On Peer-to-Peer Energy Trading between Solar RTPV and EV Charging Station

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Glossary

EV	Electric vehicle
RTPV	Rooftop photovoltaic
EVCS	Electric vehicle charging station
P2P	Peer-to-peer
LCOE	Levelised cost of electricity is a measure of the cost of energy generation over the warranted life of the asset (RTPV plant in this context)
Prosumer	Entities who can generate as well as self-consume energy (RTPV owners in this context)
DISCOM	Distribution Company
BESCOM	Bangalore Electricity Supply Company

INTRODUCTION

The use of energy from a rooftop photovoltaic (RTPV) system for charging electric vehicles (EV) is environmentally advantageous and forms a true approach towards green mobility. Further, if solar energy is generated in close proximity to the EV charging points, it results in lower transmission losses and helps mitigate detrimental effects of sudden rise in EV demand on the grid.

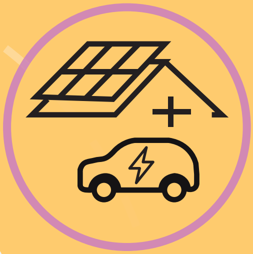
It is obvious that the two technologies can benefit each other. Karnataka has ambitious targets for both RTPV and EVs in the coming years. In this context, it is important to identify and assess the options for wide-scale deployment of a system that ensures RTPV and EV charging in tandem.

However, cost can be a major barrier for deploying such a system. To overcome the high upfront costs, a peer-to-peer (P2P) trading model can be explored. This is based on distributing the ownership of the assets involved—RTPV, energy storage (optional), and EV chargers—to different entities/individuals, to make it economically more viable.

Owing to its tech-savvy population, Bengaluru serves as the ideal city for pilot studies on P2P energy trading. Karnataka can, therefore, take the lead in creating a policy framework for solar energy-based EV charging in the state.

Key Insights

EVs running on renewable energy are cleaner than those running on coal-based grid energy.

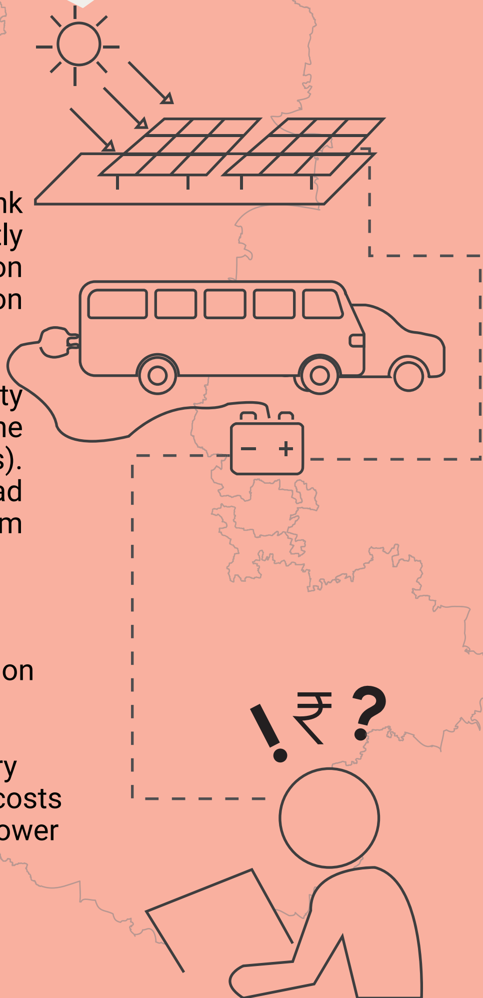


Novel market mechanism such as peer-to-peer energy trading can be explored to effectively integrate RTPV system and EV charging.

Both RTPV owners and EV charging businesses can benefit from direct energy trading.

Such a novel market mechanism calls for pilot studies for assessing feasibility, and exploring regulatory and policy options.

Possibilities



One of the options would be to link PV generation to EV charging directly through the PV system installed on the electric vehicle charging station (EVCS) rooftop.

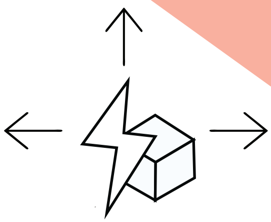
However, in this case a single entity has to bear the capital cost of all the related assets (RTPV and chargers). The drawbacks to the widespread adoption of such an integrated system are:

The (high) initial investment costs associated with solar-panel installation

As a business, EV charging is not very profitable owing to the high upfront costs (of land requirement) and relatively lower revenue from charging.

