ESMAP AND ISGF JOINT WEBINAR

PEER-2-PEER (P2P) TRADING OF GREEN ENERGY ON BLOCKCHIAN PLATFORMS

25 October 2023

09:30 AM to 11:00 AM EST (18:00 to 19:30 IST)

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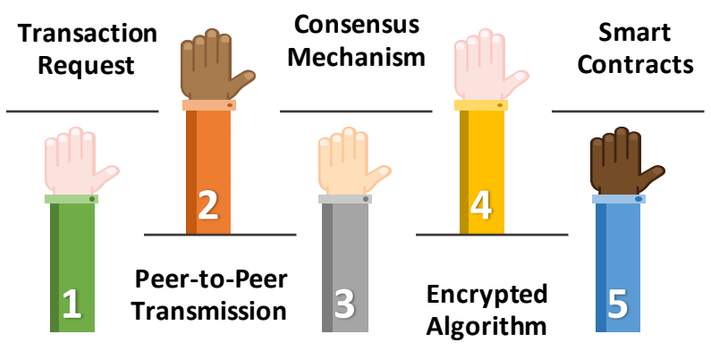
Blockchain Fundamentals

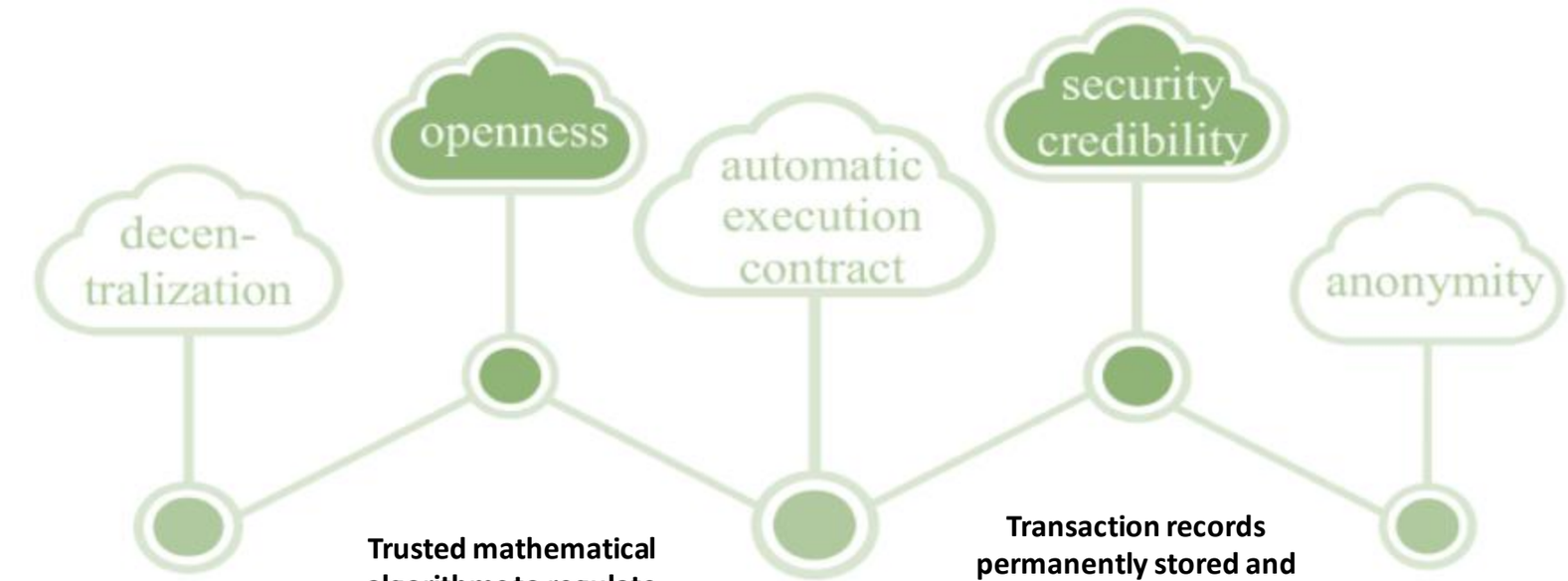
What is Blockchain?

A distributed digital ledger of financial transactions that are simultaneously stored and updated across several computers that are connected in a peer-to-peer network

Blockchain consists of:



Characteristics of Blockchain



P2P network mode, no mandatory control center

Trusted mathematical algorithms to regulate transactions

Efficient contract execution without third party supervision

Transaction records permanently stored and linked to trader information

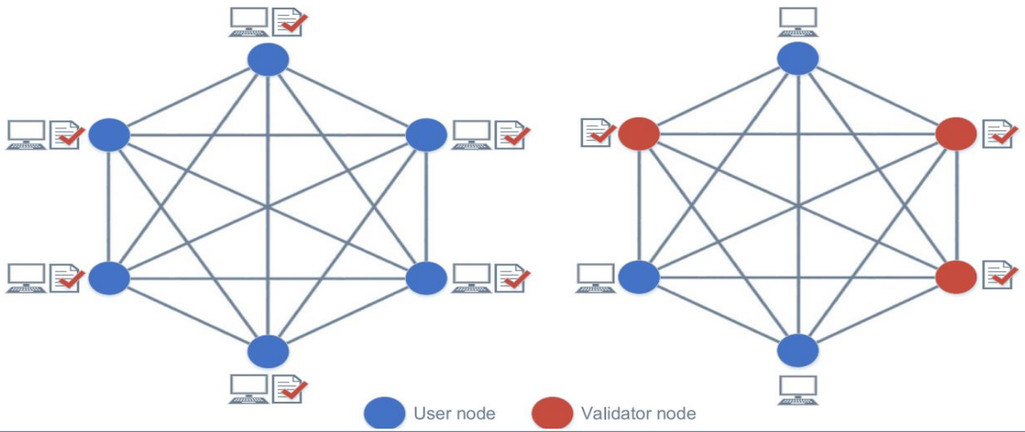
Types and Generations of Blockchains

Public Blockchain: Non-restrictive, permission-less distributed ledger system. Anyone can connect with some controls. Ex. Bitcoin, Litecoin, Public Ethereum

Private Blockchain: Restrictive or permissioned blockchain operative only in a closed network. Security, authorizations, permissions, accessibility are managed by one or small set of controlling organizations, Ex. Hyperledger, Quorum, Corda, Multichain

