Open-Source Electricity Trading through the Lenses of a Developing Country

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Abstract: A powerhouse under development, India is slowly breaking free from its traditional methods of operations. It has been chosen for analysis as it offers a plethora of diverse cultures and a variety of indigenous groups of people. The energy sector of the country is transitioning to adopt policies that are in line with its sustainable goals. Focusing on peer-to-peer energy trading and the development of blockchain technologies, unconventional methods are slowly being incorporated with the help of various experimental projects. This is backed up by peer-to-peer trading of energy providing a prosumer with an autonomous environment. The paper looks into the ongoing trends in this sector and major reforms that are required to bring about the necessary shift. Challenges and their recommendations are also been discussed along with the need to implement them. Suitable conclusions have been drawn that aim towards favoring the P2P style of open-source electricity trading as the need for such an analysis is vital to achieve a decentralized energy system.

1 Introduction

IN the massive subcontinent of India there reside 1.39 billion people [1], which is roughly 17.7 percent of the total world population [2]. Housing such many people, a highly efficient system is needed to cater to all their needs. Especially for a country that calls itself a 'developing nation', there is a fierce need for evolved and practical technology.

India is well-known to have a rich natural reserve of energy-generating ingredients. Over the years, these have been fashioned into recipes by electricity-producing giants of the nation such as the Adani Group, Tata Power, and many more [3]. In fact, electricity and power are parts of the heritage of India as well, serving as the founding grounds for cities such as Jamshedpur or 'Tatanagar' [4]. However, these methods are not sustainable in nature. As the Law of Demand and Supply follows, prices increase as the quantity of a commodity decreases. Thus, this would mean electricity costs will progressively increase as time passes leading to a shortage and more power outages. This is the current scenario of the country, a shortage of 42.5 million tonnes of coal is already expected for the next quarter which is 15 percent more than what was anticipated [5]. The nation is on the brink of a power crisis and a need for better methods for power generation is vital for the country's growth.

Here, we can start to explore the world of open trading of electricity and P2P-energy sharing which is explained with the help of Figure 1. With such a massive number of people in the country, we need to decentralize the power dynamics in the energy-producing sector so that a maximum number of people can be a part of this. Currently, this oligopolistic system enables only a few participants to govern the generation, transmission, and distribution of energy in the country. Various DISCOMs fall under the jurisdiction of the government but in collaboration with private companies.

Presently, P2P-energy policies are in play in some states in the country. The states of Uttar Pradesh [6] and

Delhi have started projects that use this technology in collaboration with companies such as TATA and PowerLedger [7]. These projects will include prosumers who can generate and sell solar energy on various platforms, this will ensure a high degree of transparency between the parties. This is solely a trial project, powered by the Australian company (PowerLedger). Although there are prevailing policies regarding net-metering in these states, it can be easily misunderstood for P2P-energy trading. Thus, Figure 2 explains the difference between the two.

Apart from this, some policies already exist for states by the P2P-energy sharing technology and net-metering. A joint initiative by the Government of India (GoI) and the respective state governments exists which comprises various objectives and challenges of the state. The '24x7 power for all' initiative discusses the need for renewable energy and how this can be implemented in that particular state [8]. A discussion about the power requirements of each state, how it manages to accomplish that is provided in this description, and the gap between the two. With the policies mainly existing per state, they also exist for the various DISCOMs that distribute this energy. Although policies cannot be reformed much at the state level, these distribution companies can help achieve this goal of setting up P2P-energy grids along with other Distributed Energy Resources (DERs).

The price and distribution of electricity are further decided by the two major energy exchanges of the country- The Indian Energy Exchange and The Power Exchange of India [9]. These provide a platform for trading and the physical delivery of electricity to whoever requires it [10]. By the evolution plans of the market, these companies too plan to work on projects favoring open-sourced electricity trading. The IEX plans to set up a physical and virtual layer to enable transactions between the prosumer and the buyer and then further enable them to physically transport the energy between parties [11]. Thus, while these 'exchanges' acted as distribution and networks earlier, they will also act as a passive intermediary between two individual parties that deal with the small-scale production of electricity.

With such an extensive discussion regarding open-sourced electricity, it's important to know how it offers an advantage as compared to other systems and set-ups. A simple argument could be, the balance of energy producers and consumers in the market. With a decentralized set-up, the power would not lie within the hands of a few, there would be no 'hub' that can claim sole responsibility for the generation of power. Thus, with a more scattered strategy, energy needs can be decided by those who use it. In the event of a foreign attack, such a layout would also be advantageous and prevent damage. In the case of cyberattacks and natural

disasters, the risk of data theft and failure of the power grid can be reduced as this system would allow a continuous supply of power due to close proximity between the consumer and prosumer [12-13]. It also ensures a stable coalition between the participating prosumers [19]. These advantages are not yet highlighted when policies are made in this respect, more impactful and practical research is needed before policy-makers turn their heads and consider these factors.

Australia, Bangladesh, Canada, Columbia, USA, and many more have already started with their P2P-energy sharing schemes [14]. Companies such as Brooklyn Microgrid, Centrica plc, Lumenaza, and many more provide a platform for prosumers to sell their generated electricity. These countries focus on renewable energy sources and some even have mandatory laws to implement such a shift. For example, in New York City, a Climate Mobilisation Act was passed in 2019. According to this act, a series of laws were passed to reduce greenhouse gas emissions responsible for 67% of the city's carbon footprint [15]. One such law stated that all buildings that were under construction/major renovations would require the installation of rooftop solar panels. These measures taken by the city council were perfect for promoting the P2P energy-sharing market.