Hence, we explore the following model to tackle the above challenges.

Direct Energy Trading to Reduce Costs



Consider the scenario wherein all the important assets are owned by a single entity **(EV charging station)**. Though the **levelised cost of electricity (LCOE)**[1] from PV is lower than that drawn from the power grid, a considerable period of time is required to recover the capital costs incurred in setting up the PV infrastructure. To overcome this, we suggest allowing the EV business to buy cheaper energy directly from solar RTPV owners, who have already installed solar panels. Such a direct trading mechanism is termed as peer-to-peer or in short P2P trading. **The trading architecture is shown schematically in Figure 1.**

In this trading mechanism, the key entities and their roles are as follows:

1. PV system owners: They can self-consume the generated energy and sell the excess to the grid, and are thus termed 'prosumers'.

2. EV charging stations: They offer charging service to EV owners, with most of them currently drawing energy from the grid. They serve as the buyers of solar energy in the model. Places that can aggregate EV loads, such as EV fleet stations, malls, hospitals, BMTC bus depots, etc., can be suitable candidates.

3. DISCOMs: They will play the important role of facilitating energy exchange between trading entities. DISCOMs may choose to charge a fee for the service in order to maintain the required infrastructure.

4. Trading platform: It is an online application that enables P2P trading/transactions.

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[1] LCOE is a measure of the cost of energy generation over the warranted life of the solar plant

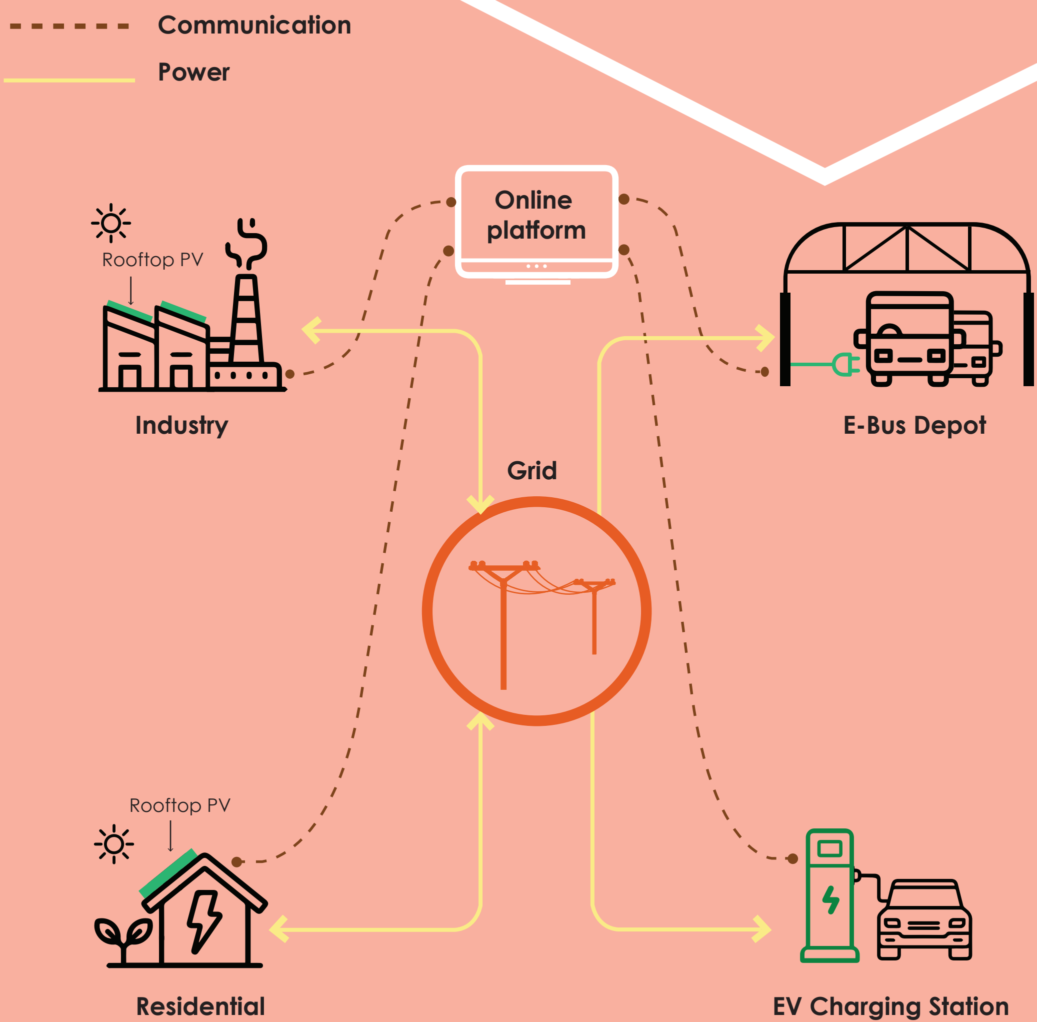


Figure 1: Schematic of a simple peer-to-peer energy trading architecture showing prosumers, grid and the consumers. The solar generators and consumers are located at different parts of the grid network.

