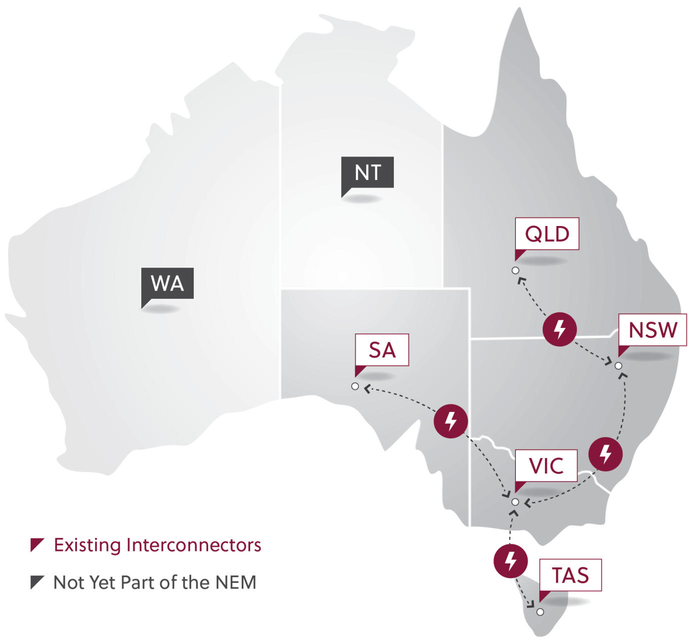
[45] O'Connor, P. R., & Khan, M. A. (2018, Sept.) *The great divergence in competitive and monopoly electricity price trends*. Retail Energy Supply Association. https://www.resausa.org/sites/default/files/FINAL%20Phil%20O%27Connor_The%20Great%20Divergence_White%20Paper%20with%20Tribute.pdf

Texas regulators have implemented mandatory participation by consumers in the retail market, which requires all consumers to choose their own competitive electricity supplier. The state has one of the most competitive retail electricity markets with around 116 retailers offering more than 300 products to consumers.[46] Although almost all the consumers do choose their electricity supplier, the Public Utility Commission of Texas has designated a few providers of last resort.[47] Providers of last resort are assigned to consumers who have not chosen a competitive electricity supplier as well as to those who need emergency backup if their supplier's service fails. These services are relatively expensive and hence customers prefer to shop for electricity from the available retailers.

Australia's National Electricity Market

The National Electricity Market operates in the eastern and southern states of Australia and delivers 80% of the country's total energy consumption (see Figure 9).[48] Currently, consumers can choose from 38 retail electricity brands in the National Electricity Market.[49] The competitiveness of the National Electricity Market is increasing with more retailers entering the market every year and the "Big 3" retailers gradually losing their market share. This is accompanied by increasing participation and engagement which has increased multifold over the years. Similar to Texas, the Australian Energy Regulator has a retailer of last resort that ensures reliable supply in case of failure of supply by the retailers.

Figure 9. Australia's National Electricity Market



Source: ElectraNet. (n.d). *National Electricity Market and Rules*

[46] Public Utility Commission of Texas. (2019). *Scope of competitive electricity markets in Texas: Report to the 86th Legislature*. https://www.puc.texas.gov/industry/electric/reports/scope/2019/2019scope_elec.pdf

[47] Public Utility Commission of Texas. (n.d.). *Electricity options: Provider of last resort (POLR).* https://www.puc.texas.gov/consumer/electricity/Polr.aspx

[48] ElectraNet. (n.d). *National Electricity Market and rules*. https://www.electranet.com.au/what-we-do/network/national-electricity-market-and-rules/

[49] Australian Energy Market Commission. (2019, June). *AEMC 2019 retail energy competition review final report.* https://www.aemc.gov.au/sites/default/files/2019-06/2019%20AEMC%20Retail%20energy%20competition%20review%20-%20Final%20report.PDF

These retail markets have received criticism and praise equally by different stakeholders. The performance of retail competition in these markets is going through various levels of evaluations; however, there are broad observations and assessments that we can draw upon to understand the benefits of retail competition, especially with respect to valuing rooftop solar and enabling demand flexibility

Retail Competition and Distributed Generation

Texas, where the Electric Reliability Council of Texas (known as ERCOT) serves around 90% of the load, has generally lagged in the adoption of rooftop solar compared with other U.S. states, and it currently ranks ninth in total residential solar capacity.[50] This particular trend is not necessarily a result of retail competition but primarily because there is no solar generation tariff in place in much of Texas (the city of Austin is an exception). Thus, there is no compensation for prosumers with solar in Texas other than the avoided energy, distribution and other charges from their own behind-the-meter consumption. Although the solar resource itself is strong due to Texas's low latitude, the low overall electricity prices and low renewable energy targets as compared with supply have largely diminished most of the incentives that potential residential solar owners need to shorten their repayment period on the solar installations.[51] So, despite consumers having opportunities to own small-scale solar generation, a lack of avenues to sell their surplus generation acts as a barrier to entry.

In Australia, 20% of current renewable energy generation is from small-scale solar PV[52] and around 20% of households in the country have installed rooftop solar.[53] However, to value these resources, only some states have mandated the use of compensatory mechanisms such as feed-in tariffs or net metering; in most states retailers may choose whether to offer a compensatory arrangement.[54] Furthermore, retailers who pay prosumers for energy injected in the grid may not always provide fair value. So, a potential rooftop solar owner has to choose a retailer that offers fair value for surplus energy injected into the grid. It often happens that retailers either offer extremely low feed-in tariffs or provide high and attractive feed-in tariffs with caveats such as extremely high retail tariffs. The prosumers have to evaluate and optimize their potential energy generation vis-a-vis consumption at different time periods and choose a retail plan accordingly. Increasingly, prosumers find it better to use the power they produce rather than sell it to the retailer.

