Powerledger

ISGF
India Smart Grid Forum

IEX
INDIAN ENERGY EXCHANGE

OPPORTUNITIES FROM ENERGY MARKET REGULATORY REFORMS IN INDIA

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Executive Summary

Meeting the target of 24.61% for Solar Renewable Purchase Obligations (RPOs) by 2030 has become one of India's most pressing energy challenges, as the utilities continues to struggle in this area. Although the ground-mounted solar capacity addition has witnessed unprecedented growth, the growth rate in addition of roof-top solar capacity has been slow due to various factors. This prompted the government, in February 2023, to extend the deadline till 2026 because it was recognised that the existing mechanisms in place were insufficient to meet the targets. Regulators in India have sought to stimulate the installation of variable renewable energy (VRE) through net and gross metering tariffs as well as Central Financial Assistance (CFA) subsidies. This has not resulted in the expected uptake of solar capacity, mainly due to low feed-in tariffs and unattractive yearly returns from the current market model for prosumers.

The successful implementation of several peer-to-peer (P2P) energy pilot projects in India has demonstrated the effectiveness of P2P energy trading as a superior market model for promoting the adoption of rooftop solar. Furthermore, the integration of batteries into P2P energy trading offers a solution to address supply and demand imbalances at the local level. Recognising the significance of P2P energy trading in promoting rooftop solar, the regulator of Uttar Pradesh has approved a new set of regulations to facilitate the seamless integration of Rooftop Solar (RTS) with the grid.

By connecting this regulatory change in Uttar Pradesh with the broader energy landscape in India, the Consortium of Indian Smart Grid Forum (ISGF), Indian Energy Exchange (IEX), and Powerledger are releasing this paper hoping that blockchain-based P2P energy trading can assist in addressing the above-discussed issues. The report aims to provide insights on the following key aspects:

- Why is P2P energy trading a superior alternative to incentivise rooftop solar?
- How can the addition of batteries in P2P energy trading help stabilise the grid and avoid infrastructural costs?
- What are the financial benefits of P2P energy trading for DISCOMs?
- How can blockchain address DISCOMs' demand for efficient, secure, and transparent systems to track and trade electricity?

While gross metering does not promote the installation of RTS due to low feed-in tariffs, the rules around net metering for the credited export threshold every month as well as the settlement at the end of the year essentially limit solar installation to just about meeting slightly more than sanctioned loads. In comparison, P2P trading offers a financially attractive model for both prosumers as well as consumers in the domestic and C & I segment, besides benefitting the DISCOMs when net metering customers switch to P2P. Further, Government subsidies, which are presently disbursed to install RTS, can be avoided.

Following the successful implementation of P2P energy trading in the Uttar Pradesh project, ISGF and Powerledger have been receiving overwhelming interest from multiple distribution companies (DISCOMs) across different states in India. These DISCOMs are keen to replicate similar projects in their respective regions. The regulatory change in Uttar Pradesh has created an opportunity for us to showcase the benefits of P2P energy trading not only in Delhi but also in several other Indian states, including Gujarat, Haryana, West Bengal, Karnataka, Telangana, Maharashtra, Andhra Pradesh, Madhya Pradesh and Rajasthan, and even international electricity markets beyond India.

In light of the findings presented in this report, we earnestly anticipate and greatly appreciate the cooperation of regulators in other Indian states in providing the necessary regulatory framework. This framework would enable DISCOMs to effectively validate and realise the numerous advantages of blockchain-based dynamically priced P2P energy trading for all stakeholders involved (see Appendix 1 for details on some stakeholders involved in our studies and their goals and objectives).

1. Introduction

As you may know, the electricity regulator of Uttar Pradesh has approved a new set of regulations to permit Rooftop Solar (RTS) to operate in a more integrated way with the grid. Delhi is contemplating similar changes.

Although you could see this as a small tweak to a fully mature energy system, to allow the 'small players' in, there is no doubt that the regulation changes being discussed here are the foothills of a much broader landscape. This is nothing short of the beginning of a transformation to a distributed way of generating and consuming electricity.

The connection between the small tweaks and the broader landscape will become apparent later on in this document.

This document was the result of close work between us at ISGF, Powerledger, energy regulators, and IEX. We are grateful for the very high level of attention to detail, thoroughness, and innovation that they brought to the task.

Having recast the regulations for Uttar Pradesh in small but significant ways, we see an opportunity for a similar approach in Gujarat, Haryana, West Bengal, Karnataka, Telangana, Maharashtra, Andhra Pradesh, Rajasthan, and indeed international electricity markets outside of India.

Before we present you with our views and analysis on re-regulating the electricity market, we thought it would be helpful to hear how the Uttar Pradesh regulator approached it in their own words.

This preface details what Mr. RP Singh, the former chairman of the Uttar Pradesh Electricity Regulatory Commission (UPERC), saw as the motivation, the opportunity, and the insights and breakthroughs that came up during the process.

2. Foreword by Mr. RP Singh, Former Chairman, Uttar Pradesh Electricity Regulatory Commission: Motivation for the New Rules in the Uttar Pradesh Power Sector

"As a regulator, we are responsible for the promotion of Renewable Energy (RE) in the distribution licensing business. But at the moment, the penetration of Roof Top Solar (RTS) in the state is not that high, and there is clearly a potential for it to be much higher.

A certain group of consumers falls into one of two categories: subsidised, or those who receive subsidies, such as agricultural or domestic consumers, and subsidising or those who provide subsidies, such as commercial and industrial entities. In our state, the subsidised group is included under the net metering system, while the subsidising group, specifically commercial and industrial (C&I), operates either under the net billing system or the gross metering system. The difference in tariffs between these systems allows for potential energy transactions between those who produce and consume energy, referred to as prosumers, and consumers who are subject to higher tariffs.

So we decided to see if we could engineer a win-win situation for all players and develop the right framework. We didn't see it as a zero-sum game.

The challenge was to see if we could do this energy challenge in a very transparent and reliable way.

We also were interested in using blockchain as a tool. Many countries use blockchain for P2P transactions in various sectors. It is an interesting technology which is often confused with cryptocurrency (and not in a good way) when it is something quite distinct, but we thought, 'Let's see how it performs'.

At UP, we have a slightly different load profile from other states. There is less load during the day and more during the evening, due to a higher proportion of domestic and a lower proportion of commercial and Industrial (C&I).

That profile means we want to encourage battery use, reduce the export of power from the grid during the day, and have the energy for when we need it during the evening. This diurnal pattern was a consideration too. Our regulatory structure is designed to encourage BESS investment.

The biggest barrier we wanted to overcome was apprehension coming from our distribution license holders. They are providing the wires, the billing and the infrastructure for the whole enterprise. And they were *worried that they were going to have their margin eroded, so it was important to keep in mind that they shouldn't lose out. Getting the price right is critical to them and indeed the success of the whole initiative.*

The success metric will be how many consumers and prosumers come forward to get involved in the market. There are other states with more prosumers and consumers than us, and they will be watching us to see what happens, but certainly, the increase in prosumers and consumers will be a key metric.