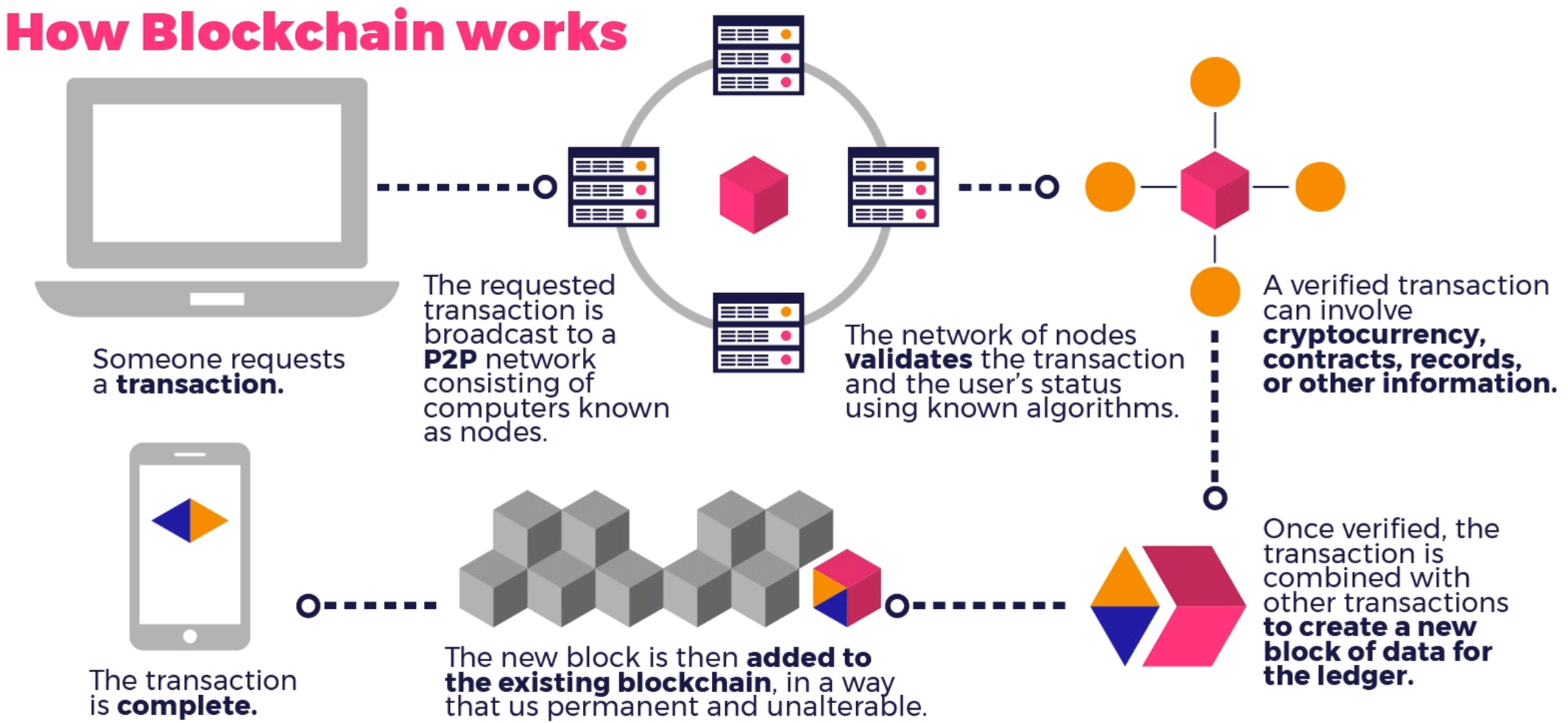
Consortium Blockchain (Public Permissioned): Semi-decentralized type. More than one entities manages a blockchain network compared to a private blockchain, where its mostly managed by a single or small set of entities. Example: R3, EWF, Hedera

Hybrid Blockchain: Combination of the private and public blockchain. It can have a private permission-based system as well as a public permission-less system. Ex. Dragon Chain



Generations of Blockchains	
Gen-1 *Bitcoin*	The original blockchain technology, the Bitcoin blockchain developed by Satoshi Nakamoto. It is energy intensive, not Turing complete; and limited scalability
Gen-2 *Ethereum*	Gen 2 blockchains introduced smart contracts (self-executing contracts with predefined conditions written into the code) using various blockchain programming languages; enabled development of decentralized applications. Lower energy consumption, faster and scalable
Gen-3 *Cardano, Polkadot, Solana*	Gen 3 blockchains utilise innovative consensus mechanisms, like proof-of-stake (PoS) or delegated proof-of-stake (DPoS), or proof-of-history (PoH) to improve scalability and energy efficiency; are capable of processing multiple blocks concurrently **"True Gen-3": Solana, Powerledger are much faster and scalable**

How Blockchain Works?



Blockchain Applications in the Energy Sector

Sl No	Domain	Applications
1	Energy Trading	i. Peer to Peer (P2P) Trading of Green Energy ii. Wholesale Power Market Transactions and Settlements
2	Emission Tracking	i. Renewable Energy Certificates ii. Certificate of Origin for Green Energy Transactions and Green Hydrogen
3	Transactive Energy & Grid Management	I. DER Generation and Service Coordination
4	Customer Empowerment	I. Green Electricity Choice II. P2P Home EV Charging
5	Energy Metering & Energy Data	I. Measurement, Recording and Verification (MRV) of Energy Data II. Load Profiling and Demand Estimation
6	Regulatory Compliance	I. Transparent Data for Regulators to Enforce Compliance
7	DER & EV Integration	i. Aggregation and Management of DER as Virtual Power Plants (VPP) on Secured Platform ii. EV Charging with Green Electricity and Roaming Anywhere
8	Cyber Security	I. Asset Register for Critical Information Infrastructure (CII) II. Trustworthy Digital Infrastructure

Local Energy Markets - A Vision for the Future

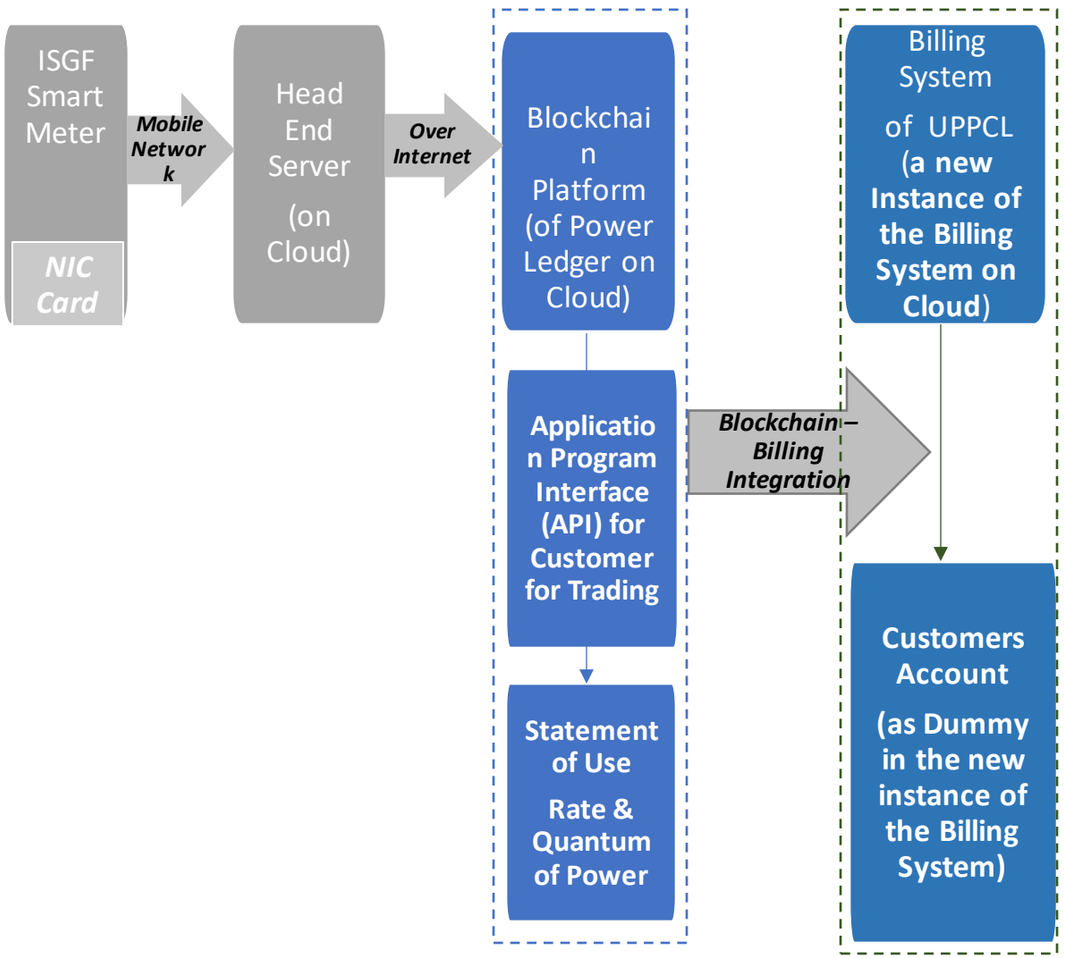
- Blockchain technology can enable the creation of local energy markets (LEM) where communities can generate, store, and trade CLEAN energy locally
- LEMs can help integrate locally generated renewable energy sources into the grid, reducing carbon emissions and increasing energy security; and also avoid transmission capacity enhancements for bringing power from far away locations to these LEMs
- Consumers can have greater control over their energy usage, with the ability to buy and sell green energy at competitive prices, and choose where their energy comes from; and can generate green energy certificates that are authentic
- LEMs can foster innovation and competition, driving down costs and increasing efficiency
- LEMs can also create new opportunities for local businesses and entrepreneurs, stimulating economic growth and job creation
- By empowering communities to take control of their energy future, LEMs can help build a more sustainable, resilient, and equitable energy system for all