Having said this, in Texas, the adoption of DERs is gradually rising. This includes rooftop solar but also distributed battery storage, natural gas power microgrids, energy efficiency

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[50] Geman, B. (2019, April). *Why Texas lags in rooftop solar*. Axios. https://www.axios.com/why-texas-lags-rooftop-solar-a4695e2e-4682-44f2-96d9-a1afae181a73.html

[51] Meir, B., & Thompson, J. (2019). *Abundant sunshine not enough to power Texas residential solar power*. Federal Reserve Bank of Dallas. https://www.dallasfed.org/~/media/documents/research/swe/2019/swe1901e.pdf

[52] Clean Energy Council. (2019). *Clean energy Australia report 2019*, p. 9. https://assets.cleanenergycouncil.org.au/documents/resources/reports/clean-energy-australia/clean-energy-australia-report-2019.pdf

[53] Smit, A. (2018, September). *The impact of rooftop solar on demand*. The Hub. https://thehub.agl.com.au/articles/2018/09/the-impact-of-rooftop-solar-on-demand

[54] Paxinos, S. (2019, August). *Are solar feed-in tariffs worth it?* Choice. https://www.choice.com.au/home-improvement/energy-saving/solar/articles/are-solar-feed-in-tariffs-worth-it

and demand response.[55] Similarly, in Australia the viability of battery storage would make rooftop solar an attractive proposition. This provides prosumers some leverage when injecting energy into the grid as they can provide peak time services. Battery storage also provides a lot of value as backup in these regions where heat waves tend to drive power demand up significantly, leading to prices touching the caps or outages during some periods. Retail competition may present opportunities for owners of DERs to shop around for the best value on their services. However, an appropriate policy framework is necessary to promote and compensate these resources fairly. Lack of a strong policy framework leads to resources not being valued fairly and retailers buying energy at undervalued prices.

Retail Competition and Demand Flexibility

As described earlier, time-varying tariffs can successfully enable demand flexibility, as consumers who are able to do so tend to shift consumption from peak to off-peak periods.[56] Retail competition is expected to bring even more variety and innovation in tariffs as several retailers compete for the same consumer base through innovative products. However, retail choice in most markets has not resulted in increased innovation in pricing options. Retailers may not find it profitable enough to pursue and sell a variety of products when they can sell mass market products such as flat-rate pricing. Also, there remains a wide gap between the intention of consumers to respond to time-varying prices and their actual uptake of such pricing options. Consumer education could perhaps be the most crucial determinant of success in using retail competition to drive demand flexibility.

The constraints on consumer adoption of time-varying and dynamic tariffs described in the earlier section continue to apply in a retail competition policy structure. For instance, in Australia, flat-rate pricing is preferred over any form of time-varying rates as consumers generally find these products too complicated to understand and their benefits are not necessarily visible directly.[57] There are varied opinions on the time-varying rates themselves, as consumers find peak-time rebates or simple time-of-use more attractive than more complex options such as real-time pricing or capacity pricing.[58] An option such as a peak-time rebate provides them with visible benefits at low risk since consumers do not worry about paying a higher rate but only gain if they reduce their consumption during peak time periods. The risk appetite of consumers for such products is often very low, and retailer suppliers resort to "risk relievers" such as money-back guarantees to encourage consumers to sign up.

A study by UCL Energy Institute, which reviewed the demand for time-of-use rates, revealed that the voluntary uptake for time-of-use tariffs is likely to be only as high as 43%, and this when there are strong efforts taken to educate and encourage consumers;

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[55] Shavel, I., Faruqui, A., & Yang, Y. (2019, March 28). *Valuing and compensating distributed energy resources in ERCOT* [Presentation to Texas Clean Energy Coalition]. The Brattle Group. https://3vq5kdns38e1qxlmvvqmrzsi-wpengine.netdna-ssl.com/wp-content/uploads/2019/03/TCEC-Brattle-study-DER-in-ERCOT-28-March-2019-FINAL.pdf
[56] Faruqui et al., 2012.
[57] Stenner, K., Frederiks, E., Hobman, E. V., & Meikle, S. (2015). *Australian consumers' likely response to cost-reflective electricity pricing.* Commonwealth Scientific and Industrial Research Organisation. https://energyconsumersaustralia.worldsecuresystems.com/grants/632/AP%20632%20CSIRO%20Report%20-%20Consumer%20Response%20to%20Cost-Reflective%20Electricity%20Pricing.pdf
[58] Stenner et al., 2015.

otherwise, it could fall as low as 1%. On the other hand, if time-of-use tariffs are applied to everyone mandatorily and consumers could opt out later, the uptake would be higher than 57%, going as high as 100%, if consumer education and confidence in these pricing structures remain high.[59]

In Texas, the Public Utility Commission undertakes specific communication and outreach activities through various mediums, such as telephone, web-based and in person. These aim to educate and assist residential and small commercial consumers especially about retail electricity options.[60] A dedicated website[61] in both English and Spanish helps consumers compare competitive electricity suppliers and their products while shopping for power. Customers also need to understand their own daily load shapes through the year to properly evaluate the various available products.

It is also important to keep in mind that a competitive market structure requires regulatory oversight to ensure that small consumers are not being misled into products that are not beneficial to them or may not entail all the benefits that retailers promise. The chapter on assessing these options discusses insights that policymakers in India can keep in mind.

4. Peer-to-Peer Trading With Blockchain

In the above options we have described how important it is for electricity producers, suppliers and consumers to interact amongst each other in response to prices that are reflective of costs. These interactions are necessary to take advantage of all the resources from both the supply and demand side. We have explored both a menu of pricing options that a utility can offer and a menu of retail electricity suppliers that consumers can choose from. But the retail competition proposals currently out there are still not designed for a world of low-cost distributed generation. Another option exists: allowing prosumers to sell generation themselves. This is peer-to-peer (P2P) trading.

We can envision that there will be more and more power systems where participants proactively take part in interacting with the grid by managing their load or injecting surplus generation. Distributed rooftop solar, which is already widely adopted, has the potential to lead the DER growth story, although other DERs such as battery storage, microturbines, electric vehicles and their charging infrastructure also have a part to play.