Looking back at the work we accomplished in providing the new regulations, perhaps the most surprising and significant insights arose when we contemplated different scenarios that could occur. One particular one that came up, was when we wanted to think about the management of electricity, was when something was promised by prosumers, but then not delivered.

We found the best way to think about it was in the same way as we deal with the problem at a higher level in the grid: deviation in dispatch from the schedule, settlement, and so on. That was one of the most surprising insights that came out of our work; that the small can replicate the big.

This arrangement brings with it for the seller, the need to avoid a penalty for non-delivery, which in turn opens up the incentive to invest in batteries, which is how grid infrastructure can get built bottom-up. India has set a target of installing a BESS capacity worth 47.2 GW by 2030 to provide "round-the-clock power to end-consumers". It will be interesting to see if these particular regulations help achieve that.

The other aspect that I find intriguing is the possibility of the emergence of a genuine market. Instead of a system clearing price, which is effectively fixed by an exchange-based algorithm, we have something much more genuine: A price arrived at mutually by two independent entities, a buyer and a seller. Their price will almost certainly not be the same as when it is just one-sided, so we have the exciting prospect of a genuine market arising.

Our ambition is ultimately to grow the RTS level by a factor of 3 over the next five years, and we are hopeful we will be able to achieve that along with our goal of 21% solar renewable purchase obligation by 2030. There are also the national ambitious goals of 500 GW of renewable energy by 2030 and the BESS capacity I mentioned earlier.

We are hopeful that we will have a positive impact on the state power sector. The proof of our work will be in the metrics achieved. Time will tell. In UP, we will of course be watching our neighbouring states to see the changes they bring and the conclusions they come to. Thus far, I have found it an exciting journey, and I look forward to seeing the results that extend the trials into something yet more concrete."

Mr. RP Singh, Former Chairman, UPERC, Uttar Pradesh

3. Who We Are, Our Consortium, and What We Would Like to Achieve in the Long Term

The Consortium of India Smart Grid Forum (ISGF), Indian Energy Exchange (IEX) and Powerledger have released this paper to discuss the importance and benefits of P2P energy trading to secure India's energy future.

ISGF and Powerledger have undertaken several P2P energy trading pilots in India, demonstrating successfully the benefits gained through P2P energy trading (see Appendix 2: Case Studies for additional details).

ISGF, established as a Public-Private Partnership initiative of the Government of India, is spearheading the mission to accelerate electric grid modernisation and energy transition in India by researching and studying evolving technologies related to the energy transition, smart cities, and electric mobility relevant in the Indian context.

IEX (Indian Energy Exchange) is India's premier energy marketplace, providing a nationwide automated trading platform for the physical delivery of electricity, renewables, and certificates. IEX has a robust ecosystem of 7,300+ participants located across 29 States and 5 Union Territories comprising 55+ distribution utilities, 600+ conventional generators, and 1,800+ RE generators and obligated entities.

IEX is interested in offering transactive and P2P energy trading to their clients, as an extension of wholesale market trading services. IEX aims to establish transparent and efficient energy marketplaces for delivering affordable, reliable energy to consumers by leveraging technology and innovation.

Powerledger's software platform has a proven track record of enabling transparent, secure, and efficient trading of energy and environmental commodities. Powerledger has formed technology partnerships with more than 20 clients in 10 countries, including large multinational corporations and government entities.

Together, the consortium intends to promote the adoption of P2P energy trading as a way to cost-effectively achieve RTS targets in India.

4. The challenges of increasing renewables and the role of P2P trading:

Problems in Increasing Renewables via Government Subsidies, Price Distortions, Excess Energy: The Time and Place Problem and What Peer to Peer (P2P) Trade can Provide

For the past two decades, regulators globally have sought to stimulate the installation of variable renewable energy (VRE) resources through the use of feed-in-tariff subsidies. Such price signals have resulted in an indiscriminate increase in VRE at locations far away from load centres. Grid operators have had to supplement energy from traditional and dispatchable sources and upgrade grid infrastructure to address spatial separation and send electricity to where there is demand. This is the place problem.

Until now, comparing only the unit cost of generation or the Levelized Cost of Electricity (LCOE) has been the deciding factor to build VRE assets. While the LCOE could be lower for VRE assets compared to traditional energy sources, the Full Cost of Electricity (FCOE), including capital expenditure for network infrastructure due to random deployment of VRE and grid balancing cost, could be much higher.

In markets that have taken this feed-in-tariff approach - the subsidies, high per-unit cost of intermittent dispatchable power, and CapEx on networks have collectively resulted in expensive electricity. See Figure 1 below from IEA showing the strong correlation between spending on renewable energy and spending on networks, due to blunt price signals.

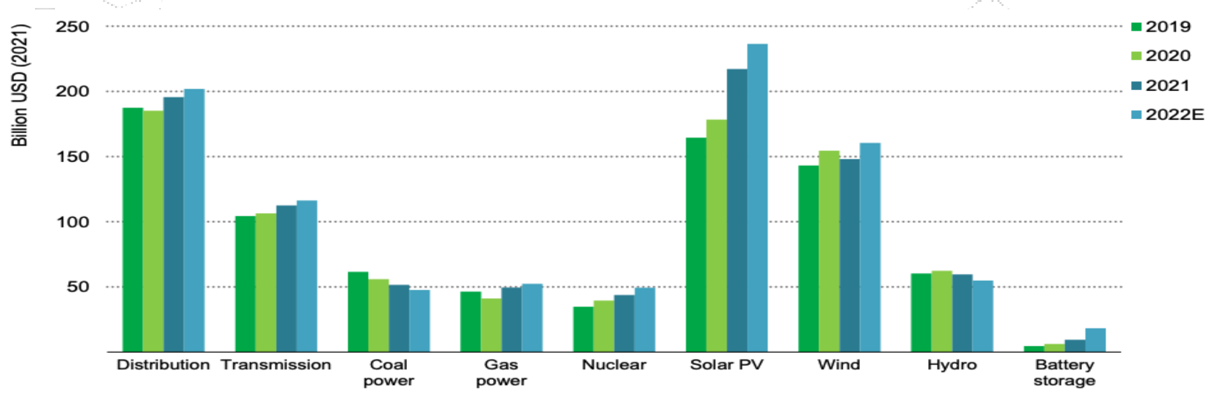

Figure 1: Global annual investment in the power sector by technology, 2019-2022E, **Source:** International Energy Agency

The following graph further illustrates the consequences of the use of blunt price signals to stimulate VRE: Demonstrating that there is a strong positive correlation between VRE penetration and high electricity costs.