Blockchain Pilot Projects in India

- Three Pilot Projects on Peer-to-Peer (P2P) Trading of Solar Energy on Blockchain Platform undertaken in India
- These projects were executed under the "Regulatory Sandbox Approach" (*Regulator accords approvals to undertake experiments/pilots and based on the results regulations are framed)*
- No money transactions in such pilots - only shadow bills generated

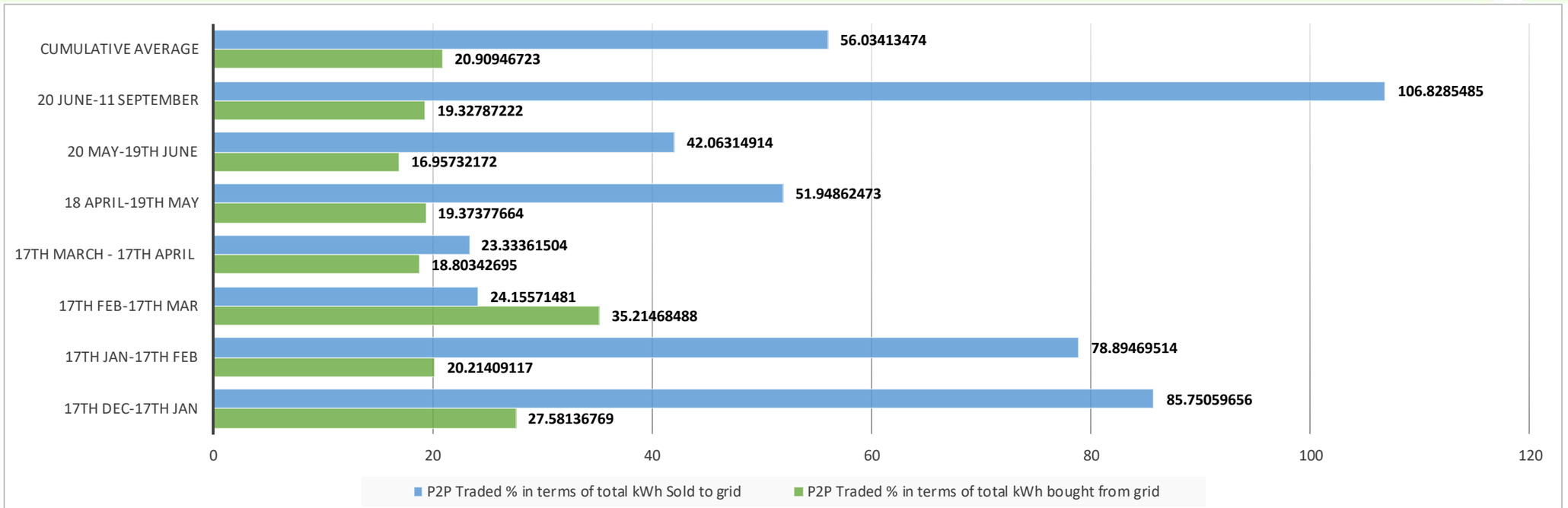
Pilot Project #1: UPPCL, Uttar Pradesh – first in South Asia

- **Scope**: To demonstrate the technical feasibility and user acceptance of P2P trading of rooftop solar energy
- Implemented by ISGF and Powerledger, Australia in 2020
- **Project Objectives**:
  - Provide prosumers more flexibility and incentivize the uptake of RTPV
  - Provide opportunity to the utility for financial gains from wheeling charges/network tariff/ transaction charges
- **Project Architecture/Features**:
- 12 participants – 9 prosumers and 3 consumers *(limited participation owing to first wave of Covid in 2020)* in Lucknow City
- New smart meters were installed in series with the existing revenue meter of the utility (UPPCL); smart meter data integrated with blockchain platform
- Installed a new Instance of the billing system on the cloud in which the 12 customers profiles were created; trading data from blockchain integrated with new billing system; and generated shadow bills
- Project Advisory Committee of external power sector experts who advised on project design and trading rules



Project Go-Live: Dec 2020

Pilot Project #1: Energy Trading Statistics



Month	Bought from Grid (kWh)	Bought from Grid (₹)	P2P Buy/Sell (kWh)	P2P Buy/Sell (₹)	Sold to Grid (kWh)	Sold to Grid (₹)
17th Dec-17th Jan	4837	34,894	1334	9,351	1556	2,870
17th Jan-17th Feb	5343	38,501	1080	6,248	1369	2,632
17th Feb-17th Mar	1819	13,479	640	2,661	2652	4,866
17th March - 17th April	3,670	27,019	690	2,940	2,958	5,471
18 April-19th May	3,653	26,948	707	2,879	1,362	2,723
20 May-19th June	4,558	33,644	772	3,111	1,837	3,673

Pilot Project #1: Price Determination Mechanisms

Regardless of what pricing method is used, the Utility's buy and sell rates are often used to set a 'ceiling' and 'floor' prices for the P2P trading

In the beginning, people were enthusiastic and used to bid every day. Since the volume of trade and money involved being very small, they reconciled to a market discovered price of INR 5.6/kWh (mid point of net metering tariff and commercial customers tariff)

Buyer's price

All P2P trades will be settled at the buyer's specified price - the benefit to the consumers is maximized since the P2P trades are settled at the minimum possible price

Seller's price

All P2P trades will be settled at the seller's specified price - the benefit to the prosumers is maximized since the P2P trades are settled at the maximum possible price

Average price

In this mechanism, whenever a buyer and seller are matched based on their min/max prices, the price would be the middle point of the two parties quoted prices

Volumetric weighted average

This mechanism is similar to the average price, but it also takes into consideration the 'weight' of buyers and sellers amount and uses it to determine the price for each trade using the following formula:

Trade price = (Seller's Weight * Sellers asking Price) + (Buyers Weight * Buyers asking Price)

Pilot Project #1: Business Case for P2P Trading in UPPCL

- Net metering tariff in the state of UP is INR 2.00/kWh and the residential and commercial tariff varies between INR 7.00-8.50/kWh. In this pilot project price discovery was around INR 5.60/kWh: WIN - WIN for both prosumers and consumers
- Provide rooftop solar owners more flexibility and incentivize the uptake of rooftop PV (RTPV) systems
- P2P trade could help uptake of RTPV and increase in local generation that could reduce the quantum of power procured through open access which will help reduce power procurement cost of the utility and strengthen their finances
- Potential investment deferral for network expansion with increase in local generation and local consumption
- Utilities can fulfil their RPO targets with increase in uptake of RTPV systems
- Help customers who want to buy green power by allowing them to purchase energy from prosumers through P2P trading platform
- Recommendations submitted to State Regulator in April 2021 – recommended wheeling charges and other services fee for the utility

Pilot Project #1: Regulations and Guidelines by UPERC

The Tariff Order issued by the **Uttar Pradesh Electricity Regulatory Commission (UPERC)** for FY 2020-21 mentioned that:

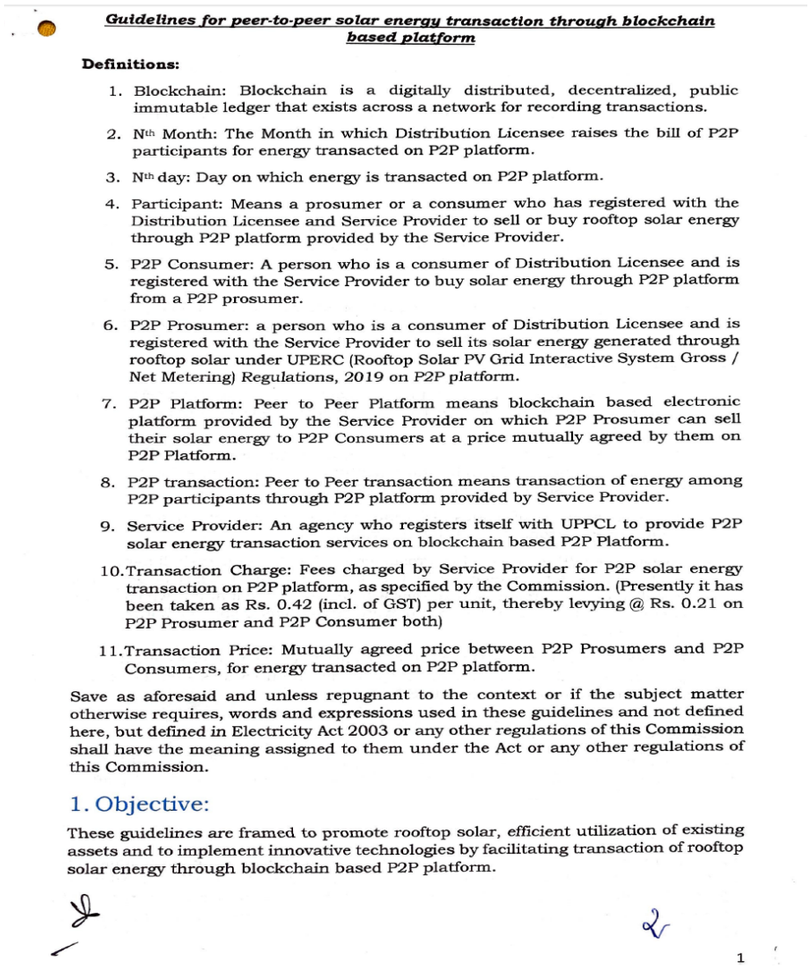
"The Commission has noted that the Licensee has successfully completed a pilot implementation of peer to peer (P2P) trading of electricity in renewable energy using Blockchain technology. The Commission encourages the Licensee to implement more of such projects including battery storage etc."

The 2022 Tariff order mentioned:

"The Commission directs the Licensees to take the blockchain pilot project forward to its next phase for integrating it with the existing billing system (ERP/ financial settlement etc) so that P2P rooftop solar energy may become operational for the prosumers and consumers of the State."

In April 2023 UPERC published the world's first guidelines for the for P2P solar energy transactions through blockchain based platform: https://uperc.org/App_File/P2P-Guidelines_UPERC-pdf416202393822PM.pdf

Guidelines for Peer-to-Peer Solar Energy Transaction through Blockchain by UPRC in April 2023



Guidelines for peer-to-peer solar energy transaction through blockchain based platform

Definitions:

1. Blockchain: Blockchain is a digitally distributed, decentralized, public immutable ledger that exists across a network for recording transactions.
2. Nth Month: The Month in which Distribution Licensee raises the bill of P2P participants for energy transacted on P2P platform.
3. Nth day: Day on which energy is transacted on P2P platform.
4. Participant: Means a prosumer or a consumer who has registered with the Distribution Licensee and Service Provider to sell or buy rooftop solar energy through P2P platform provided by the Service Provider.
5. P2P Consumer: A person who is a consumer of Distribution Licensee and is registered with the Service Provider to buy solar energy through P2P platform from a P2P prosumer.
6. P2P Prosumer: a person who is a consumer of Distribution Licensee and is registered with the Service Provider to sell its solar energy generated through rooftop solar under UPERC (Rooftop Solar PV Grid Interactive System Gross / Net Metering) Regulations, 2019 on P2P platform.
7. P2P Platform: Peer to Peer Platform means blockchain based electronic platform provided by the Service Provider on which P2P Prosumer can sell their solar energy to P2P Consumers at a price mutually agreed by them on P2P Platform.
8. P2P transaction: Peer to Peer transaction means transaction of energy among P2P participants through P2P platform provided by Service Provider.
9. Service Provider: An agency who registers itself with UPPCL to provide P2P solar energy transaction services on blockchain based P2P Platform.
10. Transaction Charge: Fees charged by Service Provider for P2P solar energy transaction on P2P platform, as specified by the Commission. (Presently it has been taken as Rs. 0.42 (incl. of GST) per unit, thereby levying @ Rs. 0.21 on P2P Prosumer and P2P Consumer both)
11. Transaction Price: Mutually agreed price between P2P Prosumers and P2P Consumers, for energy transacted on P2P platform.

Save as aforesaid and unless repugnant to the context or if the subject matter otherwise requires, words and expressions used in these guidelines and not defined here, but defined in Electricity Act 2003 or any other regulations of this Commission shall have the meaning assigned to them under the Act or any other regulations of this Commission.

1. Objective:

These guidelines are framed to promote rooftop solar, efficient utilization of existing assets and to implement innovative technologies by facilitating transaction of rooftop solar energy through blockchain based P2P platform.

1

Pilot Project #1: UPERC Guidelines for P2P Trading

Sl No	Charges	Value
1	**Mutually Agreed Transaction Price**	As agreed between P2P Prosumers and P2P Consumers, for energy transacted on P2P platform.
2	**Energy and Demand Charges (For energy supplied by Distribution Licensee)**	As per rate schedule in UPERC Tariff Order
3	**Open Access Charges**	
i	**Wheeling Charges**	**0.92 Paisa/kWh – to be charged from the Buyer (Consumer)**
ii	Cross Subsidy Surcharge	As per applicable UPERC Tariff Order – NIL as of now
iii	Additional Surcharge	NIL - 100% waiver
iv	Charges for difference between schedule and actual P2P transaction	
	a) Under injection of energy by the P2P Prosumer	Payment equivalent to difference between energy charges as per rate schedule and mutually agreed price on P2P Platform by P2P Prosumer.
	b) Over injection of energy by the Prosumer	Settlement of excess energy shall be done as per the gross/net-meter /net-feed in arrangement of Prosumer. If no schedule is submitted by Prosumer, then the energy injected by him on nth day shall be adjusted as per the gross/net meter /net-feed in arrangement of Prosumer.
	c) Under drawl of energy by P2P Consumer	Full payment of quantum of energy pledged by it on P2P platform to the P2P Prosumer(s)
	d) Over drawl of energy by P2P Consumer	No penal charges. However, settlement shall be done as per Note 1 in the Gidelines
4	**Transaction Charge**	Fees charged by Service Provider for Blockchain Platform as specified by the Commission - presently it is taken as **Rs. 0.42 per kWh (incl. of GST) - to be divided equally amongst Prosumer and Consumer**

Pilot Project #2: Tata Power Delhi Distribution Limited (TPDDL)

India Smart Grid Forum

Objective

- Pilot conducted by Tata Power Delhi Distribution Ltd (TPDDL) in collaboration with ISGF and Power ledger
- Test the technical viability and value proposition of P2P energy trading
- Develop business model for blockchain enabled P2P energy trading in Delhi

Project Architecture

- TPDDL's Grid Stations and Offices with Solar PVs and some real customers
- Smart meter data from TPDDL's MDM was integrated with blockchain; and trading data integrated with TPDDL's SAP billing system to generate shadow bills
- Simulated trading to mirror the scenarios of real trading regimes

Unique Features in this Pilot

- Involvement of a trader who will take over the trading responsibilities for customers and prosumers
- Involvement of rooftop providers who will subscribe to data feed
- Opportunity to add other elements pertaining to DERs such as EV, Storage and Demand Response