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[59] Nicolson, M., Fell, M., & Heubner, G. (2018, December). Consumer demand for time of use electricity tariff: A systemized review of empirical evidence. *Renewable and Sustainable Energy Reviews, 97*, 276-289. https://www.sciencedirect.com/science/article/pii/S1364032118306257

[60] Public Utility Commission of Texas. (2019, January). *Scope of competition in electric markets in Texas*. https://www.puc.texas.gov/industry/electric/reports/scope/2019/2019scope_elec.pdf

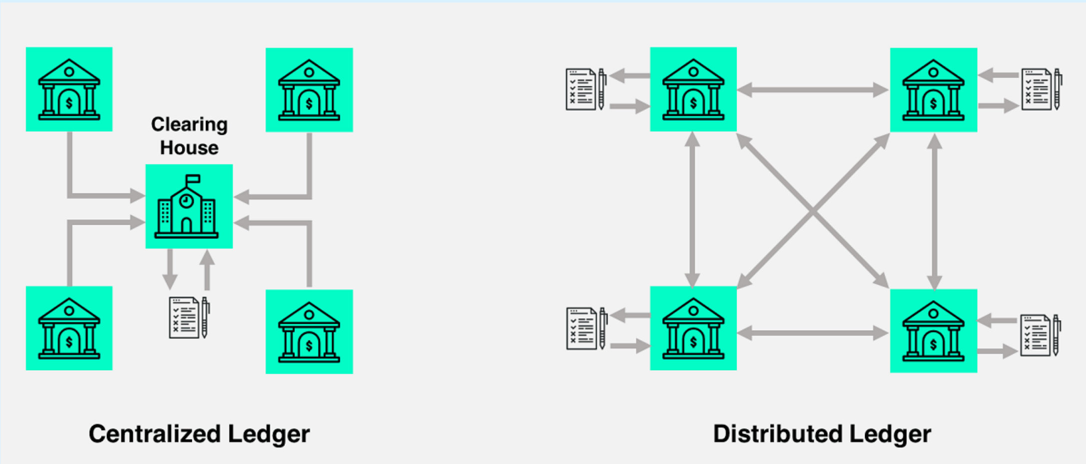
[61] Public Utility Commission of Texas. (n.d.) *Power to choose*. http://powertochoose.org

Blockchain: A distributed ledger technology

Blockchain was introduced to the world as a public transaction ledger for the cryptocurrency Bitcoin. However, over the years it has gained more popularity as a technology than Bitcoin itself. In simple terms, blockchain is a distributed ledger that records any transaction, not just monetary but of any kind of value, between two parties in a decentralized, efficient, incorruptible and permanent manner. This reduces the transaction cost to almost zero as there in no intermediary and creates a peer-to-peer network. There are several differences between blockchain and distributed ledger technology, but simply put, blockchain is a type of distributed ledger technology and has its own features. Most importantly, blockchain does not mean Bitcoin or any other cryptocurrency.

Distributed ledger technology has the potential to improve the existing retail market design as well as allow new designs to be developed, taking advantage of various resources. It takes away the need to have a central authority that validates the transactions as well as a centralized database that records all these transaction in one place. Figure 10 illustrates the difference between a centralized and distributed ledger.[62] The distributed aspect of a ledger allows transactions to be executed quickly and at a lower cost, and to be recorded at several nodes.

Figure 10. Comparison of centralized versus distributed ledger



Source: Belin, O. (n.d.). *The Difference Between Blockchain & Distributed Ledger Technology*

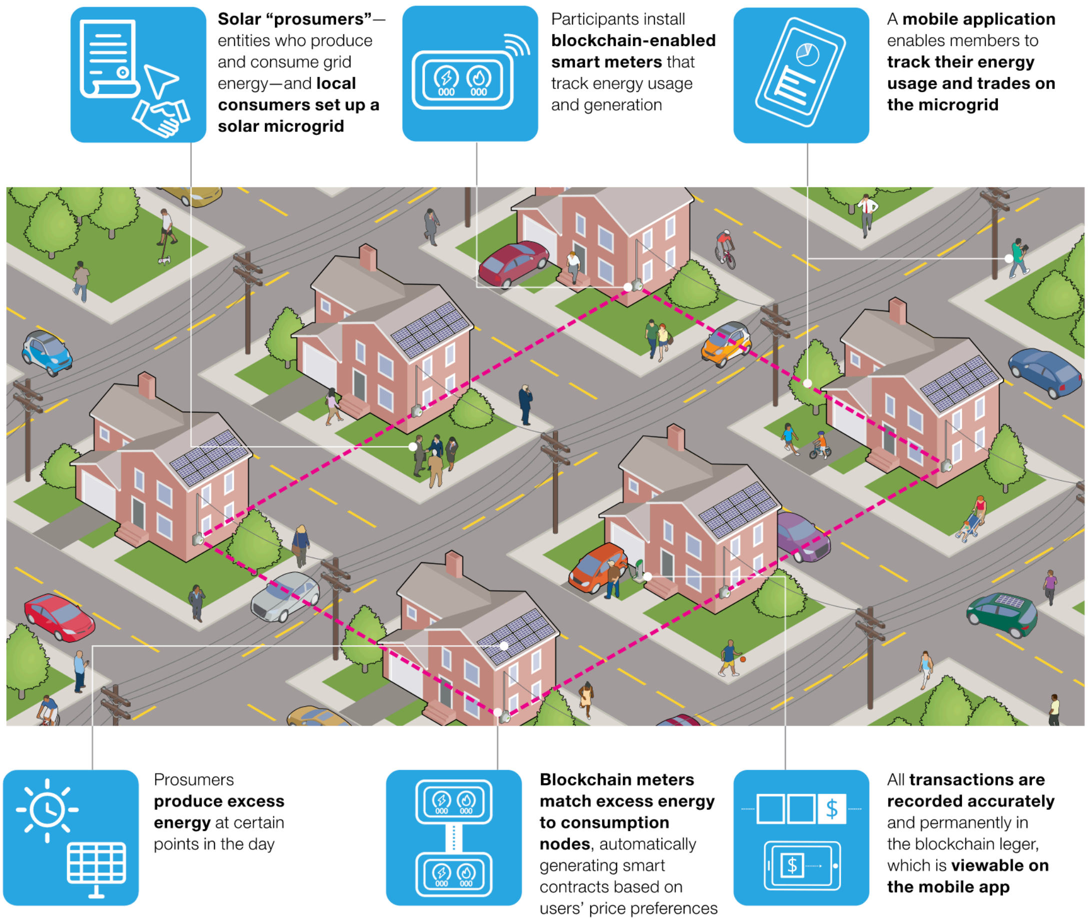
Apart from the distributed nature of blockchain, another important feature is smart contracts. Smart contracts allow users to set rules for their transactions, which makes it easier for the user to trigger the transaction in real time. For instance, a rooftop solar owner could set a condition to sell X% of their total solar generation to the market if the prices go above INR 3.5/kWh. Hence, the smart contract would be executed as soon as the price is triggered, and the prosumer would not need to worry about executing a transaction in real time. This is very useful since consumers and prosumers would not be able to track prices and trade in real time. This allows them to preset different contracts.