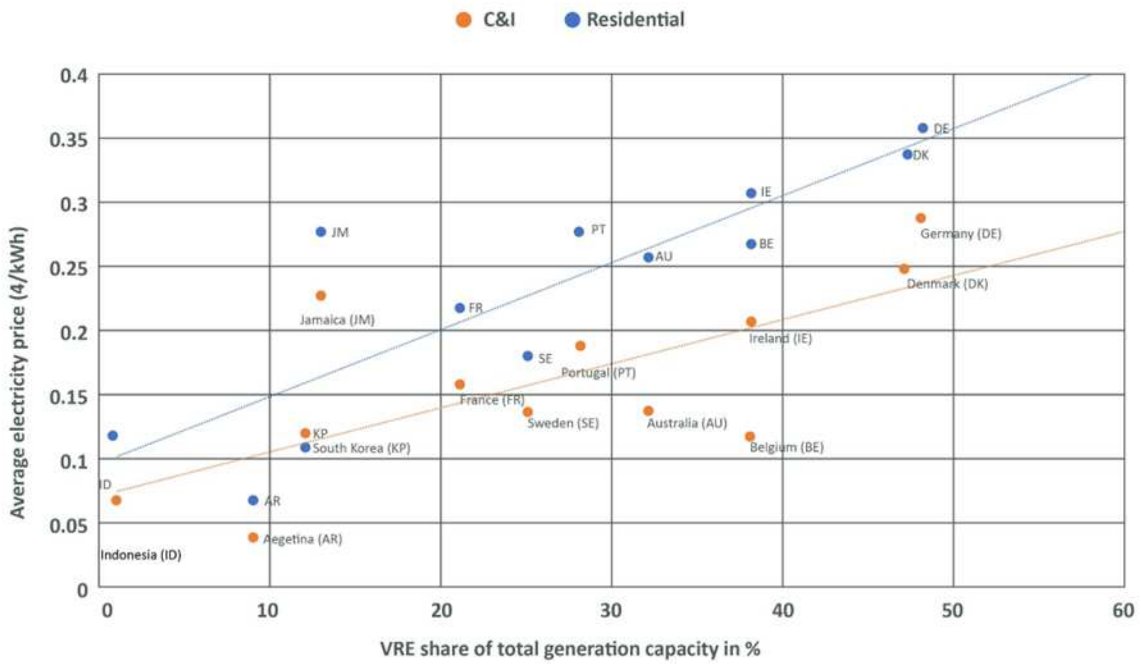

Figure 2: Average residential and C&I price in different countries, **Source:** Authors, Average retail price vs VRE generation capacity - Network upgrades to solve the time and space problem

P2P energy trading offers a superior approach to fostering renewable energy expansion by enabling the development of renewable sources closer to consumers, effectively tackling the geographical challenge created by feed-in tariffs. By facilitating direct transactions between energy producers and consumers, P2P trading incentivizes the establishment of renewable energy projects in proximity to demand, reducing network spend, optimising efficiency, and reducing transmission losses.

Distributed renewable generation, traded P2P, can help grow VRE without the high costs observed in other countries, as seen in Figure 2 above. P2P trading provides a way to achieve RE targets by using more dynamic market mechanisms to incentivise RTS, reducing the need for cross-country energy transfer.

P2P trading with RTS can efficiently address the time and place problem. Sharing of energy through P2P trading significantly contributes to addressing the growth of renewables efficiently in the following ways:

- Prosumers recover RTS installation costs through reduced electricity bills from self-consumption during daylight and selling excess solar energy to the grid at either the FiT rate (as in the case of as GM

- gross metering) or at retail energy price (as in the case of NM - net metering). GM prosumers can sell excess energy at P2P prices higher than the FiT, and NM prosumers can trade with C&I consumers at rates lower than the C&I retail price. Hence, P2P trading can yield higher revenue than GM or NM for all prosumers.

- Generally, consumers will pay a higher retail price for energy as wholesale energy prices rise due to various factors, such as inflation. P2P trading offers an optimised solution to all consumers by purchasing energy at a lower rate than the retail rate, reducing dependence on rising wholesale prices.
- The P2P marketplace has no barriers to entry for C&I consumers who want to buy renewable energy but who do not intend to install RTS or batteries. They benefit from the opportunity to purchase green energy at a lower cost than the price they would pay for energy bought from DISCOM, without having to invest in RTS.

See Appendix 2 for case studies on P2P. The following chapter discusses how both the time and place problems combined can be addressed using batteries.

5. Peer to Peer (P2P) Trading with Energy Storage: Local Energy Markets (LEMs) are Micro to Support the Macro

A few years ago when P2P trading was being experimented with; it was discovered that by including batteries, it could reduce troughs/peaks. The Pebbles Project in Germany was one such experiment. Pebbles used P2P trading with batteries to balance the supply and demand of energy at local nodes.

P2P energy trading, which includes Rooftop Solar and Battery Energy Storage System, is referred to as local energy markets or LEMs.

Excess solar energy charges the batteries of peers during sunny hours, which would then be discharged during peak load hours in the evening/night. This reduces the energy transfer to and from the superior grid and thereby reducing network violations and improving the power quality. Figure 3 below represents the impact of LEM trading on the grid exchange with the wider grid. Schema A refers to a business-as-usual (BAU) scenario with consumers and prosumers (solar PV). Schema B extends Schema A with prosumers owning a BESS for self-supply only. In Schema C, the prosumers' BESS are operated by the

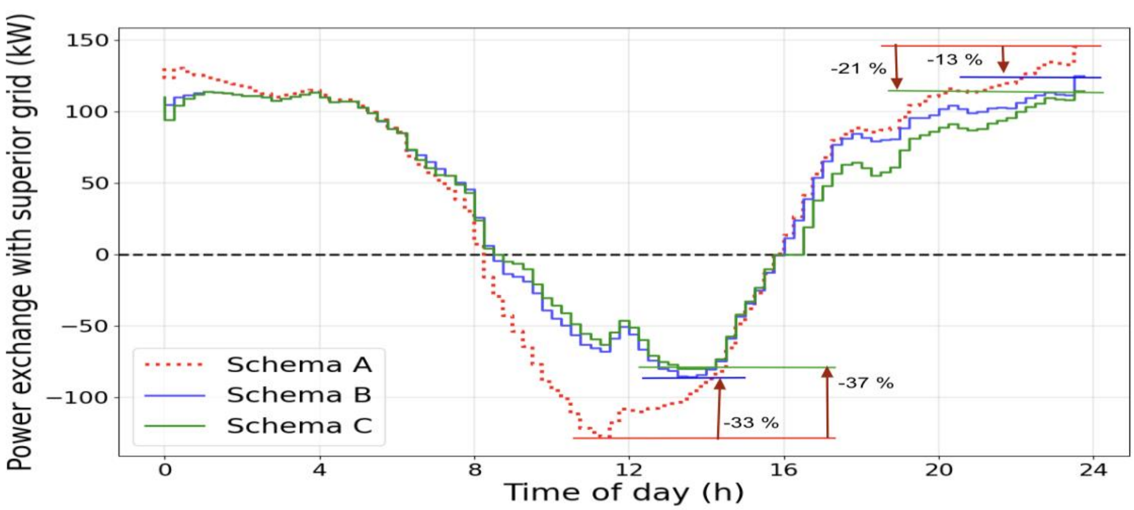

Figure 3: Reduction of imports and exports from LEM **Source:** Authors' projects

LEM platform to optimise the balancing of load and supply with P2P trading between consumers and prosumers.