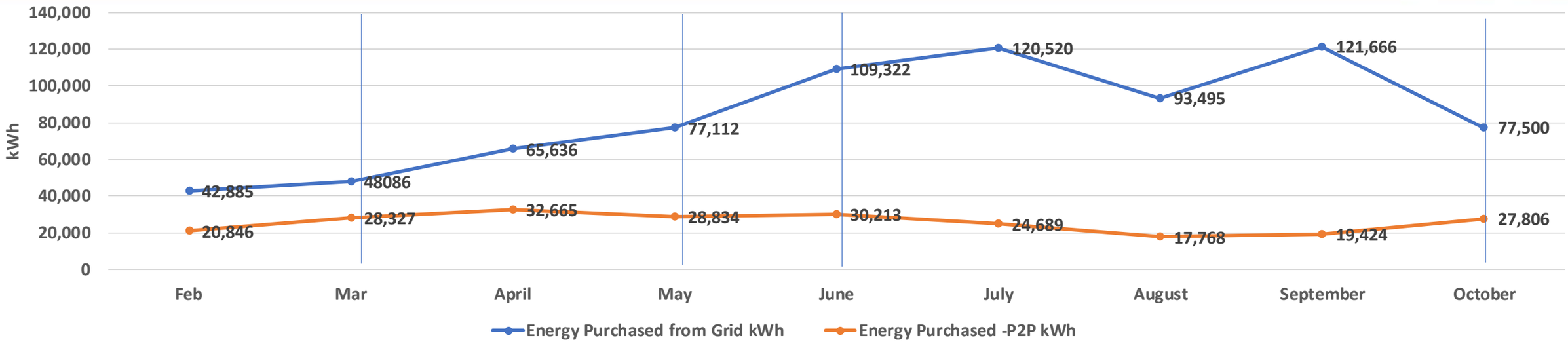
TYPE	PROSUMERS	CONSUMERS
TPDDL Offices and Sub-Stations	14	41
Real Customers	41	21
TOTAL	55	62

117 Participants in the Pilot Project

Category	PROSUMERS	CONSUMERS
Industrial	14	20
Non Domestic	2	12
Domestic	39	29
EV - 1		

Project Go-Live: January 2021

Pilot Project #2: P2P Transactions from Feb 2021 to Oct 2021



Month	Energy Purchased from Grid		Energy Traded on P2P (Sold/Bought)		Energy Sold to Grid	
	kWh	₹	kWh	₹	kWh	₹
Feb	42,885	2,98,806	20,846	1,50,147	2,685	15,576
April	65,636	4,58,667	32,665	2,34,985	7,731	44,841
June	1,09,322	7,60,172	30,213	2,27,323	1,095	6,349
July	1,20,520	8,50,000	24,689	1,85,100	604	3,500
September	1,21,666	8,67,681	19,424	1,45,885	1,254	7,274
October	77,500	5,47,117	27,806	2,07,077	5,218	30,259
Total	7,56,222	53,21,405	2,30,572	17,03,447	34,074	1,97,620

Pilot Project #2: Draft Regulations by DERC

- **Based on the project results, ISGF + Power ledger + TPDDL had submitted detailed findings and recommendations to Delhi Electricity Regulatory Commission (DERC) in November 2021**
- **DERC conducted stakeholder consultations in 2021 and 2022**
- **DERC published DRAFT REGULATIONS for P2P Trading of Solar Energy as AMENDMENTS to the Net Metering Regulations on 26 May 2023**
- **Regulations finalized in July 2023; and expected to be issued soon**
- **Link for the Draft Regulations: http://derc.gov.in/**

(TO BE PUBLISHED IN DELHI GAZETTE EXTRAORDINARY PART)
GOVERNMENT OF NATIONAL CAPITAL TERRITORY OF DELHI
Delhi Electricity Regulatory Commission
Viniyamak Bhawan, C-Block, Shivalik, Malviya Nagar, New Delhi-110017
DRAFT
F.3(664)/Tariff-Engg./DERC/2021-22/7286 - Delhi Electricity Regulatory Commission, in exercise of the power conferred under Section 181 read with Section 61 (h), Section 86 (1) (e) of the Electricity Act, 2003, Regulation 16 of *DERC (Net Metering for Renewable Energy) Regulations, 2014* and all other powers enabling it in this behalf and after previous publication, hereby amend the following Regulation in *DERC (Net Metering for Renewable Energy) Regulations, 2014* (hereinafter referred to as "the Principal Guidelines"):

1.0 Short Title and Commencement:

(1) These Regulations may be called the *Delhi Electricity Regulatory Commission (Net Metering for Renewable Energy) (First Amendment) Regulations, 2023.*

(2) These Regulations shall come into effect from the date of notification.

2.0 Proposed addition in Regulation 2 of Principal Regulations:

"(21) "Blockchain" means a special technology for peer-to-peer transaction platforms that uses decentralized storage to record all transaction data.
(22) "Peer to Peer Transaction" means a transaction, based on interconnected platform that serves as marketplace wherein Consumers and Prosumers meet to trade electricity through Blockchain or any other technology.
(23) "Prosumer" means a person who consumes Electricity from the Grid and can also inject Renewable Energy into the Grid using the same network.

3.0 Proposed addition in Regulation 4 of Principal Regulations:

Pilot Project #3: CESC, Kolkata

Project Overview

- **Objective:** To explore and develop suitable business models for a **Platform as a Service -** envisioned scalable blockchain-enabled Peer-to-Peer (P2P) energy trading platform as an offering of CESC to their customers
- **Tested the P2P trading platform and ran a 6-month pilot with 1001 C&I Customers with AMR meters (8 MW PV installations)**
- Executed various pilot test scenarios with fixed-price, preferential and dynamic-price trading scenarios
- Evaluated the benefits of P2P trading to the utility (CESC), prosumers and consumers

The Project Features

- The market-based mechanisms as an alternative to the existing Net Metering / Net Billing scheme, deriving value for customers (prosumers and consumers) and for CESC
- Empowerment of customers to trade and share their energy
- Stimulus to accelerate the uptake of solar PV systems
- Test and demonstrate scalability of the blockchain platform – 1000 participants in this pilot
- Documented the outcomes of the project; and may be presented to the West Bengal Electricity Regulatory Commission (WBERC)

Project Go-Live: August 2022 (Pilot project was done without direct involvement of customers)

Pilot Project #3: Savings with P2P Trade

Savings in energy bills		Aug-22	Sep-22	Oct-22	Jan-23
		Fixed Price P2P	Preferential P2P	Dynamic Price P2P	Stacked /Multiple Rules P2P
FiT (Gross) to P2P (USD)	Total	3455	3499	7428	3401
	Consumers	2106	876	-1029	852
	Prosumers	1350	2622	8458	2549
Net Metering to P2P (USD)	Total	-2046	-2001	-1976	-1472
	Consumers	2106	876	-1029	852
	Prosumers	-4152	-2877	-947	-2324
P2P Traded (MWhs)		101.79	92.16	178.40	86.90

Notes:

1. *Calculations are based on actual metered data, estimated rates without direct involvement of customers*
2. *Positive values indicate SAVINGS for participants*

***Fixed price P2P**: The energy trading model where the trading price between buyer and seller remains fixed*
***Preferential P2P**: The energy trading model where buyers have the choice to select the preferred seller(s)*
***Dynamic Price P2P**: The energy trading model where the trading price between the buyer and the seller is dynamic and depends on the bids and ask prices from the participants*
***Stacked P2P**: It involves adding multiple trading models to achieve additional/desired benefits*

Pilot Project #3: Key Takeaways of the CESC Pilot Project (1/2)