Transparency of data and transactions is another value proposition that this technology brings to the table. All transactions are recorded at several nodes with incorruptible properties and hence all parties can easily track the transactions. This would be mean that capturing data from different time periods, locations, systems and resources would become simple as well as secure.

[62] Belin, O. (n.d.). *The difference between blockchain & distributed ledger technology.* TradeIX. https://tradeix.com/distributed-ledger-technology

A P2P energy network can be described as a fully interconnected system of demand and supply resources that have the ability to transact directly with each other in real time without the need of an intermediary authority. This would allow providers to deliver services to the buyers in real time at prices discovered through direct trading. Blockchain and other distributed ledger technologies can provide the underlying technological infrastructure required to power these transactions in real time. Figure 11 shows an example of a potential P2P network.[63]

Figure 11. Illustrative P2P power network



A P2P network could be looked at as leaping beyond the 20-year-old notion of retail competition to a system offering customers a quantum difference in choices. We have discussed moving from buying electricity at default flat-rate tariffs, to utilities offering a variety of pricing options, to consumers choosing their retailer and selecting from a variety of products. A P2P trading system is when consumers directly transact with producers to buy electricity. This means they can not only choose the kind of power but also the exact

[63] Exhibit from "What every utility CEO should know about blockchain," March 2018, McKinsey & Company, www.mckinsey.com. Copyright (c) 2020 McKinsey & Company. All rights reserved. Reprinted by permission.

producer from whom they would like to purchase power. P2P networks can be created with more elements such as battery storage, electric vehicle charging, thermal storage or demand response programs. With a full embrace of smart meters, blockchain and Internet of Things, consumers could possibly switch off their air conditioning or start charging their distributed battery system as soon as the grid provides them with the right value. Similarly, there is no need for an intermediary to authenticate the transactions. In addition, P2P trading can take place locally or in a large system.

Currently, several such P2P programs are being tested in different markets, which can provide valuable insights. Most of these programs are still in their early experimentation phases and will develop over time. Nevertheless, it is valuable to understand their objectives, program design and variety of participants, among other things.

Quartierstrom (Switzerland)

Quartierstrom (quartier-strom.ch) is a controlled program where 37 households consisting of a few prosumers (rooftop PV), prosumagers[64] (battery storage) and consumers participate in local energy trading. The idea is to allow participants to buy or sell locally produced electricity by trading with each other directly. Consumption of local energy can help the community reduce their total costs as they do not incur the costs of transmitting power from distant power plants. Additionally, they can choose to reduce self-consumption during peak hours and instead supply to the grid where they are likely to get a higher value for their energy.

Lition

Lition, a German energy trading platform, introduced P2P trading on a much larger scale and grew its consumer base in over 100 cities.[65] Its objective is to allow consumers to get access to green power directly while promoting the producers of green energy through reduced operational and legal challenges. Consumers shop through various large-scale renewable energy producers as well as prosumers to buy power from them directly. The blockchain platform executes these deals through smart contracts directly without any intermediary. By bypassing the utilities or retailers, consumers start supporting several green producers directly while saving on their total energy costs. As per the latest numbers, consumers of Lition energy save up to 20% on their monthly energy bill while the producers receive up to 30% extra revenues.

Considerations for India

P2P trading could enable the use of locational real-time pricing for both consumption and distributed generation production (i.e., the sell rate). Moving to real-time pricing under a traditional monopoly provider or under retail competition has been complicated by the lack of enabling infrastructure, the heavy administrative burden, and — most crucially — the

[64] A consumer who produces as well as stores electricity.
[65] Picco, E. (2019, May). *Blockchain in energy use case #2: Lition.* Distruptor Daily. https://www.disruptordaily.com/blockchain-energy-use-case-lition

lack of adequate education and engagement with consumers. If — and local discussions would need to explore this uncertainty — consumers are better informed and engaged in their consumption and production through P2P trading, then it may be a valuable model to pursue.

The state of Uttar Pradesh has taken note of this emerging approach and is trying to understand its benefits and implications for different stakeholders. Papers presented at its blockchain technology conference discuss the value that blockchain or distributed ledgers can bring to the table in addressing several challenges such as efficient metering, billing and collection; reliable supply of power to rural residential consumers; peak load management by discoms; and clean energy marketplaces.[66] The value that this technology brings in terms of transparency, accountability and direct execution of transactions will be significant for India. [67] Indian Institute of Management – Ahmedabad is leading a team of six institutions[68] on a project that aims to develop information technology systems that facilitate prosumers and create decentralized, P2P transaction models for energy trading through blockchain.[69] They have collaborated with the state of Telangana to develop and deploy a pilot with a P2P platform.[70] The state government wishes to create a power system that allows consumers to trade small amounts of energy without incurring high transactional costs, which act as a barrier to higher adoption of DERs.

Assessing the Four Approaches

What might work in India for which consumers?

Context matters. International experience with the four approaches does not predict their likely success or failure in India. Robust stakeholder discussions and analyses will likely be needed to assess both the readiness and the interest in pursuing any of these options. In the meantime, however, we offer the following initial conclusions.

Enabling consumers to choose a well-designed de-averaged tariff is likely an essential component to enabling demand flexibility.

Consumer choice in tariff design could be a game-changer in India. Consumers in India, especially in the residential category, today lack the ability to choose an alternative tariff design. It is important to note that demand flexibility will emerge only if consumers are both able and interested in responding to varying system conditions. Not all consumers will be able to change their consumption or their production, regardless of the system

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[66] Uttar Pradesh Electricity Regulatory Commission. (2018, 10 October). Compendium of papers and presentations: Conference on Creation of Eco-System Using Block Chain Technology for Renewable Energy, Distributed Energy Generation and Supply. http://www.uperc.org/App_File/Compendium-pdf1010201860616PM.pdf

[67] Without the need of any intermediary to authenticate or validate the transaction.

[68] They are the Indian Institute of Technology – Gandhinagar; MS Ramaiah Institute of Technology; Florida International University; Amplus Solar; BSES Yamuna Power Ltd. and Renault Nissan Technical Business Center. Innovation Norway is the project observer.