Batteries allow for LEMs to behave akin to wholesale markets. Wholesale markets have a forward-facing aspect in that bids can be placed into the future and then dispatched. In the LEM, battery owners can schedule their charge and dispatch activities for the future. This means that batteries can provide grid-balancing network services at the local distribution part of the network. See Appendix 2 for a case study on LEMs.

How can Batteries be used in P2P to Get More Value Out of Battery Investment?

The time and place problems can be solved with BESS, which, when utilised within a P2P marketplace, can not only be used for self-consumption, but also for trading energy with peers.

The Indian national energy policy aims to deploy 47.2 GW of BESS systems by 2030, complementing the 500 GW non-fossil fuel energy target. Deploying batteries can reduce grid exports and imports by 20-25%, increasing self-sufficiency. As shown in Figure 3, in the LEM, batteries can further reduce grid exports and imports by an additional 6-10%, compared to just using the battery for self-supply, due to charging excess solar and increased self-discharge during peak demand. LEM better utilises batteries, thus reducing the need for more MW of batteries or network expenditures. BESS, in general, and even more so when utilised in a LEM configuration, reduces reverse power flow, grid congestion, and voltage intolerances during solar peak hours.

BESS in a P2P Configuration is a Better Utilisation of BESS and Reduces Costly Network Spending

BESS deployment also has a significant impact on distribution network augmentation. For instance, with a typical Australian Weighted Average Cost of Capital (WACC), deferring an AUD 30 million substation retrofit by 5 years can save AUD 5.4 million in interest. With an average Indian WACC of 12.5% and a typical cost of INR 30 crore for a 33 KV substation, deferring network augmentation for 5 years could save INR 18.75 crore in interest. Therefore, DISCOMS can save substantially by deferring CapEx for distribution transformers, switchgear, and lines/cables required for network augmentation. To illustrate, if 500 substations across India require yearly retrofit, the savings on network augmentation deferral could reach approximately INR 9,500 crore per annum.

BESS as a Part of LEM Reduces the Need for Expensive and Carbon-Intensive Dispatchable Power

Coal and gas prices increase generation costs and over-exposure to the spot markets. Grid balancing is happening more through open-cycle gas turbines, which burn twice the amount of fossil fuel than closed-cycle types, with higher costs and emissions.

LEMs[1] offer the potential for additional revenue streams for BESS owners and a decrease in energy bills. Furthermore, LEMs encourage the adoption of BESS by providing a method to effectively reduce the payback period on the capital investment in the BESS, while also assisting the DISCOM in managing minimum demand challenges. In short, LEMs are a significant win-win for all stakeholders involved.

As regulators consider how they will achieve their targets for BESS, it would be an efficient use of resources to utilise consumer-owned smaller-scale BESS, through LEMs, in a decentralised manner to reduce grid violations at distribution substation levels. LEMs involving distributed BESS, reduce the need for high-cost carbon-intensive dispatchable energy, larger-scale batteries at higher voltage levels and costly network augmentation.

[1] Read more about LEMs here (*Bhandari, "LEMs, what the devil..", Energy Central, 2022; Bhandari, "Do you want to..", Powerledger, 2022; L Ali et. al, "A Win win local..." IEEE, 2022*)

6. Why would Regulators and Utilities like to Consider P2P and LEMs

Achieving National Goals

To date, India has approximately 11.5 GW of distributed solar PV systems connected to the medium voltage and low voltage (MV and LV) grid; and out of which about 4.5 GW are roof top solar (RTS) systems. RTS uptake in India has been slower than anticipated, resulting in the December 2022 deadline to reach 40 GW being extended to March 2026.

The Ministry of New & Renewable Energy (MNRE) provides significant CFA subsidies for residential homes to install RTS. P2P trading incentivises deployment through increased revenues and would catalyse the removal of such subsidies. As per MNRE[2], a cumulative incentive amount of approximately INR 730 Cr. For a cumulative RTS capacity addition of 2872.565 MW stands released under the programme against the approved total RTS capacity of 18,000 MW and a total financial outlay of INR 4,950 Cr.

Based on the above, working with the installed capacity of 11.5 GW to date collectively would incur a one-time cost of approximately INR 3,024 Cr as subsidies, once it is disbursed. Post that, the NM scheme would cost INR 500 Cr per annum once the target is reached, as shown in the Table below.

On the other hand, for GM, where wholesale market rates are higher than GM FiT rates, C&I customers do not see an incentive to install RTS because of low FiT rates. So, while DISCOM economically benefits from GM, it is important to note that this is proving to be at the expense of India achieving RTS targets.

For the targeted RTS installation of 40GW, the below table provides an overview of the potential cost savings available to the government and hence, the taxpayers when NM subscribers switch to P2P. These figures are based on certain assumptions (mentioned in the table) related to the RTS-categorised on NM tariff structure and excess energy exported to the grid.

[2] *As per the latest MNRE sanction letter , for funds released in March 2023 to Ajmer Vidyut Vitran Nigam Ltd. on 15/03/2023.*

RTS Remunerated Under Net Metering Schemes

Targets	Implications (Current RTS Capacity – 11.6 GW)	Implications (40GW RTS Target[3])
RTS under NM – domestic and small/medium sized C&I, up to 500 kW loads	*Assumption: 50% of all prosumers are under NM comprised of* *Domestic: 25%* *Small & medium size C&I: 25%*	*Assumption: 70% of all prosumers are under NM, comprised of:* *Domestic: 30%* *Small & medium size C&I: 40%*
RTS under NM, export of 15 approx. 4 kWh/day that equates to:	*8.4[4] TWh of rooftop solar generation p.a.*	*40.8 TWh of rooftop solar generation p.a.*
Assuming 30% excess, the excess energy exported to the grid is approximately:	*2.5 TWh p.a.*	*12.2 TWh p.a.*
Assuming the 'NM adjustment' applies to all excess energy exported to the grid at an avg INR 7/kWh minus the average wholesale cost at INR 5/kWh, the NM subsidy of INR 2/kWh equates to 15 approx.:	*INR 500 Cr. p.a. (Approx. USD61m)*	*INR 2,450 Cr. p.a. (Approx. USD297m)*
Under CFA, so far, for a cumulative RTS of 2,872 MW, incentive of INR 730 Cr. Has been disbursed. Similarly, this subsidy scheme will likely cost the following amounts as the scheme progresses:	*Approx INR 3,000 Cr.*	*Approx INR 10,000 Cr[5].*

Table 1: Indicative Costs of India's Net Metering Policy and CFA

The above table illustrates that the Central Ministry of Power collectively through states and their DISCOMs, could save taxpayer money in two ways: **CFA subsidies (one-time subsidies during installation) and NM subsidies (an ongoing cost to the DISCOM in per annum).** At current RTS installed capacity of 11.5 GW, this would amount to approximately **INR 3,000 Cr. (one-time subsidy) + INR 500 Cr. Each year** and at a targeted

[3] *India has a target of 40GW RTS by 2026 (extended to 2026)*
[4] *4 kwh/day * 11.6 GW * 365 days * 50% of all prosumer metres in NM scheme*
[5] *Currently incentives have been allotted up to 18GW only and if extended up to the full quota of 40GW, it would cost the above.*

install capacity of 40 GW, it could save approximately INR **10,000 Cr. (one-time subsidy) + INR 2,453 Cr. Each year.**

P2P Helps Narrow the Gap in Economic Inequity

Homeowners who can afford to install solar panels are often wealthier than those who cannot. As a result, net metering can disproportionately benefit wealthier homeowners while doing little to help lower-income households. Peer-to-peer energy trading could help address the economic inequities of net metering. Peer-to-peer energy trading allows homeowners with solar panels to sell excess electricity directly to other homeowners, without going through a utility company. This can help lower the cost of electricity for all homeowners, regardless of their income. Peer-to-peer energy trading has the potential to revolutionise the way we generate and consume energy. By making it easier for homeowners to sell excess electricity, peer-to-peer energy trading could help level the playing field and make solar power more accessible to everyone.