- P2P trading is better than Feed-in-Tariffs, offering higher prices to prosumers
- Consumers pay less with P2P trading compared to grid tariffs
- Some customers willing to pay more than grid tariff for Green Energy on the P2P platform
- Utilities can also save when prosumers switch from net metering to P2P trading, as utility has to buy less from the prosumer
- CESC earned the most with Feed-in-Tariffs (FiT) during the pilot – not under Net Metering
- Preferential trading benefits those accepting preferred sellers; and preferential trading combining preferential and fixed-rate P2P trading adds advantages
- Dynamic trading pairs buyers and sellers effectively on the blockchain platform
- Blockchain platforms allow users to see results and adjust preferences very transparently

Pilot Project #3: Key Takeaways from CESC Pilot Project (2/2)

- P2P Trading Benefits: P2P trading offers benefits to prosumers, consumers, utility and even those on existing Feed-in-Tariffs
- Include P2P traded solar energy in the solar RPO of the utility - 'downstream' procurement of solar energy instead of the usual 'upstream' PPAs with RE producers
- The retail tariff has two parts: fixed/ demand charge, and energy charge - the fixed charge is recoverable from the customers and should, ideally, meet the fixed costs for delivering the service; so no losses to the utility by promoting P2P trading
- Customer Empowerment: P2P trading empowers customers and facilitates price discovery
- While defining P2P Energy Trading Regulations to promote proliferation of Rooftop PV the most important factor to consider is to strike a good balance between the greater good for all by defining a collection of straightforward, consistent, and equitable terms

Comparison of the Three Demonstration Projects

Parameters	UPPCL, Lucknow	TPDDL, Delhi	CESC, Kolkata	Remarks
Project Size, Participants Selection, On-boarding and Training	Prosumers – 9 Consumers-3 **Total – 12** Participants jointly identified by Utility and ISGF; prepared training materials and ISGF provided training on trading	Prosumers – 55 Consumers-62 **Total – 117** Participants identified and on-boarded by TPDDL; ISGF prepared training materials and jointly provided training on trading	Prosumers – 213 Consumers- 788 **Total – 1001** Participants identified in consultation with CESC; Consumers metered data are used in the pilot. There is no direct interaction / involvement of the consumer. ISGF and Powerledger prepared training materials and provided training on trading to CESC Team	
Project Architecture	New Smart Meters Installed, metering data integrated with Blockchain Platform; and trading data integrated with UPPCL's Oracle CC&B billing system to produce shadow bills (new instance of CC&B installed on cloud) – no interference with the production systems of UPPCL	TPDDL has Smart Meters; metering data extracted from TPDDL's MDM and integrated with Blockchain Platform; and trading data integrated with TPDDL's SAP billing system to produce shadow bills	All project participants are mixed category with AMR / Smart meters; metering data downloaded was shared with ISGF/Powerledger a day after in XML files; trading data generated on Blockchain Platform	Each project had different metering systems and billing systems. We integrated blockchain platform with SAP, Oracle and a homegrown Billing systems except CESC Kolkata.
Project Period (Implementation/Trial Period)	March 2020 to Dec 2020/ Dec 2020 to June 2021	August 2020 to Dec 2020/ Dec 2020 to Nov 2021	August 2022 to February 2023	During Covid period in 2020 and 2021 it took long time to execute the projects
Project Cost	INR 5 million + 18% VAT approved by UPERC; and paid by UPPCL to ISGF on EPC model	Confidential	Confidential	
Total RTPV Capacity involved in the Project	Below 100 kW	5 MW	8 MW	

Pilot Project Design Principles

- First and foremost principle of a pilot demonstration project is to ensure that it will NOT disturb the Utility's production systems and the revenue management cycle; and demand minimum resources from the Utility!
- Maintain absolute clarity in defining the objectives of the demonstration project and conveying the same to all stakeholders to get their buy-in
- Ideally, should obtain regulatory approvals; or keep the regulators informed of the pilot project
- Undertake an AS-IS study to assess the existing infrastructure (both HW and SW systems) in the Utility and identify the interfaces for the pilot project that wouldn't cause any constraints on the Utility's day-today business operations
- Assess the grant/fund available for the pilot project and select the key functionalities to be demonstrated and the project size based on the available funds
- Prepare the architecture of the pilot project based on the AS-IS study, key functionalities and project the size
- Prepare the list of HW and SW systems required for the pilot project based on what existing systems in the Utility can be leveraged; and prepare the procurement plan
- Prepare the project timelines
- Once the pilot project is successfully demonstrated, document the project results

Implementation of P2P Energy Trading in Developing Countries

Choosing the Right Locations

- **High Solar Potential Regions**: Identify areas with ample solar irradiation to maximize renewable energy generation, making the investment viable for prosumers
- **Urban Areas with Prosumers**: Focus on urban regions with rooftop solar installations and prosumers willing to participate
- **Regions Facing Energy Access Challenges**: Target underserved or off-grid areas to enhance access to clean and affordable energy

Implementing the Projects Beneficial to all Stakeholders

- **Regulatory Approvals**: Obtain regulatory approval for P2P trading; and specify the trading rules and guidelines with clarity
- **Metering and Billing Systems**: Implement smart metering system for the project participants; metering data to be integrated with the blockchain platform where trading and settlements are calculated which need to be integrated with the Billing System of the Utility
- **Trading Settlement Agency**: Fix agency responsible for money collection and settlement – this should be ideally the utility itself or it could be a third party. The framework of Trading and Settlement to be thought through and lay the rules what can be practically implemented
- **Blockchain Services Provider**: Selection and appointment of reliable Blockchain Service Provider and the business model to engage the service provider – Opex **OR** Capex+AMC ?
- **Project Participants Onboarding and Training**: P2P participants to be onboarded and trained on trading rules and benefits
- **Potential to Build Clean Energy Communities:** Examine the potential to invest in Energy Storage Systems and build clean energy communities in areas where grid is unreliable or in off-grid areas
- **Enhanced Grid Resilience**: P2P trading can enhance grid resilience by reducing the strain during peak demand periods
- **Community Building and Cooperation**: P2P programs foster community engagement, building trust and cooperation among participants

THANK YOU

For discussions/suggestions/queries email:

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www.indiasmartgrid.org
www.globalsmartenergy.org
www.isuw.in
www.dumindia.in
www.rejikumar.com

Backup Slides

Contents:

1. UPERC Guidelines on P2P Trading of Rooftop Solar Energy
2. Consensus Mechanism in Blockchains
3. Blockchain Programming Languages

UPERC Guidelines for P2P Trading

Objective

To promote rooftop solar, efficient utilization of existing assets and to implement innovative technologies by facilitating transaction of rooftop solar energy through blockchain based P2P platform

Registration of Service Provider

Service Provider shall register with the Distribution Licensee, where it will provide services. The registration shall be initially valid for a period of 3 years after commissioning and commercial operationalization, which can be extended on mutually agreed terms

Registration of P2P participants

Distribution Licensee and Service Provider shall jointly prepare and publish a registration form having formats including, but not limited to, user's information, checklist of system/technical prerequisites required by P2P participant to participate in P2P exchange. Provided that only such prosumers having rooftop solar installed in their premises under UPERC (Rooftop Solar PV Grid Interactive System Gross / Net Metering) Regulations, 2019 can register on P2P platform only as sellers

UPERC Guidelines for P2P Trading

Steps of Registration for P2P Participant

1. Any P2P participant who wants to participate shall register themselves with their respective Distribution Licensee, who in turn shall communicate it to the Service Provider

2. Withing 15 days of submission of registration, Officers from Distribution Licensee and Service Provider shall jointly check the compatibility of P2P participants' system for readiness for P2P exchange

3. In case of rejection of request, Distribution Licensee and/ or Service Provider shall convey reasons to applicant, in writing

4. To avail the P2P services, P2P Prosumers and Consumers shall have postpaid smart meters installed in their premises. If post-paid smart meter is not installed in their premises, then they will have to install it at their cost. The cost of any additional hardware/software beyond meter shall be borne by the Service Provider

5. In case of acceptance of Distribution Licensee and Service Provider, the P2P participant shall be registered on P2P platform within 15 days after the activity is carried out in accordance with Sl.No.2 above

UPERC Guidelines for P2P Trading

Scope of P2P Transaction

P2P participants shall be able to transact energy through P2P Platform within the area of a Distribution Licensee. The Service Provider shall develop a rollout plan, in consultation with Distribution Licensee.