[69] Indian Institute of Management – Ahmedabad. (n.d.) *P2P energy trading*. https://www2.iima.ac.in/p2penergy/index.php

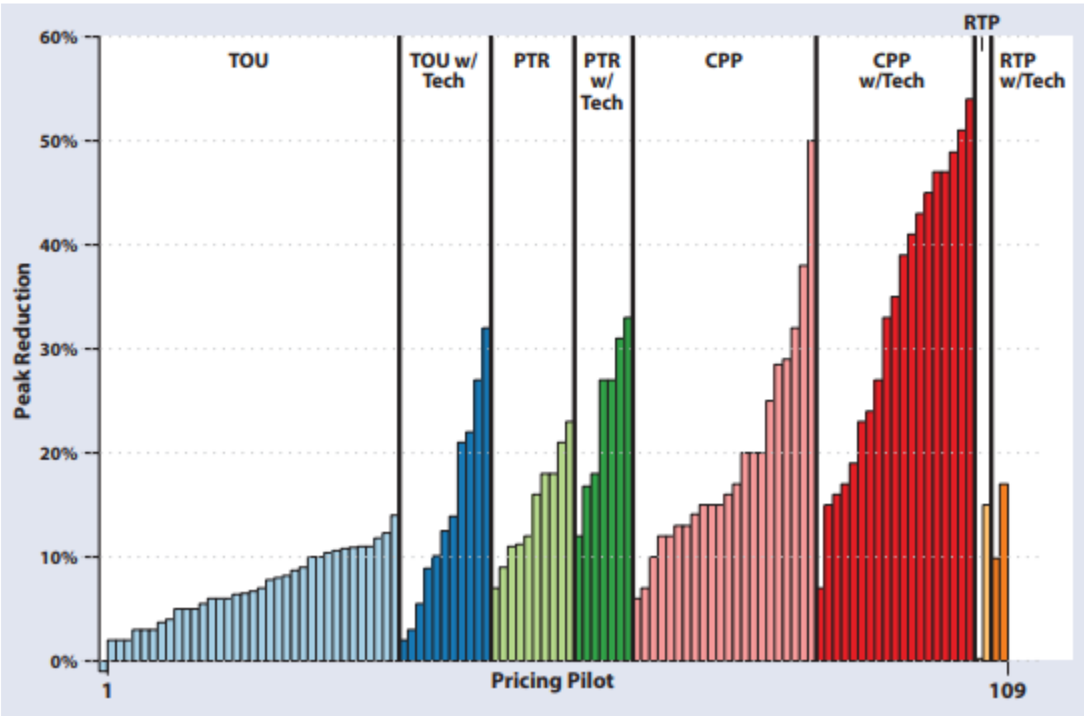
[70] Sur, A. (2019, August). Telangana government collaborates with IIM-Ahmedabad to increase transparency in power sector transactions. *The New Indian Express.* http://www.newindianexpress.com/states/telangana/2019/aug/09/telangana-government-collaborates-with-iim-ahmedabad-to-increase-transparency-in-power-sector-transactions-2016207.html

conditions or the prices they face. Some loads cannot be shifted, such as life-saving medical equipment; and some consumers will not have sufficient flexible load to benefit from de-averaged tariffs. Placing these consumers on a de-averaged tariff could be perceived as effectively forcing them to face higher electricity bills. Mandating a universal shift towards de-averaged tariffs is likely to be perceived as unfair and politically unfeasible.

However, many consumers are likely able to shift some of their demand and would do so if they perceived a worthwhile benefit. Alternative tariff designs can reveal the benefits of shifting consumption by revealing the potential savings from lower rates for off-peak consumption. Designing these tariffs effectively enough to foster consumer interest and acceptance will be crucial. For instance, evidence from other jurisdictions suggests that consumers are increasingly likely to reduce on-peak consumption as the peak-to-off-peak price ratio increases.[71]

Which designs are most effective will likely depend on consumer needs and interests. For instance, evidence from other jurisdictions suggests that residential consumers are generally more responsive to time-varying rates where they have access to enabling technology, such as automated thermostats. The importance of technology is illustrated by Figure 12.[72]

Figure 12. Enabling technology aids consumer responses to time-varying rate pilots



Source: Faruqui, A., Hledik, R., and Palmer, J. (2012). *Time-Varying and Dynamic Rate Design*

[71] Faruqui et al., 2012.
[72] Faruqui et al., 2012.

What is enabling technology?

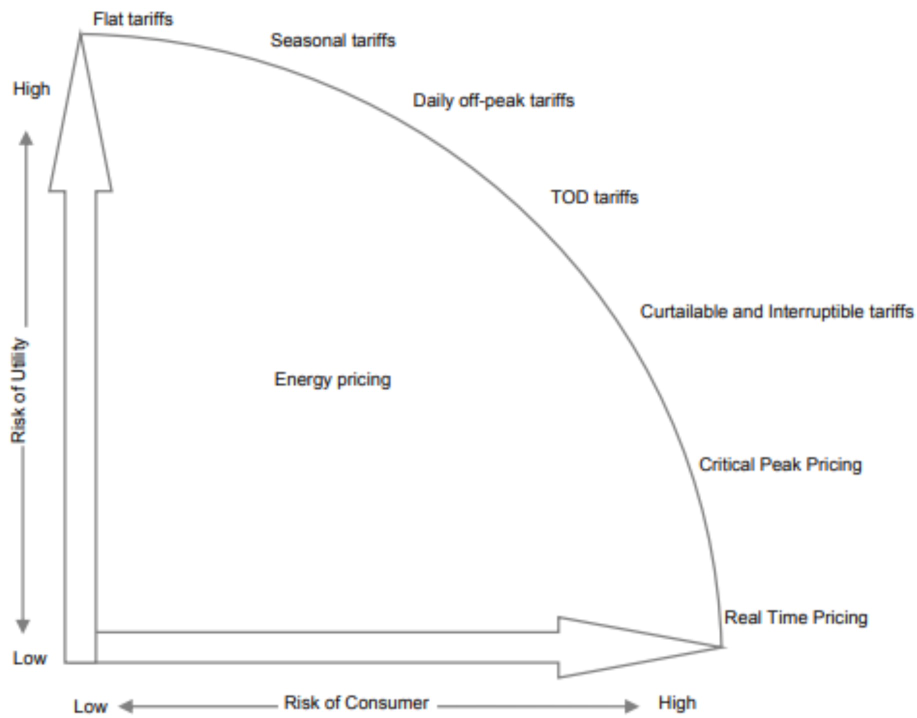
People are most familiar with smart meters that enable the use of varying retail tariff designs, but other technologies are emerging that enable consumers to benefit from varying tariff designs with minimal effort. These technologies can be as simple as automation that a consumer can program in advance. For instance, under a time-of-use tariff design, consumers might program a water heater to only power on during off-peak periods when the consumer knows that costs will be lower.