Net metering can disproportionately benefit wealthier homeowners because they are more likely to be able to afford the upfront costs of installing solar panels.

Lower-income households are less likely to be able to afford solar panels, and they may also have less access to sunlight, which can make solar panels less effective.

As a result, net metering can widen the gap between the rich and the poor.

Considerations for Utilities

P2P trading can increase RTS deployment and benefit subscribers and DISCOMs in the following ways:

1. Domestic NM prosumers can sell at prices higher than the domestic retail rate to C&I consumers, as they would pay less than their current C&I retail rate.
2. Consumers without VRE assets benefit from P2P by paying less than the retail rates.
3. Domestic as well as small and medium-sized C&I consumers, with under the 500Kw sanctioned load, would be incentivised to install new RTS or upsize current RTS installations. This is made possible by DISCOMs maintaining a difference between the domestic and C&I retail rates.
4. DISCOMs can benefit through the following means:
   a) buying remaining excess solar above the P2P traded amount at cheaper rates;
   b) meeting Renewable Purchase Obligations (RPOs) by reducing upstream purchases through renewable energy PPAs and avoiding penalties;
   c) expanding their customer footprint through acquisition and retention in a Free Retail

Contestability (FRC) market; and

d) reducing imports and corresponding expenditures for network augmentation.

In a hypothetical scenario, if permitted, all the generated Residential Rooftop Solar (RTS), which accounts for 100% of residential energy production, could be traded on a peer-to-peer (P2P) platform with C & I consumers thereby mutually benefitting them. In this scenario, DISCOM stands to gain two-fold. Firstly, it gets to supply the consumption of residential customers during surplus solar hours, gaining from the difference between retail and wholesale rates. Secondly, it gains through the fee per unit charged for the entire generation traded on the P2P platform.

As a nodal agency for driving RTS up-take, as directed by regulators, DISCOMs need to create innovative models to incentivise, through increased revenue streams for prosumers of energy, both C&I and residential. For example, DISCOMs can charge a fee for each unit of P2P energy trading, creating a win-win proposition for RTS entities, C&I consumers, and DISCOMs. DISCOMs can also aggregate distributed energy resources and participate in the wholesale market for any surplus.

The implementation of P2P energy trading and Local Energy Markets (LEMs) not only helps regulators and DISCOMS achieve their renewable energy targets but also significantly reduces the reliance on subsidies. By incentivizing renewable energy deployment and creating cost savings, P2P and LEMs provide an effective and sustainable approach for regulators to promote renewable energy adoption without incurring substantial subsidy expenses. Furthermore, these models enable DISCOMs to meet their obligations, expand their customer base, and reduce network augmentation costs, fostering a more efficient and economically viable renewable energy ecosystem.

7. The Power of Blockchain: Revolutionising Electricity Markets Tracking and Trading

In today's rapidly evolving energy landscape, the demand for efficient, secure, and transparent systems to track and trade electricity has never been greater. Traditional, centralised approaches to electricity markets have limitations, including the risk of fraud, lack of transparency, and lengthy settlement processes. However, the emergence of blockchain technology offers a transformative solution to those limitations. In this section, we explore why blockchain should be used in electricity markets for tracking and trading energy, and how it can unlock a new era of efficiency and trust in the sector.

1. Enhanced Transparency

Blockchain technology provides a decentralised and transparent ledger that records all transactions in a secure and immutable manner. This transparency is particularly crucial in electricity markets, where multiple stakeholders, such as generators, distributors, and consumers, interact with each other. By leveraging blockchain, every transaction, from electricity generation to consumption, can be recorded on a shared, immutable ledger that is accessible to all participants. This unprecedented security and transparency mitigate the risk of manipulation and enables stakeholders to verify the authenticity and accuracy of transactions, ensuring fair and equitable trading.

2. Improved Efficiency

Traditional electricity markets often suffer from lengthy settlement processes, complex intermediaries, and high administrative costs. Blockchain can streamline these processes by automating transaction settlements through smart contracts. Smart contracts are self-executing agreements that automatically trigger predefined actions once specific conditions are met. By eliminating the need for intermediaries, blockchain enables faster and more efficient transactions, reducing administrative burdens and operational costs.

Moreover, blockchain's decentralised nature facilitates P2P energy trading. P2P trading empowers individuals and businesses to directly buy and sell electricity from one another, bypassing traditional centralised intermediaries. This disintermediation fosters a more efficient energy market, where excess energy can be monetised and consumed locally, reducing transmission losses and optimising resource allocation.

3. Enhanced Security

Cybersecurity threats pose a significant challenge in today's interconnected energy systems. Blockchain offers robust security features that protect against tampering, fraud, and data breaches. The technology's distributed architecture ensures that transaction records are replicated and synchronised across multiple nodes, making it extremely difficult for malicious actors to alter or manipulate data. Additionally, blockchain employs advanced encryption algorithms, providing an extra layer of protection for sensitive information within the electricity market ecosystem.

4. Decentralised Renewable Energy Integration

As renewable energy sources like solar and wind gain prominence, integrating them into the existing grid infrastructure becomes crucial. Blockchain can play a vital role in this integration by facilitating the monitoring, verification, and trading of renewable energy certificates (RECs) and carbon credits. Blockchain's immutable ledger ensures the traceability and authenticity of RECs, promoting transparency and trust among market participants. Furthermore, blockchain-enabled platforms allow small-scale renewable energy producers to monetise their excess generation by directly selling it to consumers, encouraging the adoption of clean energy and fostering a decentralised energy ecosystem.

5. Industry Use

In time, asset registries will be added to the list of blockchain use cases, which is already happening with carbon credits. Blockchain MRV (measurement, reporting and verification) technology, for certifying green hydrogen and other environmental attributes, has already been developed by industry leaders. The Interwork Alliance, in collaboration with Microsoft, will, in 2023, finalise its Digital MRV Framework. In the first instance, this will be used by issuers of carbon credits.

6. Government Recommendations

The Government of India's public policy think tank, NITI Aayog, has outlined the need for trust and the benefits of blockchain with energy trading as one of the use cases. The Ministry of Electronics and Information Technology (MeitY) has prepared the National Strategy to implement a National Blockchain Platform and will work with various Government organisations to implement the strategy and realise the advantages of blockchain technology in terms of enhanced security, trust and ability to create tamper-proof transactions.