But, as all good things go, there will surely be some major problems while setting up this new system. Due to the varied variety of seasons that are experienced in different parts of the country, it is not possible to follow just one form of electricity generation. 1/10th, that is, 8.9 percent of the total energy generated is RE by wind and solar [18]. But, solar panels and hydro-electric methods pose their challenges and in general cannot be used throughout the year. In addition to the legal and physical challenges, such a system would oppose the traditional network of the electric grid [16]. India has the potential to grow up to 5 percent over the next 30-50 years [17]. So, the need for awareness is a must, and campaigning is required so people understand the uses and advantages of this technology. We shall discuss these challenges in detail and also recommendations to overcome them. Along with that, we will also analyze the world of open-sourced electricity in the Indian context to grow this sector even more and exploit it in the best way possible.

2 P2P-Energy Trading Projects in India

2.1 Tata Power- DDL, India [20-25]

This is an initiative by Tata Power in collaboration with The Indian Smart Grid Forum (ISGF) and an Australian company called Powerledger. With an effort to introduce the concept of P2P-energy sharing in the Indian market, this Ethereum-based platform provides a basis for efficient transactions between the prosumers and   consumers.
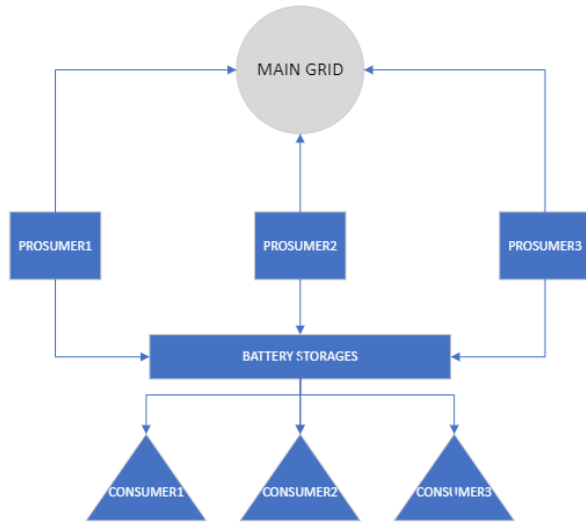
Fig.1 Simplified concept of P2P-energy sharing.

a. Net Metering

b. P2P energy sharing
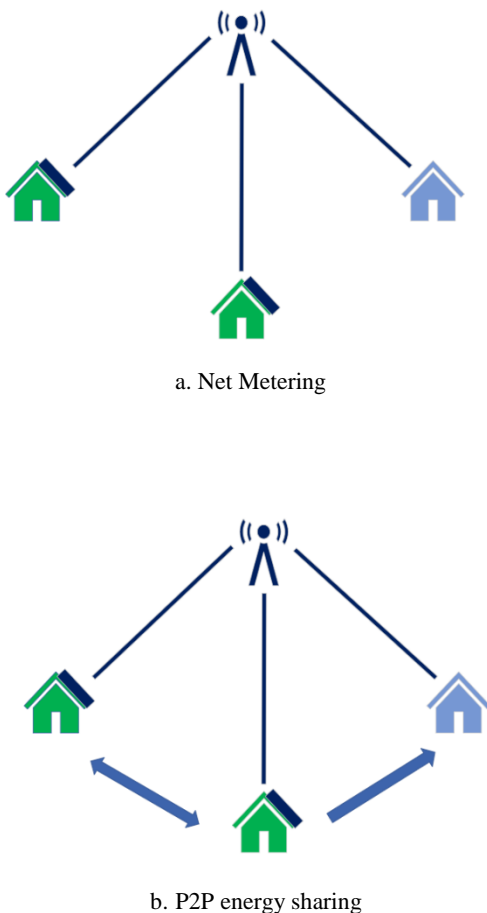
Fig. 2 (a) Net metering v/s (b)P2P energy sharing.

This project consisting of 150 energy meters includes the Tata Power Delhi Distribution Limited

locations and also their customers with solar generating assets. The main motto is to decentralize the energy market and provide economic and monetary benefits to the participants. This will encourage India's rapid adoption of renewable energy powered by Power Ledger and (ISGF) [20].

Such a platform enables prosumers to set their prices according to the units of electricity they can spare. It ensures a high level of transparency as participants can track the transaction process in real-time. Such a need for independent energy-producing units is a must in a country with a high population density.

The project focuses on the TPDDL grid as a whole while also providing energy to EV charging stations and battery energy storage systems. This would enable their development, help in increasing their usage, and promote green energy.

The project is also aligned with International/National initiatives. These are:

1) International Solar Alliance: 'To scale up solar energy, reduce the cost of solar power generation through the aggregation of demand for solar finance, technologies, innovation, research and development, and capacity building' [21].

2) National Strategy on Blockchain, MEITY:

This P2P-based project will be revolutionary in the Indian market as it would directly enable the citizens to figure out their power needs. With the country on the brink of a power crisis, it is important that the people of the nation become increasingly aware of the concepts of power generation and make their respective contributions. This technology will pave way for the future generations to be more involved in the power sector as a whole and be responsible for their needs. Electricity is a vital 'resource' in today's world, it's like blood in the veins of our developmental infrastructure. To grow as a nation, it is extremely important that this is abundant and easily accessible.

2.2 Uttar Pradesh Government, India [26-31]

The UPPCL, Madhyanchal Vidyut Vitran Nigam Limited (MVVNL), and UPNEDA have launched a project involving blockchain technology for energy sharing in Lucknow. This energy is mainly generated by installing rooftop solar panels. The government has waived the per KW transaction fee and meter per day fee. Such projects are supported and funded by the GoI and encouraged by the Indian Smart Grid Forum (ISGF).