How it works?

- Any EV charging business (buyers), which is part of the trading network, can advertise the amount of energy required on the online trading platform.
- Sellers (RTPV owners) on the same platform will then compete to supply the required energy at a price determined through competitive bidding.
- This transaction will be successful if

  i) the selling price is greater than the LCOE or the net metering tariff, and

  ii) the cost price (to the EVCS) is lower than the tariff charged by DISCOM

This is depicted schematically in Figure 2.

Blockchain is a popular, resilient, and trustworthy software technology that is enabling P2P energy trading around the world. It is essentially a distributed ledger that keeps a record of all transactions in the network, is regularly updated, and all participants in the network have a copy.

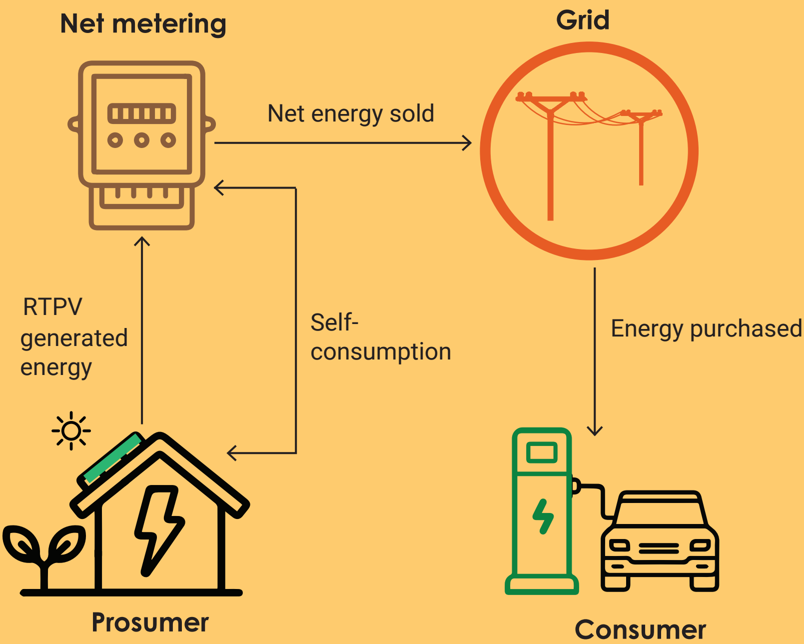
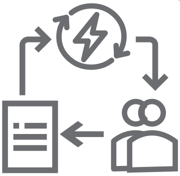


Figure 2: In the above figure, the seller (RTPV owner) will benefit if the net energy is sold at a price greater than that availed by the net metering (~INR 3.5 per unit in BESCOM jurisdiction), and the buyer (EVCS) will benefit if the purchasing cost is lower than that offered by the grid (INR 5 per unit in BESCOM jurisdiction).

Is there a business case for Bengaluru?



A pilot P2P energy trading project consisting of 18 (phase 1) and 30 (phase 2) households was trialled in Perth, Australia recently (from November 2019 through January 2020). Participants were allowed to sell electricity to one another across the low-voltage distribution grid by fixing their own transaction rates. The different cost parameters used in this study are detailed in the Appendix A1. Consider a scenario wherein a similar cost structure is adopted for trading energy between RTPV owners and EVCS businesses in Bengaluru (specific details in Appendix A2). Currently, the commercial and industrial players generate RTPV energy at a relatively lower cost compared to residential RTPV owners (refer to Table in Appendix A2), and hence can avail higher gains in trading. Hence, in the following analysis, consider the P2P energy-trading scenario between commercial entities owning RTPV and public EV charging stations in Bengaluru city.