For the above-mentioned reasons and those also foreshadowed in the introduction, the UPERC guidelines for P2P solar energy transactions refer specifically to the blockchain. By harnessing blockchain's power, India can create localised markets that transform the energy sector and enable innovative solutions that

are more transparent and completely tamper-proof. As the world continues to transition toward a more sustainable and digitally connected energy future, embracing blockchain is essential for creating resilient, flexible, and equitable electricity markets. The time has come to unlock the power of blockchain and pave the way for a new era of energy tracking and trading.

8. The Importance of the Right Price

In recent months, there has been wide-ranging debates about what should be the fairest pricing for the power that ‘prosumers’ can charge for the electricity they produce.

There are two classic types of tariff structures to compensate solar prosumers - one is to pay the prosumer, at retail price, for an excess generation not consumed by the premise behind the meter. This is called Net Metering, which favours the prosumer and does not entitle DISCOM to any network or surcharge fees. The second is Gross Metering, which pays a low-rate feed-in-tariff for all of the solar generated by the prosumer. This favours the DISCOM as the feed-in tariff has been continuously decreasing since solar attained grid parity.

The low rate of Gross Metering tends to suppress the growth of solar PV installation, and the high rate of Net Metering tends to result in grid congestion and curtailment of excess energy. Neither structure encourages the growth of BESS which will, over time, become the lifeblood of a distributed network.

The current choices both appear to be negative ones, but the dichotomy is, we believe, a false construct of two suboptimal choices. While DISCOM economically benefits from GM, it is at the expense of achieving RTS targets.

9. Finding the Optimal Way

Powerledger's sophisticated software offers a much more nuanced approach to pricing, being preferential pricing based on the seller's and buyer's wishes, or better still, dynamic pricing that reflects instantaneous local supply, demand and grid network situations. Dynamic pricing is the approach used by stock markets the world over and it involves a bid price, a sell price and a matching process of the two. The reason it's used in the world's great bourses is that it combines transparency, fairness and flexibility, and creates the best markets in the short, medium and long term. The best markets create the best sustainable growth.

We are confident that what has emerged from case studies, detailed in Appendix 2, and what will emerge from prospective pilots, is the blueprint for a pricing structure that produces markets where stakeholders largely are better off than they were expecting. Most importantly, it will be a pricing structure that stimulates healthy behaviour and appropriate future choices, leading to the growth of resources to ensure that the distributed energy system continually improves.

10. Conclusion and Recommendations: Pioneering Technologies as a Catalyst for India's Sustainable Energy Future

India has a unique opportunity to achieve its RE targets earlier than other countries, by leapfrogging other nations by embracing better market-based approaches that are supported by technology. Indian regulators are already paving the way forward through market reforms that benefit society, C&I establishments, and the DISCOMs.

P2P and LEMs create both the right market and price signals to boost the deployment of RE assets, like RTS, to meet India's national RE targets of 2030 and beyond. As evidenced by the case studies in the Appendix 2, the key benefits that can be derived from P2P trading are as follows:

1. Incentivise the deployment of RTS to expedite and meet India's national RE targets in order to reduce the need for carbon-intensive dispatchable energy sources;
2. Increase the viability for NM prosumers to switch to P2P and trade with C&I consumers;
3. Potentially offer higher revenue than GM to current subscribers;
4. Reduce losses incurred by DISCOM through NM;
5. Help DISCOMs to meet their RPO targets and avoid penalties;
6. Reduces energy transfer on transmission corridors thereby deferring CapEx for network augmentation;
7. Help to remove CFAs for RTS installation in the domestic sector; and
8. Addresses energy inequity by enabling consumers w/o RTS to purchase cheaper, green energy from prosumers and be part of the renewable economy.

The suitability of blockchain technology for both low-trust environments and high-information cost environments makes it ideal for the energy sector. With a secure and transparent record-keeping system supported by smart contracts, complex transactions can be automated, ensuring efficient and reliable energy transactions. While most blockchain use cases are in finance, supply chain management, and identity management, it holds great promise for asset registries and energy trading platforms.

It is important to acknowledge that blockchain is not a one-size-fits-all solution, however, when used appropriately, blockchain can facilitate the establishment of new markets and products that were previously non-existent or unfeasible. Whilst there may be setup costs and challenges associated with user education, these challenges are outweighed by the potential benefits of energy security, sustainability, and market innovation.

By embracing blockchain technology, India can transform its electricity networks, enabling secure, decentralised energy transactions, empowering consumers, and accelerating the integration of renewable energy sources. With the right vision, investment, and collaborative efforts, India can pave the way for a future where energy security, sustainability, and technological advancements go hand in hand.

Appendix 1: The Eight Stakeholders Involved in Our Studies

1. Central Governments and Central Regulators: Looking to reduce the burden on taxpayers, meet CO2 goals, increase economic growth and enable affordable electricity. Address National and Global requirements and goals through policies.
2. State Governments & State Regulators: Looking to achieve the above for the Government, and balance this with fair revenue for DISCOMs and pricing for consumers
3. Citizens: Looking to reduce the tax burden for meeting climate goals
4. DISCOMs: Looking to supply energy and maintain the grid cost, efficiently
5. Prosumers: Domestic owners of rooftop PV and consumers of electricity who need a stable and affordable supply of electricity
6. Domestic Consumers: Domestic consumers of electricity who need a stable and affordable supply of electricity
7. Commercial & Industrial Consumers: prosumers and consumers who need a stable and affordable supply of electricity
8. Powerledger: Technology provider, looking to facilitate all of the above using its blockchain-enabled P2P trading platform

Appendix 2: Case studies

Insights from the Frontier of Distributed Energy

Here is a collection of case studies and case prospectuses of P2P pilots undertaken by Powerledger and ISGF, in recent years. The early pilots tested the basic concept of P2P, sometimes in a limited ‘desktop’ format. But the later pilots have evolved and are exploring quite nuanced features like preferential pricing and dynamic pricing, often in real-time, with real participants using real domestic appliances, consuming real Kilowatt Hours from Solar PV Systems connected to the grid.

In all cases, we are concerned with the problem from much the same angle as a regulator might view things. We have no particular interest in making the consumer better off at the expense of the retailer or utility, or vice versa. Neither do we see this problem as a zero-sum game.

Instead, the overarching goal of these pilots was to find an optimal system for P2P sharing and LEMs, one that benefits all stakeholders and, above all, is conducive to good market behaviour. In other words, behaviour that will help the entire system improve over time and support the attainment of national renewable energy objectives.