Metering

P2P Prosumer and P2P Consumer shall have post-paid smart meters installed to participate on P2P platform. Service Provider shall utilize the data of Distribution Licensee's meters through MDM to capture P2P transactions for the purposes of billing and also to reconcile the schedule transaction with the actual transactions on P2P platform

Submission of Transaction Schedule

For day ahead transactions, P2P participants shall submit their schedule for the energy to be transacted on P2P platform on nth day, by 1700 hrs. of (n-1)th day. No deviation in schedule shall be allowed beyond this time. For intraday transactions, P2P participants shall submit their schedule for the energy to be transacted on P2P platform at least four-time blocks before the commencement of schedule. No deviation in schedule shall be allowed beyond this point. Provided also that P2P Prosumer shall not transact energy more than their own solar generation per day

UPERC Guidelines for P2P Trading

Billing Process

1. Billing cycle of P2P Platform shall be in sync with the billing cycle of Distribution Licensee - Distribution Licensee and Service Provider may mutually decide the modalities of settlement if the billing cycles differ
2. Service Provider shall fetch time block-wise meter data for each day for both P2P Prosumer and P2P Consumer for actual energy generated and consumed respectively
3. The bill shall be raised for total demand (P2P transaction + purchase from Distribution Licensee) by the Distribution Licensee as per the provisions of Tariff Order and Supply Code
4. The payment made by P2P Consumers shall be settled proportionately towards the energy transacted by them on P2P platform, Service Provider transaction charge, energy supplied by Distribution Licensee and Open Access charges
5. Open Access charges will get devolved to Distribution Licensee. The Open Access Charges shall consist of Wheeling charges and Imbalance charge as detailed in the Table in previous slide #28
6. Service Provider transaction charges will be given to Service Provider by Distribution Licensee after settlement with P2P participants

UPERC Guidelines for P2P Trading

Transaction Charge

Fees charged by Service Provider for P2P solar energy transaction on P2P platform, as specified by the Commission - presently it is taken as Rs. 0.42 per unit (including GST) - Rs. 0.21 each on P2P Prosumer and P2P Consumer

Transaction Price

Mutually agreed price between P2P Prosumers and P2P Consumers, for energy transacted on P2P platform

Default in Payment

1. The P2P Consumer shall have to clear all the dues for the energy transacted on P2P platform as per due date. P2P participant shall be deactivated from P2P platform, if the dues are not paid

2. In the event of default in payment for energy supplied by Distribution Licensee, appropriate action shall be taken as per Electricity Supply Code

UPERC Guidelines for P2P Trading

Rights and Responsibilities of P2P participants

1. P2P participants shall not indulge in cartelization or gaming to deter the financial interest of licensee
2. It has to be ensured that participating into P2P exchange does not compromise aspects of electrical safety
3. Data privacy and cyber security shall be maintained by Distribution Licensee and Service Provider

Roles and Responsibilities of Service Provider

1. Service Provider shall create awareness and train P2P participants and Distribution Licensee officials regarding functioning of P2P platform
2. Service Provider shall ensure that the systems installed by it for facilitating P2P exchange does not disrupt Distribution Licensee's system
3. Service Provider shall ensure that there is seamless settlement between P2P partners
4. Service Provider shall ensure that its cloud & communication facility is flexible to accommodate any operational or regulatory change
5. If a meter is installed by the Service Provider in series with Distribution Licensee's meter and this meter becomes defective, then it shall be incumbent upon the Service Provider to replace its meter within 24 hours

UPERC Guidelines for P2P Trading

Roles and Responsibilities of Licensee

1. Licensee shall work with the Service Provider to integrate their systems
2. To ensure that metering is in order, if a defect emerges in the Distribution Licensee's meter of a P2P participant, the Distribution Licensee shall replace the meter as per provisions of Electricity Supply Code
3. If the distribution system is under outage, then no penal imposition will be made on either P2P Prosumer or P2P Consumer for the failure to transact as per committed transaction. However, UPERC Standards of Performance Regulations shall be applicable for P2P Consumer

Power to Amend

The Commission may, at any time add, vary, alter, modify or amend any provision of these guidelines

Redressal Mechanism

If there is any dispute between the P2P participant and licensee/Service Provider, then the P2P participant shall approach the corresponding CGRF. If there is any dispute between the Distribution Licensee and Service Provider, then Distribution Licensee/ Service provider shall approach the Commission

UPERC Guidelines for P2P Trading – Definitions

Blockchain: Blockchain is a digitally distributed, decentralized, public immutable ledger that exists across a network for recording transactions

Nth Month: The Month in which Distribution Licensee raises the bill of P2P participants for energy transacted on P2P platform

Nth day: Day on which energy is transacted on P2P platform.participants for energy transacted on P2P platform

P2P Transaction: Peer to Peer transaction means transaction of energy among P2P participants through P2P platform provided by Service Provider

Participant: Means a prosumer or a consumer who has registered with the Distribution Licensee and Service Provider to sell or buy rooftop solar energy through P2P platform provided by the Service Provider

UPERC Guidelines for P2P Trading – Definitions

P2P Platform: Peer to Peer Platform means blockchain based electronic platform provided by the Service Provider on which P2P Prosumer can sell their solar energy to P2P Consumers at a price mutually agreed by them on P2P Platform

P2P Prosumer: a person who is a consumer of Distribution Licensee and is registered with the Service Provider to sell its solar energy generated through rooftop solar under UPERC (Rooftop Solar PV Grid Interactive System Gross / Net Metering) Regulations, 2019 on P2P platform

P2P Consumer: A person who is a consumer of Distribution Licensee and is registered with the Service Provider to buy solar energy through P2P platform from a P2P prosumer

Service Provider: An agency who registers itself with UPPCL to provide P2P solar energy transaction services on blockchain based P2P Platform

Consensus Mechanism in Blockchains

Consensus mechanism is the methods used to achieve agreement, trust and security across a decentralized computer networks. Consensus mechanisms play an essential part of securing information by encrypting it and using automated group verification

All consensus algorithms attempts to solve the Byzantine Fault Tolerance (BFT) - an approach that resists a system to get into the Byzantine Generals' problem. It also means the system should stay intact even if one of the nodes (or General) fails. In addition, BFT aims to reduce the effect of malicious byzantine nodes (or General) on the network

Sl No	Consensus Mechanism	Description
1	**Proof of Work (PoW)**	PoW is a common consensus algorithm developed in 1993 which was revived and demonstrated successfully by Satoshi Nakamoto in 2008 for the Bitcoin network. It requires a participant node to prove that the work done and submitted by them qualifies them to receive the right to add new transactions to the blockchain. PoW requires high energy consumption and long processing time; but is the most secure method against byzantine failures.
2	**Proof of Stake (PoS)** – *Delegated PoS; and Leased PoS*	PoS is another common consensus algorithm that evolved as a low-cost, low-energy consuming alternative to the PoW algorithm. It involves allocating responsibility in maintaining the public ledger to a participant node in proportion to the number of virtual currency tokens held. This mechanism randomly chooses a maximum coin owner to validate a transaction. It also allows the owner to create a block for the same coin. This mechanism requires comparatively less energy and transaction time. Coins like Etherium 2.0, Polkadot, Cosmos, Cardano, ThorChain, Nxt and Algorand use PoW. If one person (node) owns 51% or more of a particular coin, then that person will get sole ownership of its network which is a security risk.