The country needs such P2P projects involving clean energy. Thus, the government should target major money-makers in the state most of which could be corporates and other large institutions. By doing so, awareness could be raised and people would understand the importance and the concept of such initiatives.

This has proven to be a success in Lucknow and has led the UPERC to create a tariff order directing that all

utilities in the state make provisions for P2P trading. This makes UP the first state in India to adopt such a policy on blockchain-enabled solar power trading. The Union Government has also set a target of installing 40 Gigawatt of rooftop solar power generation capacity by 2022. This would enable prosumers to have a better understanding of their energy needs and make them conscious of wastage and excessive use of electricity.

Uttar Pradesh became the first state in India to do P2P trials and the government has introduced blockchain technology to enhance the rooftop solar power segment. It is also the only state that has amended its regulatory framework to enable controlled P2P energy trading in the country.

Moreover, in 2022 the World Summit Awards (WSA) recognized Powerledger as the winner in the Environment and Green Energy category for the UP project. They have successfully shown how this P2P model can support societal challenges and can help in achieving the United Nations Sustainability Development Goals.

2.3 BSES Rajdhani, India [32-34]

BSES Rajdhani Power Limited in collaboration with Power Ledger has proposed trials for solar power trading in Dwarka, Delhi. This trial would focus on demonstrating that P2P solar trading can be successfully undertaken in populous metropolitan cities. It became the first DISCOM in India to introduce a blockchain technology-based platform to trade electricity.

The pilot project will include selected groups of gated communities (CGHS) in the region that have the capacity to generate 5-6MW of solar power. They can further use this platform to trade power with willing consumers residing in adjacent buildings and neighborhoods.

P2P-energy sharing has numerous advantages for both the parties involved. The energy-generating bodies i.e., the prosumers can sell electricity at their price. The consumers can buy it at their liberty as per the requirement and benefit from this cheaper and cleaner electricity.

BRPL (BSES Rajdhani Power Limited) also benefits from this P2P project as they don't have to buy solar energy to export it to the grid, rather than they can gain their revenue by charging a transaction fee and formulating an engaged relationship with its consumer base in this blockchain-based platform.

Therefore, this project shows that a blockchain based platform can be a good way to trade electricity with many benefits and can also be considered for virtual net metering, EV charging, and many more applications.

3 Indian Scenario

India ranks last out of 180 countries in the Environmental Performance Index [35]. According to the Global Status Report of 2022, India is globally in 4th position for total renewable power capacity [36]. The Govt. of India has planned to set up the installation of 175 GW of renewable energy capacities by the end of 2022 which further breaks down as 100 GW from solar energy, 60 GW from wind energy, 10 GW from biopower energy, and 5GW from small hydropower energy [37]. As of now India has met nearly half of its target of 175GW renewable energy capacity and is one of the top three nations leading renewable energy growth. Additionally, it is predicted that while meeting this target it could create 1 million job opportunities for over 30,000 people in the country [38].

More than 70 billion dollars have been invested in the past 7 years for renewable energy development in India [39] and more investment is expected. India is considered to be a growing economy and the increasing rate of urbanization as well as per capita income demands more energy consumption as well as generation [39]. A total budget allocation of INR 6900.68 crores was reserved for the Ministry of New and Renewable Energy by the Union Government [40].

Renewable energy provides an opportunity to reduce carbon emissions giving us a chance to sustain a better life. In a country like India with a population of 1.39 billion, fossil fuels are likely to be scarce due to their limited amount and their prices would increase in the near future. They have negative impacts on the environment and contribute to the global CO_2 emissions. Thus, it is necessary to adopt eco-friendly policies that are in line with the sustainable development goals of the country.
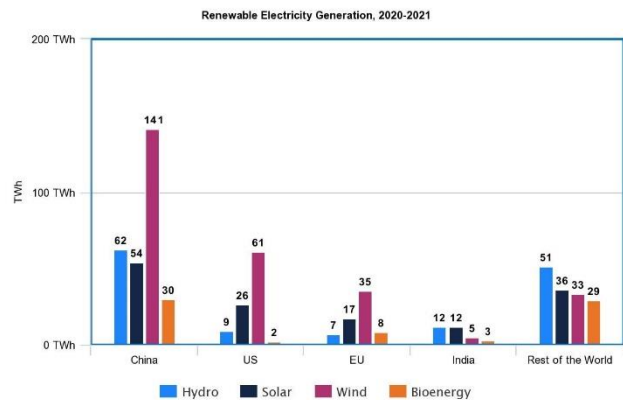
Fig. 3 Renewable Energy Generation, 2020-2021.

With the help of Figure 3 we can see that fuels created from non-renewable resources are the most popular source of power generation across the World.

Coal, natural gas, and petroleum are amongst the most popular means of power generation, especially in a country like India.

From Figure 3, we can observe the distribution of energy sources in India in terms of their installed generation capacity in megawatts (MW). The total reserves of coal in India are expected to be 319.02 billion tonnes. Jharkhand has the most reserves followed by Odisha and Chhattisgarh [46]. Almost 80% of energy needs are met by mainly three fuels which are coal, oil, and solid biomass [41]. India is the 3rd largest emitter of CO_2 around the world [42] despite having less per capita carbon emission if compared with other countries [43]. According to the sustainable development plans of the country, the goal is to increase green energy capacity to 500GW by 2030 and a target of achieving net zero emissions by 2070 [44-46].
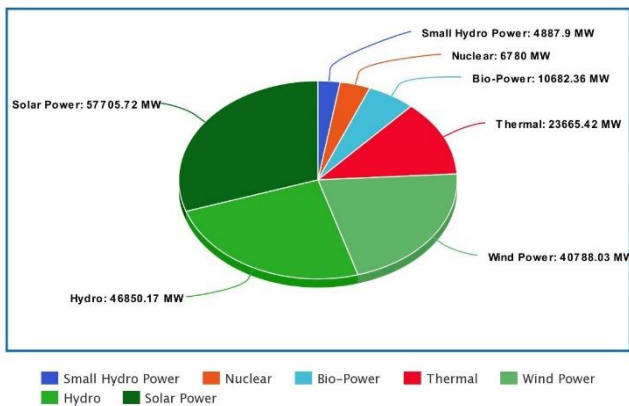

Fig. 4 Distribution of renewable energy sources in India [88].