Conditions for effective trading can be summarised as:

a. Sellers/prosumers should be able to sell energy at a cost greater than the net metering and the LCOE of RTPV system (whichever is higher) plus the fee charged by the trading platform

b. Consumers should be able to purchase at a cost lower than that charged by the grid, minus the service fee charged by the trading platform

c. To overcome the fixed costs to the grid, a certain minimum units of energy needs to be sold/bought daily, beyond which profit can be made.

The above ideas are expressed graphically for better understanding in the below figures.

- The plots identify regions wherein the energy-trading exercise can be viable (shown as green-coloured bands).
- Any point in the green area involves a net profit to both the buyers and sellers (though in different proportions).

Scenario1 (Current Scenario):

- Current cost of electricity sold (in BESCOM jurisdiction) to EVCS business at INR 5/kWh
- Cost values for LCOE of RTPV and net metering rate are specific to Bengaluru

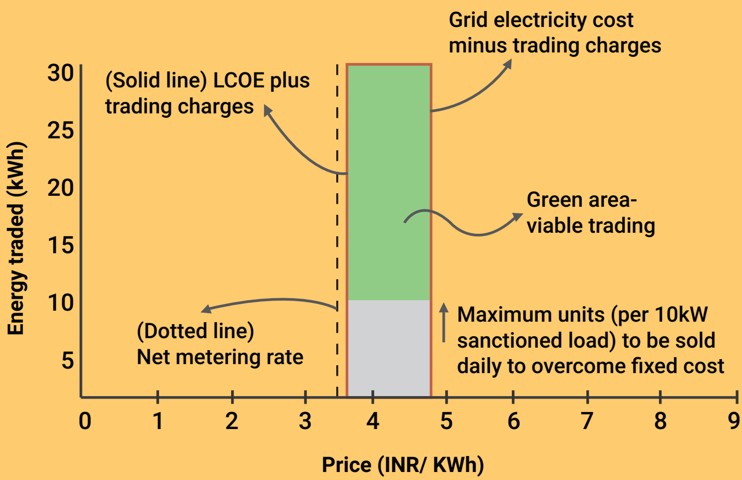


Figure 3: Assessing the viability of P2P energy trading between commercial entities with RTPV and EVCS business under current cost scenario in Bengaluru. Trading charges refer to the charges imposed by the trading platform.

Scenario 2 (Alternate Scenario):

- Cost of electricity to EVCS business is increased from the current rate (which was introduced to promote EVs in the city) to be on par with charges applied to commercial and industrial consumers (which is around INR 8.5 /kWh)[2].

- Other cost parameters are the same as in Fig. 3

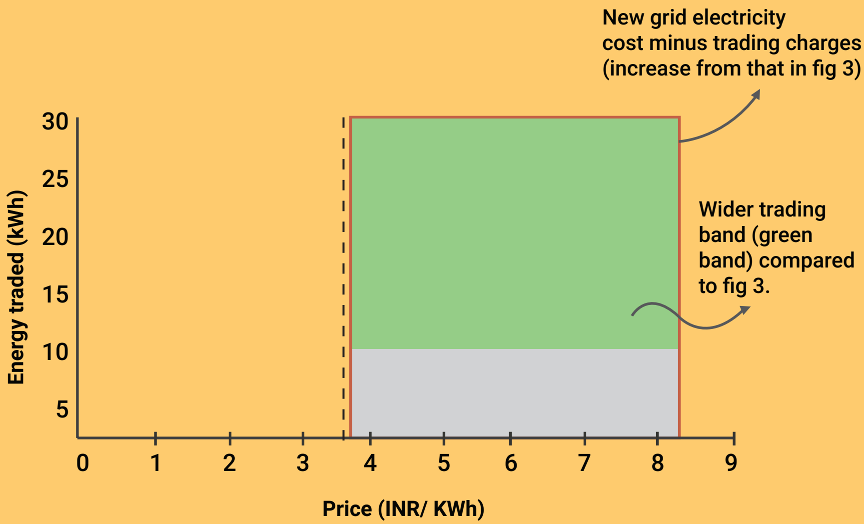


Figure 4: Scenario wherein the grid-electricity cost to EVCS business is on par with the charges for commercial entities in Bengaluru

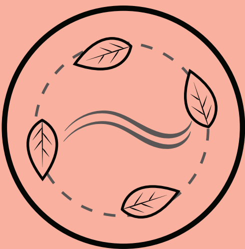
[2]https://karunadu.karnataka.gov.in/kerc/Tarifforders2019/Tariff%20Order%20 2019/BESCOM/14-BESCOM%20-%20ANNEXURE%20-%204.pdf

Preliminary analysis suggests

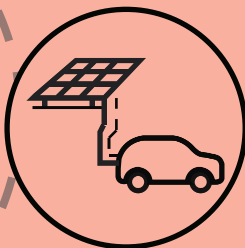
Under the current cost structure for Bengaluru, P2P energy trading can be explored between RTPV owners (mainly commercial) and EVCS businesses (consumers), since both can benefit from direct trading rather than selling and buying from the grid, respectively. However, the gain is relatively low (~ INR 0.5 / kWh for each entity in the analysis).