1. UPPCL P2P Pilot Project in Uttar Pradesh: Revenue Through Transactions as the Way Forward

Name or Territory	Uttar Pradesh
Dates	Project Go-Live: Dec 2020
Purpose	Help the state of Uttar Pradesh meet its RPOs and grow the economy in India's most populous state.
Authority / Sponsors & Findings	Uttar Pradesh Power Corporation Limited, (UPPCL) / Madhyanchal Vidyut Vitaran Nigam Ltd (MVVNL). Findings: The solar energy traded on the Platform accounted to meet RPO targets. Solar energy traded on the Platform accounted to meet RPO targets
Regulator & Findings	Uttar Pradesh Electricity Regulatory Commission (UPERC). Findings: DISCOM charges are recommended to be 10% of the P2P price - split between buyer and seller.
DSO or DISCOM & Findings	Madhyanchal Vidyut Vitaran Nigam Ltd. (MVVNL). Findings: Understanding consumer behaviour and interaction preferences.
Prosumers & Benefits	9 [8- Residential, 1 - C&I] Residential: Retail rate: 7.0 INR/kWh, FiT: 2.0 INR/kWh, Average P2P rate: 5.2 C&I: Retail rate: 8.7 INR/kWh, FiT: 0.0 INR/kWh, Average P2P rate: 5.5 Findings: Extend the platform to KUSUM scheme Financial benefit - Total: 39,658 INR (Per meter and month: ~551 INR)
Consumers & Benefits	3 [2- Residential, 1- C&I] Residential: Retail rate: 7.0 INR/kWh, Average P2P rate: 5.2 C&I: Retail rate: 8.7 INR/kWh, Average P2P rate: 5.5 Findings: P2P price 25.7% lower than retail price for Residential customers. P2P price is 36.7% lower than the retail price for C&I customers. Financial benefit - Total: 5,690 INR (Per meter and month: 237 INR)
No. of Meters	12

Pricing model	Fixed P2P pricing, Dynamic pricing, Dynamic with preferential pricing
Conclusion(s)	Rather than seeing requirements to use renewable energy as purely a cost, the UP Government could see it as a solution for the bigger issue of high energy prices. P2P savings were 38% lower than the retail tariff. Transaction fees could make up for reduced energy fees for a DISCOM.

Table 2: UPPCL Pilot Project Summary

The takeaways from the study were significant. The Indian Government has set an ambitious target of attaining 500GW capacity from renewable sources by 2030[6]. However, the state DISCOM (UPPCL) was sceptical about the cost of achieving this. What became clear for the DISCOM through the study was that rather than seeing requirements to use renewable energy as purely a cost, and P2P as a problematic challenge, one could be a solution for the other. P2P could generate revenue through transaction fees and at the same time, help the DISCOM meet its RPOs. There was also a saving on the energy market buy price, the P2P price was 25.7% lower than the retail price for residential customers, and 36.7% lower than the retail price for C&I customers.

This result demonstrated the value of P2P and has prompted a call for regulatory change in the state to allow further expansion of the scheme. That change is now underway, with a rule change announced in April 2023.

[6] Source: https://economictimes.indiatimes.com/industry/renewables/govt-launches-plan-for-transmission-of-500-gw-green-energy-by-2030/articleshow/96065618.cms?from=mdr

2. Tata Power (TPDDL) in New Delhi: Case History Confirms the Value of P2P Trading

One of the motivations for the study was to see if the base of solar panel ownership could ultimately be expanded. At the moment, most households size their solar panel requirement based on the minimum demand of their household. There's no calculation that they could upsize their solar panel installation and pay off the extra cost by gaining revenue from selling the excess, and thereafter make a profit.

Name or Territory	Tata Power Delhi Distribution Limited, New Delhi
Dates	January 2021 - October 2021
Purpose	Help the state find the correct regulatory change and see if solar PV can be expanded beyond self-supply
Authority/ Sponsor & Benefits	Tata Power Delhi Distribution Limited, India Smart Grid Forum. Benefits: Customer empowerment to manage consumption and prioritise RE at a better price than the DISCOM
Regulator & Benefits	Delhi Electricity Regulatory Commission (DERC). Benefits: Maximised financial benefits for prosumers
DSO or DISCOM & Benefits	Tata Power Delhi Distribution Limited. Benefits: Visibility over price signals in the local distribution for the DISCOM
Prosumers, Domestic & Benefit	39 Domestic Prosumers. Retail rate: 6.5 INR/kWh, FiT: 5.8 INR/kWh, Average P2P rate: 7.3 INR/kWh Financial benefit: Total: 130,600 INR. Per Meter and month: ~371 INR
Prosumers, C&I & Benefit	16 C&I Prosumers. Retail rate: 7.75 INR/kWh, FiT: 5.8 INR/kWh, Average P2P rate: 7.6 INR/kWh Financial benefit: Total: 182,831 INR. Per meter and month: ~1039 INR

Consumers, Domestic & Financial Loss	29 [including 3 EV stations]. Retail rate: 6.5 INR/kWh, Average P2P rate: 7.0 INR/kWh (fixed P2P rate was set above retail rate of domestic consumers for parts of the trial duration to provide benefit to prosumers and C&I participants. During the remaining time of the trial, energy was traded at dynamic prices chosen by the participants which led to benefits for all participants. However, this was not enough to recover from the loss from the fixed price period.) Financial loss: Total: 29,061 INR Per meter and month: ~ 81 INR
Consumers, C&I & Benefit	32 C&I Consumers. Retail rate: 7.75 INR/kWh, Average P2P rate: 7.4 Financial benefit: Total: 33,142 INR. Per meter and month: ~112 INR
No. of Meters	117
Pricing model	Fixed price, dynamic pricing, preferential pricing, trading aggregator
Conclusion(s)	"Customers liked the simple approach of fixed price" Ganesh Srinivasan, Tata Power. There was an enthusiastic response to the opportunity to share excess solar energy. Some expressed the view that it should be rolled out sooner rather than later. The opportunity to balance voltage also was confirmed by the work. For the DISCOM, a reduction in distribution network losses, as power was traded more locally; the study confirmed that a reduction in capital expenditure would be expected, and as in the Ekwateur study, new opportunities for revenue generation could be considered.

Table 3: TPDDL Pilot Project Summary

Here, Tata Power Company (TPDDL), ISGF and Powerledger collaborated to run a 117-customer pilot comprising 55 prosumers and 62 consumers. The Electricity Regulator in Delhi State, the Delhi Electricity Regulatory Commission, was kept in the loop about this pilot project and the results of the pilot were shared with them through a detailed project report.

In summary, this has also highlighted the significance of peer-to-peer (P2P) and sparked a demand for regulatory reform. A proposed draft of the reform was issued on May 26th, 2023, aiming to facilitate the scheme's extended growth within the state.

"Customers expressed enthusiasm for the scheme and also a preference for the keep-it-simple approach of fixed price."