3.1 Effects on the Economy

There exists a directly proportional relationship between electricity consumption and the growth of an economy. Specifically speaking for wealthy and developed nations, it was observed that more consumption of electricity by the developmental institutions led to a higher contribution by them to the GDP in the country [47]. This would be a more valid argument for developed OECD countries that already have a solid set of policies in place ensuring that their energy reserves are taken care of [48]. Although looking at the provided statistics and reports this would surely seem like a positive trend, we need to consider all variables that factor in a country's actual development. According to a report, the USA ranked first as a country with the highest contribution to the world GDP and GDP per capita, while China ranked second position [49]. This data can be highly misleading while analyzing the actual development of a country and its contribution to the world. Another report depicting the CO_2 emissions of various countries ranked China and the USA as first and second, respectively with their contributions to worldwide GHG emissions [50]. Thus, it can safely be

concluded that these 'developed' countries need to reform their policies to ensure sustainability [51].

India is a partner of the Organization of Economic Cooperation and Development (OECD) but has not been included as a member due to various political factors, it does participate in surveys and policy discussions. This is also due to the fact that India is considered to be a 'developing' nation and is still working on its developmental framework. The OECD Commission consisting of the countries highlighted in Figure 5 would list this as a disadvantage but it can be useful to bend to policies to parallel with various sustainable development goals.

Fig. 5 OECD countries on the world map [89].

India is the second largest producer of electricity in Asia and achieves this goal by using coal, natural gas, biomass, nuclear power, and some other non-conventional resources for power generation [52]. The generation of electricity starts at power plants/generating stations by generators that make use of coal, wind, natural gas, and water to generate electricity. The generated current is further sent to industrial transformers in order to increase the frequency and decrease the power loss. This electricity is then sent to high voltage transmission lines that connect various substations. Substations decrease the voltage so that it can reach smaller power lines which connect to local neighborhood distribution networks. Further, pad mount transformers are used to reduce voltage so that the power is safe to be used in households. These distribution lines are passed through household meters to record the usage of electricity. Thus, power generation is centralized at high-capacity plants and households rely on them for their power supply. However, this layout is not deemed to be feasible for the future of the country. This can be understood easily in Figure 6.
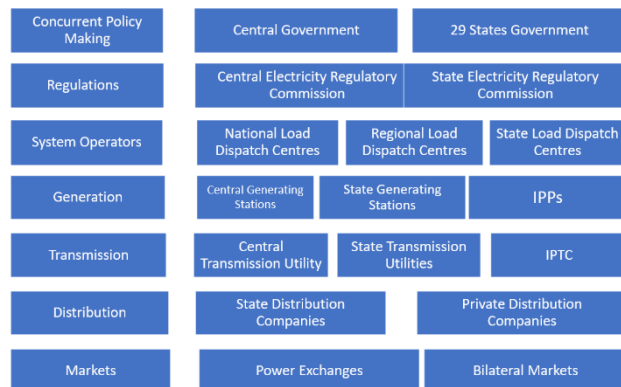
Fig. 6 Power Structure of India [91].

Seeing the trend of growth, India's GDP is now expected to grow at 7.1 percent in 2023-24 [53]. Although this seems like a positive outcome of the prevailing policies it is difficult to determine whether it directly benefits its citizens. The country ranks 131 out of 189 countries on the Human Development Index presented by the UNDP in 2020 [54]. Such contradictory statistics indicate a vital reform in developmental policies.

Looking at the power-generating policies of our topic of research, 75 percent of the total electricity generated comes from the Ministry of Coal and Thermal Power [55]. Other non-conventional resources such as solar power only account for 4 percent of the total energy produced.

India now aims to reach 450GW of renewable power generating capacity by 2030 [56]. It is also the only country in the G20 League of Nations that is on the path to achieving its targets under the Paris Agreement [57]. There are various schemes: -

- Rent-a-roof policy – This policy was aligned with the sustainable development goals of the country with an ambition to generate 100GW of clean energy by rooftop solar panels. Under this policy, developers are to be responsible for installing panels and then leasing them to households. The generated power is to be supplied to the grid and a general scenario of net-metering will be observed [58].
- The union government allocated funds of 19,500 crores for the development of high-efficiency solar modules in the country [59].

Many other policies and decisions made by the government aimed at expanding renewable energy capacities and making it the major source of power in the country.

The sector of renewable energy is vast and highly unexplored. When we talk about this market the first thing that comes to mind are the various sources of this green energy. Major research in our country is also aimed at solely the extraction and exploration of these non-conventional resources. In this new era, we have to move forward with our research and try to explore ways to put these resources to practical use.
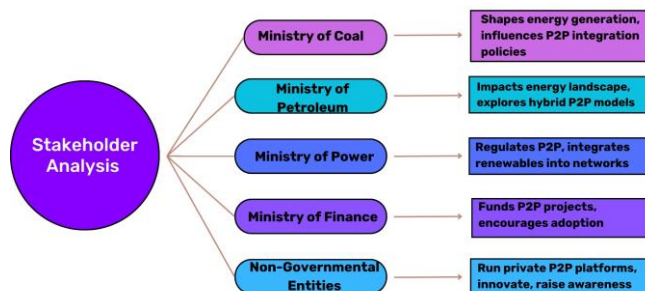

Fig. 7. Stakeholder Analysis for P2P.