Alternatively, these technologies might be advanced enough to interact with the grid, receive real-time pricing information, and adjust consumption accordingly. For instance, a consumer might set a Wi-Fi-connected or "grid-integrated" home thermostat to keep the house between a certain range of temperatures. Under real-time pricing, the thermostat would follow prices and decide when to turn on and off the appropriate heating or cooling devices to provide the consumer's desired temperature at minimal cost. Additionally, some devices might utilize artificial intelligence machine-learning capabilities to become increasingly effective at reducing costs to consumers.

These technologies are emerging, but many remain out of reach of a significant subset of consumers. Plus, some consumers, like renters, may not have the option of installing them. As these technologies become more widely used and available, they will facilitate consumers' ability to pursue the potential rewards of varying electricity prices while minimizing the risks consumers face.

Enabling technology can reduce some of the financial risk that consumers face on de-averaged tariffs. This risk exists because of the possibility that a consumer will not shift consumption, either voluntarily (but perhaps forgetfully) or involuntarily. A consumer who unwittingly consumes power during a peak time could pay a high cost on a real-time pricing tariff but would not pay nearly so high a cost on a flat-rate tariff. Figure 13 illustrates how different tariff designs may pose more or less financial risk to consumers.[73]

Figure 13. Different tariff designs may pose more or less risk to consumers

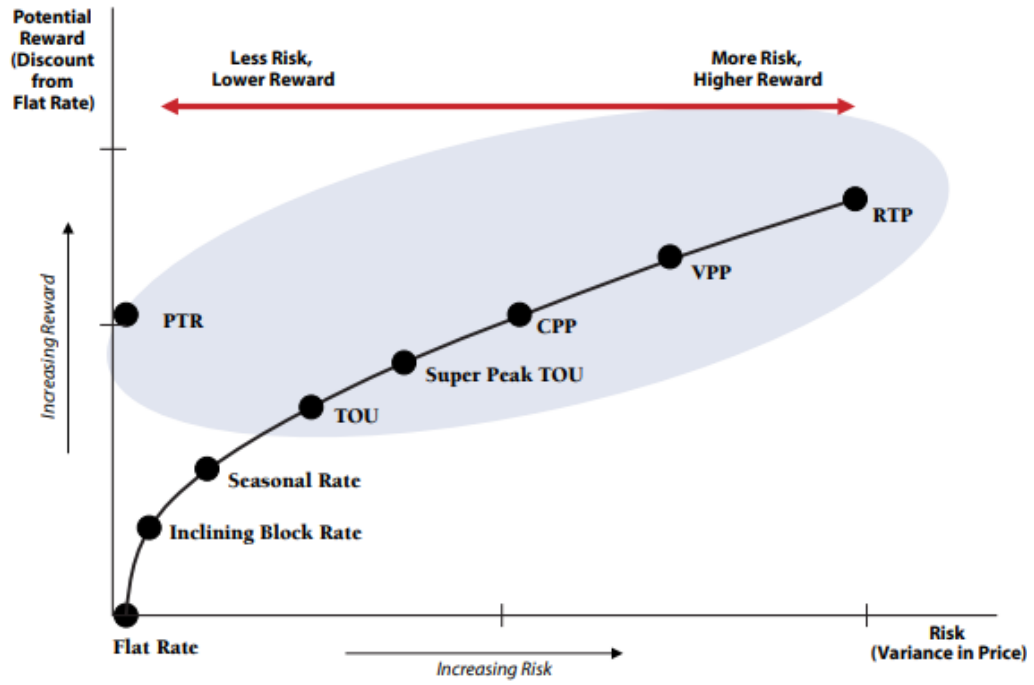


PricewaterhouseCoopers India Private Ltd. (2010). *Assignment on Implementation & Impact Analysis of Time of Day (TOD) Tariff in India.* Forum of Regulators

[73] PricewaterhouseCoopers India Private Ltd., 2010, p. 5.

Without enabling technology, some residential consumers are likely willing to adopt a low-risk tariff, such as a time-of-day tariff, but less likely to adopt a high-risk tariff, such as real-time pricing. Consumers are unlikely to adopt any new tariff unless they see potential benefits. Figure 14 offers a different view of the riskiness of different tariff designs to consumers by contrasting it with the potential reward they could enjoy from different tariff designs offering increasingly low off-peak prices.[74]

Figure 14. Conceptual representation of the risk-reward tradeoff in rate designs



Source: Faruqui, A., Hledik, R., and Palmer, J. (2012). *Time-Varying and Dynamic Rate Design*

Peak-time rebates are noticeably less risky to consumers, as they operate only as a reward and never as a penalty. However, peak-time rebates may not be as effective unless existing tariffs are increased from their current low levels in many states, providing an incentive to reduce consumption and value the rebate. A pilot program or study would be helpful in clarifying the potential for this approach especially as proving a negative is particularly hard where little data is available. Discoms might find it difficult to ascertain whether a consumer truly reduced consumption.

While the evidence suggests that generally customer response increases as rates become more de-averaged, this may not be true in every instance. Figure 12 above illustrates the consumer response for each different pilot program studied under the respective rate. Note that every pilot program demonstrated a consumer response. However, the real-time pricing pilot programs noted in this figure did not show the same magnitude of response as some of the other rates. This may be due to various factors; for instance, the response shown could be under-stated by a pilot program

[74] Faruqui et al., 2012.

having a shorter length than others illustrated.[75]

Different consumers will have different appetites for risk. However, as tariffs become more de-averaged, the risks of inflexible demand that are currently imposed on discoms (and ratepayers as a whole) will decrease. Therefore, there are benefits to enabling consumers — even a subset of consumers — to adopt de-averaged tariffs. The best way to target the consumers who both can and would respond to new tariff designs is likely to let them choose themselves to be billed under a new tariff design option. Substantial consumer engagement will likely be instrumental to making these consumers aware of their ability to choose a new tariff once tariff choice emerges.