- Ganesh Srinivasan, Tata Power

Finding an Optimal Solution Using Different Scenarios

For sustainable win-win pricing for all stakeholders, another tariff system has to be developed and explored, that was the focus of this study. Various scenarios were created to see who would benefit and who would be disadvantaged by the pricing structure in force. In addition to feed-in-tariff and net metering, other possibilities were tested, including:

1. Fixed pricing: A price established by DISCOM and Powerledger, typically INR 4/kWh. Given the complexity of the segmentation of the pilot participants, setting a fixed price wasn't straightforward.
2. Preferential pricing: The seller gets to agree to a certain price with the buyer that they are sharing their power with. This might be typically around INR 8/kWh.
3. Preferential with Low Guarantee: If the buyer, who has agreed to the preferential rate, can't take the power on offer, under the rules of preferential pricing, the seller can still sell it to the grid for INR 4/kWh. This is the most dynamic of the arrangements and therefore the most challenging.
4. Dynamic pricing with randomly set prices: simulation of buyers and sellers bidding on the energy available, setting their buy and offer prices. The prices were randomly generated, within a predetermined range, and changed every 2 days.
5. Dynamic pricing with users setting the prices: to demonstrate how valuable user engagement is, a different version of dynamic trading was enabled, where real pilot participants set their bid and offer prices, simulating a real-time marketplace.

For comparison, the grid price would be INR 9.21/kWh.

3. Shakti Tata LEM in Delhi: A Model for Local Energy Markets in Microgrids

Name or Territory	Delhi, Tata (Shakti micro grid)
Dates	March 2023 - December 2024 (still in progress)
Purpose	Objective 4 of IElectrix -TPDDL: explore LEM benefits and resolve the choices for energy pricing, beingNet versus Gross Metering, or Feed-in-tariff.
Authority/ Sponsor & expected benefits	Tata Power Delhi Distribution Limited. Expected benefits: Becoming a proficient player in new tech space
Regulator & expected benefits	Indian Government Regulator. Expected benefits: Better market signals
DSO or DISCOM & expected benefits	TPDDL. Expected benefits: New billing and wheeling revenues possible
Prosumers & expected benefits	3 solar C&I sites with a total of 200 kW capacity Expected benefits: Improved visibility of transactions
Consumers & expected benefits	20-30 (Residential and C&I). Expected benefits: Cheaper energy
Community battery	1 (274 kWh / 200 kW)
No. of Meters	~24-34
Platform technology	Powerledger LEM energy trading platform
Pricing model(s)	Dynamic versus preferential
Expected Conclusion(s)	New revenue streams for prosumers, lower prices for consumers and an incentive for increased solar ownership beyond self-supply . Prove the use of grid-connected and island mode

Table 4: TPDDL LEM Summary

The Shakti project will demonstrate the use cases of a micro grid, both in grid-connected mode and island mode. Excess solar from the three (3) prosumers with a total of 200kW of solar PV can be traded with the balance (approximately) thirty (30) consumers and simultaneously charge the 200kW BESS. This is possible by introducing the grid battery as another participant. The BESS will be discharged, as per the limits on the stage of charge, during the evening and night. Coordination with the existing microgrid controller to charge the battery with excess solar to minimise charging from the grid, as well as discharge the battery to reduce grid imports whilst respecting the backup capacity needed in island mode. LEM is operational 24/7, 365 days and can complement the current operational set-up of the microgrid, both in grid-connected mode as well as island mode.

The LEM incorporates a Forecasting Module which, along with the Trading Platform, optimises the energy transfer between buyers and sellers and transmits control signals to the BESS. This optimisation and control feature is a significant addition to traditional P2P trading that was demonstrated in the earlier TPDDL project (see Appendix 2). Forecasted solar generation and consumption data as well as BESS State of Charge (SoC) in forward-facing time intervals are utilised for this purpose. In the Shakti trial, the Powerledger software trading platform can interface with the existing BESS system (presumably, Schneider) to collect the forecast data and transmit commands to the grid battery through the energy management system.

Aims of the pilot

The LEM promotes P2P trading between multiple buyers and sellers by offering buy and sell rates that are more attractive than current buy tariffs and the FiT. LEM supports both flat tariff and time-of-use tariff structures. Increased utilisation of the battery significantly reduces grid exports and imports which, in turn, mitigates grid congestion as well as voltage intolerances. This largely benefits the DISCOMs through CapEx deferrals for network augmentation.

The LEM automated platform for P2P trading, accompanied by optimised charging/discharging of the BESS, yields the following benefits:

1. Increased self-sufficiency of the LEM by reducing the imports from the grid.
2. Reduced grid exports and imports mitigating grid violations, and the increasing product lifecycle of MV equipment in the substation thereby reducing CapEx for network upgrades.
3. Participant empowerment to trade energy and reduce their energy bills.

4. Insights and Learnings on International Projects

Powerledger has pioneered P2P trading in more than fourteen countries. This has helped inform our understanding of how regulations will need to adapt to successfully allow renewables onto the grid.

Below is a table summarising some of these projects. These projects offer key insights, including technical requirements, potential benefits and challenges and the regulatory framework necessary for successful implementation, that Indian regulators can draw on to develop similar systems.

Furthermore, by drawing on the experiences of other countries, Indian regulators can learn from best practices and avoid potential pitfalls, thereby accelerating the development and adoption of a decentralised energy system in India.

Type	Customer Example	Settlement	Volume, Regulatory Support, Challenges, Learnings
C&I Cross Store P2P	Woolworths, Australia	Via retailer	Several hundred MWh traded. No regulatory approval is required i.e. undertaken using existing regulatory provisions. Straightforward to implement - similar to real-time VNM.
C&I to Residential P2P	Carlton United Brewery/Asahi, Australia	Tokenised value exchanged for beer	Sized to power Australia's largest brewery. No regulatory approval is required i.e. undertaken using existing regulatory provisions. Anchored by retailer.
P2P Energy Communities	Energy Steiermark, Austria Fenie Energia, Spain	Via retailer	Contracted to sign up +100k customers. Facilitated by reg change called Clean Energy Package which allows for energy communities and P2P trading. Anchored by retailer. Project scaling up now, on track. Now also considering Web3 loyalty for token redemption at eV charging stations.
C&I P2P Bangkok	BCPG, Thailand	Through DISCOM	Seven large commercial buildings including a school, shopping centre, hospital, apartment building and office blocks. Regulatory sandbox. Received international media attention. Pilot results have led to regulatory change in the country. There were some

			challenges around meter data integration to facilitate real-time trading.
Smart Campus Tracking of Energy and Emissions Intensity	Chiang Mai University, Thailand	Via university faculty billing	142 campus buildings, 16 MW solar, storage and EVs. Regulatory sandbox. Metering has slowed down the project deployment. This has become a showcase for smart energy campuses around the world, we are seeing interest from campuses planning to be smart in the US.
Real-Time Blockchain Provenance Tracking and Green Certification (Choose Your Mix)	Ekwateur, France	Via retailer	Rollout to 25k C&I and residential customers this year. Premium green tariff, emphasising the need for verification. No regulatory change is required. Getting the customer interface right has taken a bit of time. We think this could be a great implementation for Tata in Maharashtra.
Marketplace for Attribute Certificate Trading (Recs, Carbon Credits)	M-RETS, USA, largest REC registry in North America.	Via platform and registry	Addressing a market of 120m RECs pa, which requires pricing transparency and ease of competitive trading. No regulatory changes were required, but integration with the REC registry was needed, which was the first integration they had done, which took some time.

Table 5: List of Some Powerledger Applications that are Used Globally

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NOTES

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