Figure.7. presents the essential contributors in India's power sector displaying their roles in advancing P2P energy trading. Ministries including Coal, Petroleum, Power, and Finance are highlighted for their unique contributions. Additionally, non-governmental entities like private P2P players, research institutions, and grassroots initiatives are showcased.

Open-sourced electricity refers to power generated by a prosumer using their means. This power would be sufficient for their use and the surplus can be supplied to the grid in exchange for money. In such a market, electricity can be viewed as a commodity that can be produced on a vast scale. Employing all major rooftops using solar panels and then eventually accommodating even the households of the nation, the country can be transformed into an "electricity farm" where each household is responsible for its energy needs. This concept can surely work wonders in a utopian society where the general politics and complexities of our world do not exist. But even so, for the sake of intellectual argument, we can try to hypothesize this for our world.

In India, the demographics usually play to the disadvantage of the people. According to a report, 86.8 million people in the country live in poverty (BPL) [60]. The country has a very poor standing according to the HDI and large rural parts live in the absence of modern technology. Some villages even live depreciated of electricity. Of all the villages that are accounted for by the government of India, 4 percent have no access to power [61]. These people who are completely unaware of the concept of an 'electrical-grid' live backward lives and are not subjects of growth. Even after various schemes by the government such as USHA and Rajiv

Awas Yojana, these villages live in a shadow of poverty [62].

Even if we talk about villages that have access to power, they live their lives largely powered by government subsidies for their various basic needs. Largely talking about the population that falls under the employment of the primary sector, residing in villages and at farms. The GoI offers support in the form of subsidies for food, fertilizers, LPG, and many more basic commodities [63]. Even the electricity received by most households is subsidized and one can ask for it if they are financially troubled [64].

The paper acknowledges conflicts among different parties like ministries, government, and non-government entities regarding P2P energy trading in India. These conflicts arise due to differing policies and authority issues due to various reasons. For instance, the Ministry of Power and the Ministry of New and Renewable Energy have different priorities—ensuring grid stability versus promoting renewables. This clashes with P2P trading's reliance on renewable sources, which might not fit traditional grids. Also, conflicts arise due to differences in jurisdiction and state-level support for implementation. To tackle these, the paper emphasizes collaboration among stakeholders, aiming for common goals like promoting renewables, better energy access, and stable grids.

3.2 Indian Energy Exchanges

Power Exchanges provide a platform to buy/sell power where the underlying asset is electricity. The Exchange-based power trading is regulated by the Central Electricity Regulatory Commission (CERC). An exchange represents a market-driven economy where prices of electricity are decided by the forces of demand and supply.

3.2.1   The Indian Energy Exchange [65-66]

The Indian Energy Exchange, often abbreviated as IEX, is an electronic-based power trading platform regulated by the Central Electricity Regulatory Commission. It serves as a nationwide forum for the physical delivery of electricity, renewables, and certificates.

In their innovative strategy for the future, IEX plans to make use of P2P-energy trading technology to bridge the gap between green energy and its active investors. They plan to exploit this world of renewable resources and have formulated a plan in the context of the Indian subcontinent.

The goal is to establish a system where the participants can decide their power needs and manage them accordingly. This is to optimize consumption costs and maximize revenue. The IEX has an extensive plan to establish a virtual and physical layer wherein the prosumer and consumer can customize their plans according to their needs.

The virtual layer would take care of settling the financial matters between the buying and selling parties as they carry out the necessary transactions. It ensures an equal platform between all the participants where information can be exchanged between participants. Consumers can customize their plans and mention specific requirements. On the other hand, prosumers can mention their power generation capacity and what they can offer. Once a prosumer matches with a consumer, they can contact each other and finalize a deal. This layer securely takes care of the monetary aspect of the deal as well.

Upon the completion of this step, the physical layer would provide the structural framework in the form of traditional grids or separate physical micro-grids. These may be managed by independent system operators or DISCOMs.

With both these layers, a P2P energy trading market can be set up with IEX as the regulating party. This would help in development of the renewable energy and provide various other benefits for the DISCOMs as well as the prosumer.

3.2.2   Power Exchange India Limited [66]

Power Exchange India Limited also known as PXIL works exactly like IEX, in principle. It provides an electronic platform for power-related transactions and its allied products. PXIL is governed by the Central Electricity Regulatory Commission (CERC) and was launched on February 20, 2008. It boasts itself as India's first institutionally promoted power exchange. Apart from power trading, PXIL is also used for transmission clearance. This exchange also provides Renewable Energy Certificates.

Currently, it deals with 3925 active clients and has served 2.8 million MWh of power to date. Its mission is to increase transparency and to make transaction speed high by optimal utilization of local and global insights. This ensures constant growth and evolution which is vital for a major institution of India such as the PXIL. It has also been backed by the National Stock Exchange (through its subsidiary NSICL) and National Commodity and Derivates Exchange Ltd (NCDEX).

PXIL has played a crucial role in transforming the power market of the country. From the start, their aim has been to provide a developed technology solution to meet the growing needs of its participants. Their major contributions include: -

- "Make in India" trading system - PXIL has developed an IT-based trading platform that has

evolved over the years and has proved successful. It has high scalability and can efficiently incorporate new products and services. It also ensures minimum time to execute the trade as compared to its various counterparts.