Consumer choice could be powerful, but it may be that adopting a mandatory de-averaged tariff for all consumers becomes worthwhile. As more variable renewable energy sources come online, the need for increased demand flexibility may necessitate placing more consumers on a time-varying tariff than those who voluntarily opt in to one. In California, the regulatory commission mandated the investor-owned utilities move towards default time-of-use rates for almost all residential consumers because it found the benefits to consumers convincing and the adoption rate under the optional tariffs unacceptably slow.[76]

> "For a default [time-of-use (TOU)] rate to be successful, the design should be based on empirical evidence that supports both measurable benefits of TOU on the grid, and the acceptance and understanding of TOU rates by the residential customer."
>
> ***— California Public Utilities Commission***[77]

As a starting point, offering consumers the choice of de-averaged tariffs appears to be an effective and feasible approach. If necessary, default de-averaged tariffs could be implemented several years down the road, after consumers have become acquainted with the tariff designs and have had a chance to reorient their consumption patterns.

Reforming compensation tariffs to reflect system costs is crucial to guiding investments in rooftop solar and other distributed generation.

De-averaging compensation tariffs to reflect system costs can also deliver substantial benefits to the power sector. Utilizing distributed generation can avoid investments in expensive generation as well as in distribution and transmission infrastructure while reducing technical losses. Revealing the variation of these avoided costs through de-averaged tariffs could encourage consumers to invest in the places and forms of distributed generation that can offer the greatest value to the system (and therefore the greatest compensation to the consumer). This benefits the discoms, especially if consumers with tariffs lower than their cost of supply pursue DERs. The utility itself or in partnership with an energy service company could drive these investments.

The political barriers to de-averaging retail tariffs are less likely to hinder de-averaging compensation tariffs. Some continuity seems fair for consumers who have already made

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75 Faruqui et al., 2012.

76 California Public Utilities Commission. (2015, 3 July). D1507001 Decision on Residential Rate Reform for PG&E, SCE, and SG&E and Transition to Time-of-Use Rates. http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M153/K110/153110321.PDF

77 California Public Utilities Commission, 2015.

investments. But investors have less justification than consumers to expect tariffs to remain constant. The value of a commodity varies, and most sellers understand that.

Changing compensation tariffs might require more than changing the compensation levels, however. The metering and billing arrangements may also need to be changed. Most states in India offer net metering today; net metering often applies with only a flat-rate or time-of-day tariff. Dissatisfaction with this approach has already led some states to adopt gross metering policies. However, gross metering is not a panacea. If the compensation rate is lower than the retail rate, it may encourage illegal wiring as prosumers seek to avoid paying the higher retail rate by self-consuming.[78] The potential for gaming and the ease of enforcement are important considerations when setting different retail and compensation rates.

The third option for metering and billing arrangements, namely net billing, has not received much attention in India. However, net billing could enable the adoption of highly de-averaged compensation tariffs — perhaps even real-time pricing — with less risk of gaming than under gross metering. This is, however, a hypothesis. Whether net billing could work more effectively than gross metering is uncertain at this point. Further studies and greater data are required.

Competitive markets promise good opportunities but adequate policy support and oversight is important.

Introduction of competition in India's power distribution sector is expected to alleviate several problems that exist presently. It is expected that retail competition will improve technical and operationally efficiency as well as optimize power procurement as these two functions will be handled by different entities — i.e., the distribution company and retail supplier, respectively. Consumers, as a result of competition, could benefit from lower prices, innovative products, better quality of service, etc.[79] While such deregulation has the potential to achieve the above, it is important to be aware of the risks associated with it. The transition towards competitive markets needs to be extensively thought through, keeping in mind the vulnerabilities of stakeholders, especially consumers. For instance, consumer advocates in the United States, Australia and other markets have often strongly voiced their opinion against retail electricity suppliers or third-party suppliers that engage in marketing activities that take advantage of the information asymmetry to mislead consumers.[80]

Focusing on the experience of other deregulated markets, we observe that competition alone is unlikely to deliver on objectives for better demand flexibility or adoption of DERs such as rooftop solar. As discussed earlier, consumers require a lot of education

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[78] Zinaman, O., Aznar, A., Linvill, C., Darghouth, N., Dubbeling, T., & Bianco, E. (2017, October). *Grid-connected distributed generation: Compensation mechanism basics*. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy18osti/68469.pdf. Electricity theft is a persistent problem in India, although the evidence does not strongly implicate above-cost consumers.

[79] Forum of Regulators and PricewaterhouseCoopers Private Ltd., 2015.

[80] See Silber. C. (2019, February). Eliminate third-party electricity suppliers, officials urge. *The CT Mirror*. https://ctmirror.org/2019/02/04/eliminate-third-party-electricity-suppliers-officials-urge; and Australian Competition and Consumer Commission. (2018, June). *Alinta Energy misled consumers on discounts*. https://www.accc.gov.au/media-release/alinta-energy-misled-consumers-on-discounts

and awareness to ensure that they understand the benefits of time-varying rates to voluntarily adopt them. Commercial and industrial consumers, given their ability to deploy resources to understand and shop for the best products, are more likely to purchase electricity at better rates. On average across the 14 jurisdictions in the United States with retail choice, 85% of C&I consumers get their electricity from retail suppliers and they engage with the market frequently.[81]

On the other hand, residential consumers are less likely to be equipped to understand and evaluate the information related to the risks and benefits of the various products available as easily as C&I consumers. Furthermore, in the process of searching and evaluating products, doing the necessary paperwork involved in switching and termination fees, small consumers may find that the transaction costs of switching suppliers are higher than the potential benefits that they would realize.[82] This would discourage them from actively engaging with the retailers and nudge them to stick to their existing retailer. Moreover, retailers themselves are more likely to pursue large C&I consumers with time-varying rates given the large individual load profiles of C&I consumers, which can vary from the average load profiles,[83] and their ability to value such products more easily than residential consumers.