Consensus Mechanism in Blockchains

Sl No	Consensus Mechanism	Description
3	**Proof of Authority (PoA)**	In this unique mechanism, there are validators with approved accounts which authorize transactions and the creation of new blocks. These validators must disclose their true identity to get the right to validate a transaction. PoA is used for permissioned public and private Blockchains. The main requirement for this method is that all participants should be known and highly trusted.
4	**Proof of Activity (PoA)**	This mechanism is a combination of both PoW and PoS designed to combine the best features of both. In the beginning, the Proof-of-Activity mechanism functions like PoW. Once a new block is completed, it starts to function like a Proof-of-Stake mechanism. Coins such as DCR (Decred) use this mechanism.
5	**Proof of Provenance (PoP)**	PoP is a concept used in blockchain technology to verify the origin and authenticity of certain data or assets. It ensures that the information stored on the blockchain is reliable and can be traced back to its original source. It also focuses on establishing a trustworthy record of their origin, ownership, and journey. This record is crucial for industries where the traceability and integrity of information or physical items are of utmost importance.
6	**Proof of Elapsed Time (PoET)**	Intel Corporation created this mechanism to permit blockchain to decide the person who will create the next block. It uses a lottery system to decide the next block creator. Thus, it gives a fair chance to all traders to create the next block. It is an efficient process involving lesser resources and low energy consumption.
7	**Proof of History (PoH)**	PoH was developed by the Solana Project - it is similar to Proof of Elapsed Time (PoET), which encodes the passage of time itself cryptographically to achieve consensus without expending many resources.

Consensus Mechanism in Blockchains

Sl No	Consensus Mechanism	Description
8	**Proof of Capacity (PoC)**	The PoC mechanism heavily relies on free space available in the hard drive. This is because there are many solutions to a coin's hash problem that a trader needs to store. It is highly efficient as compared to PoW and PoC mechanisms. Coins such as Burst, Storj, Space Mint and Chia use these mechanisms. Example – Burst coin and Space Mint
9	**Proof of Burn (PoB)**	PoB aims to improve the quality of blockchain so that it can be used easily and extensively as a tool for faster and more secured transactions. After PoW and PoS, PoB is designed to prevent fraud activities on a blockchain network. Cryptocurrencies such as Bitcoin use this mechanism to offer secure transactions to traders. Example – Slim Coin

- **Since there is no central authority in a blockchain network to validate the transactions, consensus algorithm is used to arrive at consensus to verify every transaction**
- **The consensus protocols ensure that every new block added to the blockchain is the one and only version of the truth that is agreed upon by all the nodes in the blockchain**
- **Consensus algorithms assume that some processes and nodes will be unavailable at times; algorithms also assume some communications will be lost in transmission – however a response is required from available nodes; algorithms may require at least 51% of nodes to respond to achieve consensus**
- **Consensus algorithms ensure consensus is achieved with minimal resources**
- **Each block is intended to generate a hash value; and the nonce is the parameter that is used to generate the hash value**

Programming Languages for Blockchain Applications*

Blockchain Language		Pros	Cons
Solidity	• Solidity is the most widely used programming language for developing smart contracts on the Ethereum blockchain	• Statically typed Blockchain Programming language • Easy-to-use feature • Provides high accuracy rate • Application Binary Interface	• Additional feature cannot be added to the contract • Insufficient code coverage • insufficient centralised documentation of known vulnerabilities
Java	• JavaScript is a versatile programming language commonly used for web development. It is also used for developing decentralized applications (dApps) on blockchain platforms like Ethereum.	• Java is a platform-independent language • Developer friendly • Secure interface- Java reduces security threats by avoiding the use of explicit pointers • Multithreaded and dynamic	• Memory Consuming • Java provides no backup facilities • it is verbose, which means it contains many keywords and consists of long and complex coding.
Python	• Python, renowned for its versatility, boasts an extensive ecosystem comprising numerous libraries and frameworks. Within the realm of blockchain development, Python plays a significant role in various tasks, including the creation of blockchain applications, interaction with blockchain networks, and data analysis.	• Extensible features • Object-Oriented Programming language • Extensive library • Short codings	• Weak in cell phone devices • Frequent run-time errors • Memory consuming language
C++	• C++ is appreciated by blockchain programming developers for its richness in run-time polymorphism, function overloading, and multi-threading.	• Structured programming language • Global data and functions are used in C++ • Developer-friendly • Comparatively rapid and powerful	• Doesn't support Dynamic Memory Allocation • Complexity increases with the length of coding • Platform Specific Language
Rust	Rust provides developers with several advantages. First and foremost, its emphasis on memory safety eliminates common issues such as null pointer dereferences and buffer overflows, which are critical for secure blockchain applications	• Rust's ownership system and strict borrowing rules eliminate common memory-related vulnerabilities • Focus on low-level control and zero-cost abstractions • Lightweight concurrency model • Rust has a growing ecosystem of libraries and frameworks	• Investment of time in learning and understanding its concepts • Rust's emphasis on safety and correctness may require more code and effort compared to other languages • It may not have as many resources, tools, and community support
Ruby	The primary emphasis of Ruby is on simplicity and productivity, making it user-friendly and easy to handle. Additionally, it supports cross-platform compatibility, allowing developers to work seamlessly across different platforms.	• It is a Multi-Paradigm Language • Rail frameworks have a huge and strong developer community (Ruby on Rails); • Can be installed in Windows as well as PIOX	• Difficult to debug • It has lower Flexibility • Processing speed is comparatively low

** Source: Sana Afreen, Senior Research Analyst, Simplilearn, 2023 (https://www.simplilearn.com/blockchain-programming-languages-article*

Programming Languages for Blockchain Applications

Blockchain Language		Pros	Cons
Vyper	• Vyper is Blockchain programming language built on Python 3. So, even if Vyper does not have all of Python's features, the Vyper syntax is also legitimate Python 3 syntax.	• Strong focus on security and includes built-in features and restrictions • Vyper's syntax is designed to be similar to Python • Vyper's simplicity and restrictions make the code more auditable and verifiable • Create more predictable behavior in smart contracts.	• Vyper intentionally restricts certain advanced features and low-level operations • It may require a learning curve for developers • Vyper has a smaller community and ecosystem. • The tooling and documentation might not be as extensive or mature
Golang (Go)	• Golang, or the Go language, is a statically typed and compiled programming language that has gained popularity among developers globally for Blockchain Programming development due to its notable features	• Run-time Efficiency • Smooth web application building • Garbage collection • Organized typing	• Error Handling • Still new in the market • No niche like Java • Comparatively fewer packages
C#	• C#, pronounced as "C Sharp," is a highly popular open-source programming language created by Microsoft.	• Rich library class • Memory loss is not a problem • Assembly concept makes the issue of version control easier and handles it well. • Act as a support for the distributed system	• A programmer cannot access low-level things like using and interacting directly with hardware through drivers and firmware • It does not have an independent compiler • It uses byte codes and the JIT compiler as a link between machine code and hardware which makes the execution process lengthy and time taking
Rholang	• Rholang is widely recognized as an excellent programming language for smart contract development.	• It is reliable and Secure • User-friendly • It is designed for Speed in blockchain programming	• Still new in the market and fewer users know about it
Hypertext Preprocessor (PHP)	The widely used PHP language, based on the Zend Engine, is an open-source and platform-independent programming language	• Open-source programming language • PHP is a platform-independent language and it can be used along with any operating system • It is simple and straightforward • It has built-in database connection module	• It has not the huge content-based web applications • It does not allow modification in the core functions • Runtime errors are frequent • PHP is tough to manage as it imitates the features of the Java language
Simplicity	Simplicity was developed to be in harmony with Blockstream's Elements platform. It is seen as an opportunity to open up to Liquid Network users such as trust-reduced escrow, vault, and other sophisticated smart contracts.	• Reliable • Recently, the development of EVM failed during the testing process because usage does not match the result of the calculation • Simplicity overcomes all the limitations of other languages and is a secure and reliable application for blockchain programming	• The code optimizers can still be developed • It is still left to combine functional and formal correctness of cryptographic protocols for the smart contracts to be fully verified.