- MILP-based matching engine- The Mixed Integer Linear Programming engine is a uniform clearing price matching model developed by IIT Bombay. This engine determines optimal matches between power suppliers and the market demand.

PXIL has a membership from all prominent trading licenses, they contribute nearly 95% of their total volume. It plays a crucial role in monetizing sustainable-led activities by providing the prosumer with REC and energy-saving certificates. The exchange is currently working on developing other market mechanisms and contracts while the health of the environment into consideration.

This would provide a reliable and robust platform that can manage the distribution and generation of electricity efficiently and also provide stability to the grid.
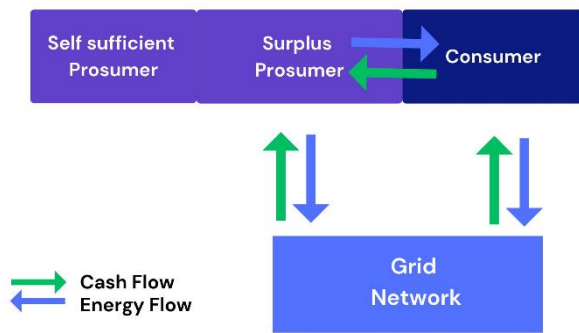
Fig. 8 Energy and Cash flow in P2P framework.

Figure.8. illustrates the dynamic energy and money interactions involving self-sufficient prosumers, surplus prosumers, consumers, and the power grid within the peer-to-peer electricity trading framework.

3.3 Policies
3.3.1. 24 X 7 Power for all [68-69]
A joint initiative by the central government and state governments of India aims to provide 24 x 7 power supply and "connect the unconnected" that remain detached from the grid.
The objectives mainly include –
- Focusing on strengthening the transmission and distribution network so that it can be established as an efficient grid.

- Plans to introduce modern technology to ensure reliable power supply like substations and automation of the prevalent infrastructure.
- State-specific power needs have been considered in conjunction with the states in the form of PFA papers to achieve the aforementioned goals. According to the PFA document, it covers generation, transmission, distribution, financial viability, renewable energy, and efficiency of energy.
- The developments would be actively monitored and discussed in the span of the next 4 years to ensure necessary developments.

The roadmap document to achieve these goals has been signed by all 29 states and all 7 Union Territories of the country.

3.3.2 Green Energy Open Access Rules [70]

An additional significant change to support renewable energy through Green Energy Open Access which enables consumers in commercial and industrial sectors to go green. Consumers can specifically request DISCOMs to supply them with energy produced by non-conventional resources. These regulations are notified in order to encourage the generation, evolution, and consumption of clean energy including the bulk generated by waste-to-energy plants.
Features -
- Any consumer is eligible for Green Open Access. The Open Access transaction limit has been reduced from 1MW to 100kW for green to make it possible for small consumers to purchase open access.
- The rules are supposed to ease the overall approval process for providing Open access and simplifying the grid network. Such a system would also encourage local energy producers.
- Consumers are eligible for green certificates if they consume green power.

3.3.3 Electricity Act 2003 [71-72]

This act was introduced to the Parliament of India and is currently enforced by the Ministry of Law and Justice. Under the jurisdiction of this law, all major energy generating, transmitting, and regulation capacities of the country are affected by the norms (except those of the state of Jammu and Kashmir).
Features –
- Hydro-electric power producing stations fall under the implication of this act and respective

generators are to follow the new norms set under this policy.

- To promote the development of local energy producers, this act relieves a potential power-generating capacity from possessing the required licenses to set up a unit.
  However, necessary documents are required for a green light on making use of the main grid for the transmission, distribution, and trading of electricity.
- A bid to make the system more transparent focused on publicizing information regarding government aid and subsidies.
- A major boost to policies that focused on safeguarding and promoting environment-friendly mechanics.

3.3.4 Integrated Energy Policy [73]

An Integrated Energy Policy (IEP) created by the government of India was formulated in 2014 addressing all major energy sources, including non-conventional resources. During the 12th Plan period (2012–17), the Ministry of New and Renewable Energy (MNRE) created a plan to introduce around 30,000 MW of power capacity from various renewable energy sources throughout the nation.

For the advancement of solar power capacities in the nation: -

- A long-term objective of adding 20,000 MW of grid-connected solar power by 2022 was established. The National Solar Mission was undertaken to increase the usage of solar energy for power generation as well as direct thermal energy applications in the nation.
- Off-grid/decentralized solar power generation installations will be given a capital subsidy.
- A plan to promote off-grid-connected roof-top PV systems has also been developed with a 30% subsidy aid.

A roadmap is to be created for the optimal utilization of common infrastructure and the development of solar parks. This would lower costs in addition to other fiscal reliefs offered by this policy.

4 Advantages

In our previous discussions, the system and set-ups of open-sourced electricity have been elaborated in brief. They are mainly by the needs and the infrastructural capacity of the country. But it is also important to highlight what advantages this method offers over other conventional as well as non-conventional systems [74].

P2P-energy trading falls in an entirely new sector of "energy sharing", we cannot solely classify it as an energy-generating or transmitting technique. It mainly focuses on enabling the citizens with the power to be self-sufficient for their electricity needs. With a developing economy, the country needs certain things to be easily available in order to grow. Viewing electricity as a commodity is the first step, as we see in the two energy exchanges- a product that can be mass-produced with cost-efficient means and can maximize profit for both parties.

Many countries have adopted policies to incorporate consumer-friendly techniques for the benefit of their nation and to battle climate change. A good way to analyze the motivation behind choosing a P2P-based structure would be to look at these countries and their reasons.