Having said this, Indian policymakers must keep in mind that competitive markets elsewhere were not necessarily designed to achieve specific objectives such as enabling demand flexibility and facilitating DER adoption. These experiences may therefore not necessarily tell us that retail competition does not achieve these objectives, but only that competition alone may not lead to expected outcomes. There are additional policy measures needed to guide the market towards the socially optimal outcomes. First, it is crucial to protect the interests of consumers, especially small consumers, from unscrupulous practices of retailers that may increase in a deregulated market structure. In addition, to ensure residential consumers understand and adopt time-varying rates, it will be important to educate and equip them with tools that help them make informed decisions.

There are always trade-offs present between options. Competition is likely to bring benefits such as operational efficiencies, innovation in products and better power procurement, but it also opens up several avenues for businesses to pursue their profit maximization targets at the cost of consumers. Regulated monopoly utilities may not have the same incentive to engage in false marketing and baiting consumers the way competitive retailers have been known to. Indian policymakers must keep this in mind and look to the experience of other regulatory authorities such as the Telecom Regulatory Authority of India or the Securities and Exchange Board of India that provide good precedents in protecting the interests of consumers against malpractices by businesses. Additionally, regulators should interact

[81] Littlechild, S. (2018, February). *The regulation of retail competition in US residential electricity markets*. Energy Policy Research Group, University of Cambridge. https://www.eprg.group.cam.ac.uk/wp-content/uploads/2018/03/S.-Littlechild_28-Feb-2018.pdf

[82] Morey, M., & Kirsch, L. (2016, February). *Retail choice in electricity: What have we learned in 20 years?* Christensen Associates Energy Consulting LLC. https://hepg.hks.harvard.edu/files/hepg/files/retail_choice_in_electricity_for_emrf_final.pdf

[83] Littlechild, 2018.

with consumers through the appropriate channels to understand and assess their engagement with the market and ensure that consumers are able to voice their concerns.

Targeted programs will be necessary to ensure that consumers without flexible load are not left behind.

As noted above, not all consumers will be able to respond to de-averaged pricing. And, as discussed, not all consumers have the ability to invest in distributed generation, no matter how favorable the compensation tariff may be. Targeted programs will be essential to enable these consumers to benefit from and offer benefits back to the changing power sector. Which targeted programs will be most effective or most needed is a question beyond the scope of this paper. We are certain, however, that targeted programs are critically important and need to be pursued.

Peer-to-peer trading offers substantial promise, but further research is needed.

P2P interaction in energy is still blooming as a concept and regions around the world are trying to experiment with it. The motivation behind exploring a P2P system can be ascribed to the possibility of a future where "generation drops to kilowatts and generation itself moves to rooftops or closer to consumption, requiring near zero transaction costs to make balancing and settlement worthwhile."[84]

P2P trading promises to open up new avenues for different consumers that have to be explored and evaluated further. Large C&I consumers can take advantage of rooftop solar, thermal storage, battery systems etc. and the heterogeneity in demand amongst them to transact on a decentralized platform. For instance, commercial parks or special economic zones (such as the Maharashtra Industrial Development Corp.) could have a platform where they transact directly to take advantage of distributed resources and flexibility in consumption. The demand of large consumers such as C&I tends to be price elastic,[85] which allows them to explore different ways to shift their consumption, sell energy to the grid during peak hours or store energy during off-peak periods. This can be operationalized in real time without the need for an intermediary through decentralized platforms based on distributed ledger technology.

P2P platforms with business models like Lition can allow residential consumers to take advantage of cheaper and cleaner power available in the grid by contracting directly with distributed generation producers without any conventional transaction costs associated. Consumers can also benefit from smaller P2P platforms that allow prosumers to trade their generation directly with other consumers rather than selling it to the utility. Indian regulators and other stakeholders, as in other countries, will have to implement several pilots to evaluate the value that business models based on such technology can bring to consumers and the grid. The different use cases reveal potential benefits such as process

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[84] Shipworth, D. (2018, March). *Peer-to-peer energy trading using blockchains*. DSM Spotlight. http://www.ieadsm.org/wp/files/March2018_revised_Ver4.pdf

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efficiencies, better accountability and transparency, reduced transaction costs and more. However, improved metering infrastructure and other smart devices could be an important prerequisite to using this technology effectively for better demand flexibility and providing DERs with a platform for trading their energy.

Lastly, as the discussion around P2P trading and distributed ledger technology in energy picks up, it is important for policymakers and regulators to allow experimentation with different business models and system designs before developing any policies and regulations. Early adoption of a particular model should not kill the drive to experiment and develop other innovative models. The energy sector will need to understand how use of this technology impacts the role of discoms, regulators, the grid or consumers.

Conclusion

The four approaches show great potential in promoting demand flexibility and clean distributed energy resources, but further analyses at more local levels are needed to nail down the correct solutions.

The transition to low-cost renewable energy can provide significant benefits to India, its people and its discoms. Flexible resources that can follow the variable output of renewable resources will be needed. Enabling demand flexibility and offering fair compensation for services from distributed energy resources, such as rooftop solar, will be necessary to achieving the transition in an affordable manner.

Various options exist to meet these two objectives and facilitate the overarching transition. These include targeted programs, alternative tariff designs and market structures as well as upcoming models like P2P trading through new technologies. These options are not mutually exclusive. Proceeding simultaneously with different options may serve to accelerate the velocity towards an affordable transition.

Which approach or approaches work best for which consumers is an open question. In this report, we have projected the outcomes from each. But what is clear is that further study at more granular levels is critically needed. For instance, a change in tariff design may be needed in multiple jurisdictions, but some consumers may be more interested in and responsive to different alternative tariff designs. Pilot programs will likely be needed to identify the optimal choice for a given consumer group. Further, analyses of consumer interest and responsiveness are needed to identify which consumers can most benefit and add value through participation in retail choice markets as well as targeted programs. There is no one-size-fits-all solution.

It has become increasingly obvious that as the financial indebtedness of discoms rises, change is urgently needed not only to improve the distribution sector but to maintain its role as a driver of the overall economy as well as individual livelihoods. The options presented must be explored further at the central and state level to ensure that policy-makers and regulators can incorporate the priorities and needs of different consumers while progressing towards the common goal. It is our hope that this report serves as the first step towards robust discussions and deep exploration of these options so that progress can be made towards achieving the affordable, clean and reliable power that India needs.

Energy Solutions for a Changing World

Regulatory Assistance Project (RAP)®
Belgium · China · Germany · India · United States

50 State Street, Suite 3
Montpelier, Vermont 05602
USA

info@raponline.org
raponline.org