A European Union-funded project aims at creating 'virtual pools' of connected energy storage within the neighborhood [75]. It essentially provides a P2P-interoperatibility network to connect domestic renewable energy sources (RES) directly to consumers relieving most Electric energy storage (EES) capacities. The unit cost of electricity is relatively higher when extracted from EES rather than directly from RES. Thus, a monetary relaxation can be provided to users making this model highly economical [76]. Various other benefits have been highlighted [77]: -

- Reduces the peak and minimizes various power losses faced by the network. This would also help in integrating P2P energy trading into the grid.
- The fluctuating energy supply generated by this decentralized system can be accommodated as demand can be shifted to various other participating RES and a single institution is not burdened by load.
- Ensures grid stability as the entire network cannot be broken down by the failure of one supplier.

Apart from the advantages offered by the aforementioned document, some others are: -

- Such a decentralized model proves to be an advantage in the event of a natural calamity as harm is not imposed upon the entire network in case some of them are subjected to unfortunate circumstances. Similarly, leakage of data can be prevented if a cyber-attack occurs to disrupt the convention. This can be additionally improved by enhancing existing cybersecurity measures to ensure safe and reliable data management and communication.
- Incorporating technologies such as smart meters into the P2P energy trading ecosystem

offers several benefits like enabling real-time monitoring of energy consumption, accurate billing, and transparent data exchange between consumers and prosumers. Allowing consumers to make informed decisions about their energy usage, aligning it with renewable energy availability, while prosumers receive fair compensation. The transparent data exchange enhances trust among participants, fostering cooperation and contributing to a more sustainable energy landscape.

Apart from lower costs of units of energy, generating power on a small scale can be a source of passive income for prosumers.

5 Challenges

India is one of the few countries that has witnessed massive growth in all major sectors that constitute and run a nation. Speaking from an economic point of view, the GDP of the country has been on a constant rise since the Economic Depression of 2008-09 [78] where there was a decrease of more than 2 percentage points. A comeback was made after the Government and the Reserve Bank of India took drastic measures [79]. The country also improved the general life and well-being of its citizens by ensuring easy access to basic amenities for all.

Since 2000, around half a billion people are now connected to the grid and have access to electricity. As announced in 2018 by the Indian Prime Minister, the country has achieved its target ahead of schedule and now provides electricity to all villages [80]. This is undoubtedly an extraordinary feat that makes a mark in the history of power and energy. People in rural areas of the country have shifted from unsustainable kerosene lamps and candles to light bulbs. This in turn would help in reducing the costs for buying oil to run lamps which would reduce the costs of an average rural household by 11.2 percent. This would amount to a total of $69 billion in savings on lighting alone [81]. But even after connecting every village to the grid, the country still faces an emergency.

Being highly relied upon by the centralized main grid, most rural and even urban areas face constant power outages. Despite all this progress, a large number of people still remain poor and with glow-less bulbs. Even with the present scenario of power generation in the country, 80 percent is obtained from unsustainable resources like coal and natural gas. This leads to highly detrimental impacts on the environment contributing to global CO2 emissions and global warming. As seen in our earlier discussions, India ranks highly for producing GHG gasses and in contrast, ranks extremely low on the Human Development Index [82]. So even if it can be rightfully argued that the majority of the population is now connected to the grid, it does not directly benefit or ensure the well-being of the people.

There is a need for a system of energy generation that is convenient and can be a passive part of people's lives. Such a method is conceptualized by P2P-energy sharing where local energy producers are average households and electricity is viewed as a commodity. But certain challenges arise while we try to implement this model: -

- A considerable amount of energy would have to be produced by individual households and setting up such capacities requires a stable fiscal income.

- As of now, the most popular non-conventional energy-producing source is solar panels. These are costly to set up and are high maintenance. Such a set-up might not be economically feasible for the average Indian household.

- Solar energy generation requires at least 300 sunny days [83]. Thus, only some states of the nation can use these to generate a considerable amount of electricity.

- People are highly unaware of this new technology and miss out on the benefits it has to offer. If they are oblivious to its existence, they cannot make use of it.

- Pilot projects undertaken by private companies or government-funded initiatives are important not only to check their viability but also their social effects. Such projects that had been initiated as experiments expose people to the possibility of evolved technologies. Thus, they help with increasing awareness about new initiatives. The government of India should also step in and campaign for such initiatives that harbor sustainable energy goals in the country.

- The government can also launch schemes and subsidies to provide monetary support once the idea of P2P-energy trading is popular and people accept it. Thus, willing participants can shift from traditional methods with ease.

- Challenging the traditional grid system would mean going against prevalent norms- legal and social. However, due to its major influence over the energy sector of the country, this can be seen as an advantage rather than a challenge. Along with the citizens, these existing collaborations would also benefit from this evolved technology. But they will have to make room for more players. This would be a slow and rigorous process, but surely a step towards a better future.

- The blockchain-based platform, Powerledger has recorded transactions and the data shows that after the implementation of this technology, it has led to a 43% lower buy price than that of the usual retail tariff. This also faced some regulatory challenges as the law made it a hassle to carry out transactions between parties. Various reforms have been made since then to enable such projects
- In 2018, the Indian Institute of Technology (IIT) Madras launched a pilot project for P2P energy trading in Chennai. The project involved installing solar panels on the rooftops of 50 houses and enabling them to trade excess solar power with each other. It pilot project faced challenges with the communication infrastructure, which affected the reliability of the system.

6 Recommendations

Open-sourced electricity trading still requires a lot of development before it can be practically implemented. It offers a real chance to transform the current structure of the grid to support the sustainable goals of the country. Thus, an investment of time and money should be promised to this sector of development, it surely parallels our goal to become self-sufficient as a country. Some start-ups and companies have realized the untapped potential that lies within this technology: -

6.1 TroonDx [84]

TroonDx is a Chennai-based SaaS start-up that provides solutions for decentralized set-ups such as P2P energy trading. In the current OTC (Over the Counter) setup, some inefficiencies prevailed that caused the failure of the buyer-seller matching forum mainly existing in hyperlocal markets. The company aims to secure digital transactions without depending on any other central authority. Transactions are carried out using chain codes as smart contracts on this decentralized platform. Moreover, the platform provides transparency in real-time trade and creates a multiple self-sufficient market which reduces the dependency on the main grid. It maintains the record of each transaction which is then used for bill settlement. Thus, TroonDx mainly focuses on advancing the virtual layer of this network.

6.2 Nimray Solar [85]

Nimray Solar aims to safeguard the interests and market presence of local producers. Generally, dominant companies tend to buy solar energy at low prices from generators and sell it to the electricity grid at higher prices making high margins of profit from consumers and small-scale electricity producers.

Nimray tries to create a network of solar energy trading to challenge the dominance of large companies. It helps consumers produce their energy and sell the surplus to neighboring households/buildings at a relatively lower price through the Nimray network.

6.3 Cygni [86]

Founded by Venkat Rajaraman, this company mainly focuses on manufacturing energy storage devices and smart grid solar panels. Being one of the first to take part in India's start-up campaign, it has contributed to the world of energy processing and storage. Now for the next decade, it focuses on a new age of electric vehicles and has introduced many such products to complement its aim. They include the lithium-ion battery for two-wheelers/E-rickshaws and solar hybrid solutions.

If we focus mainly on solar power grid solutions, as it parallels our motive, this company has the caliber to provide and contribute to the world of P2P energy sharing in India. With the practical knowledge and technology that it possesses, it can provide the much-needed intellectual investment that this particular sector demands.

6.4 Edgegrid [87]

This company provides a forum for users to share clean energy and offers various perks promoting smart grid technology. It is a digitally connected network that enables people to sell and buy green energy at low costs.

The "energy cloud", as they refer to it, is the system of these networks that are changing the face of energy distribution technologies.

It is extremely important for our country to shift to renewable energy generation for a sustainable and bright future. This climate-friendly power is surely the way ahead and platforms like this promise considerable change in the sector.

Such companies based on clean energy utilization should be boosted by the government. Some other measures can also be taken to harbor the growth and development of this sector: -

- Since solar panels are the most practical among non-conventional sources, they can be installed by financially secure institutions possessing stable infrastructure. This would be a stepping-stone to cultivate this market and could spark a trend.
- Government aid is an absolute necessity if such a change is to be implemented.

6.5 CleanMax [92]

CleanMax is an Indian company that specializes in providing renewable energy solutions to businesses and commercial entities. The company focuses on delivering sustainable and clean energy through solar and wind power installations. CleanMax offers a range of services, including designing, installing, and maintaining solar and wind energy systems for its clients.

The company's primary goal is to help businesses reduce their carbon footprint and transition towards more environmentally friendly energy sources. CleanMax operates on a build-operate-transfer (BOT) model, wherein it builds and operates renewable energy systems for a predetermined period before transferring ownership to the client.

- CleanMax's services often include power purchase agreements (PPAs), where the client agrees to purchase the energy generated by the renewable systems over a set period of time. This allows businesses to benefit from clean energy without the upfront costs associated with building and maintaining such systems themselves.
- In 2021, the company powered up with Meta to invest in 33.8 MW renewable energy projects in India [93]. This gave a boost to enable solar-powered initiatives in the country. Such initiatives also challenged the traditional grid and enabled direct energy transactions. However, the main challenge posed is the lack of infrastructure to generate viable prosumers from general households. Thus, this initiative lacked domestic participants and focused solely on industrial applications.

7 Conclusions

India is a powerhouse of growth and development; it has been the first to do things that the world could barely even wrap its head around. Setting an example and formulating creative policies for the benefit of the nation, is still 'developing' and surely has a long way to go. A reform in the power sector is absolutely necessary in order to ensure this growth. As stated earlier, electricity is like the blood in the veins of our developmental infrastructure; hence, it should be free-flowing and abundant for the proper functioning of our national body. The following points capture the essence of our paper: -

- Open-sourced electricity is the next evolved form that the traditional convention morphs into. It refers to clean energy that can be easily accessed through a decentralized grid network.
- With the use of prevalent power-related major institutions, a shift can be brought about in terms of shifting to clean energy. This will also be supported by new companies that solely work on peer-to-peer energy trading and simplifying the grid.
- Various experimental projects set-up in different parts of the country have been successful in carrying out P2P energy trading. This paper brings them together for a cumulative impact in favor of promoting this technology.
- Coal and other unsustainable resources still dominate the power-generating sector of the country. It is vital that this trend changes as it directly affects the national economy. By taking the example of various other countries, it can be concluded that a successful shift is possible. Statistics show a growth in the GDP of the country but real development can only occur when the citizens directly benefit from the ongoing policies.
- Various policies have been introduced by the GoI in an effort to promote clean energy. Most of the set targets have been met but there is still a need for major changes in order to ensure actual growth.
- The advantages of P2P energy sharing and clean energy have been extensively highlighted in an effort to support them.
- Major power-related challenges faced by the country that hinder the growth of the renewable energy sector have also been elaborated.
- Some recommendations have been mentioned so that challenges can be dealt with.

In conclusion, an extensive amount of work is needed and highly detailed country-specific research needs to be carried out in this sector of peer-to-peer energy trading.

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