Currently, BESCOM offers electricity to EV charging at a cheaper rate (of INR 5 / kWh) to promote EVs. In the event of this cost being increased to match the rates being charged to commercial consumers in the city, the profit margins for P2P trading increase, thereby enabling a more viable trading market.

BENEFITS



1. Promote clean energy: The use of RTPV energy for EV charging is eco-friendly, as it is a greener form of energy than that derived from coal.

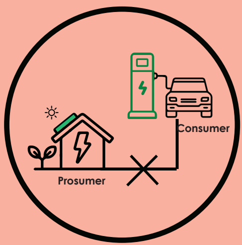


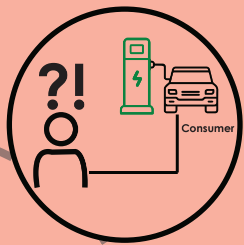
2. Benefits to RTPV owners (sellers) and EVCS business (buyers): EV charging business can avail green solar energy at a relatively low cost. RTPV owners will be able to sell energy at a rate higher than their cost of generation (and net metering), resulting in a higher internal rate of return on their investment.

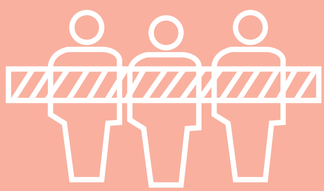
3. Benefits to grid: Since P2P trading provides a source of income to RTPV owners, DISCOMs can consider rolling back the net metering incentive, which was initially aimed at supporting RTPV adoption. Similarly, DISCOMs can consider selling electricity to EVCS businesses at the same cost charged to commercial and industrial consumers.

BARRIERS

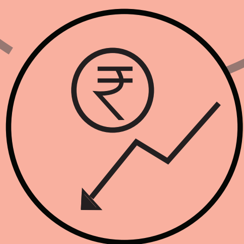
1. Under the current regulation, direct buying and selling of electricity among the prosumers and consumers is not allowed.







2. There is limited understanding regarding enabling technologies such as Blockchain and the trading mechanism. Market-design-related challenges are expected in the latter case.



3. DISCOMs can potentially incur losses as they will be competing with prosumers as alternative sellers.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ACKNOWLEDGEMENT

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APPENDIX

A1. Excerpts from a pilot case study in Australia

A pilot project on P2P energy trading consisting of 18 (phase 1) and 30 (phase 2) households was trialled recently in Perth, Australia[3]. The project, RENeW Nexus, was carried out from November 2019 through January 2020 with PowerLedger's online trading platform. Participants were allowed to sell electricity to one another across the low-voltage distribution grid by setting their own rates for transactions. The following are the main features of the study:

- The success or failure of the trading exercise was dependent on the tariff structure and the cost parameters.
- Further, due to the tariff structure, a high self-consumption of energy led to better financial outcomes rather than the quantity of energy traded.
- Another influencing factor was the mix of prosumers (sellers) and consumers. Higher ratio of consumers to prosumers (sellers) seemed to produce better results.

The following was the cost structure of the pilot:

Table 1 : Cost structure used in the P2P trading pilot project carried out recently in Perth, Australia[3].

S.No.	Cost Parameter	Comment/description
1	Retailer peak rate	Energy provided by DISCOMs
2	Retailer off-peak rate	Energy provided by DISCOMs
3	Retailer buy-back rate	Feed-in-tariff/Net metering
4	P2P energy rate	Buying/selling cost set dynamically during trading hours
5	Online trading platform transaction fee	Service fee charged by the trading platform
6	Retailer capacity charge	Costs associated with services provided by the electrical grid
7	Network operator network charge	

[3] https://www.powerledger.io/wp-content/uploads/renew-nexus-project-report.pdf

APPENDIX

Note that the cost parameters 6 and 7 are fixed charges, whereas the rest are based on the number of kWh consumed.

This exercise resulted in the following outcomes:

- This form of trading was favoured by customers. Participants were willing and able to shift their energy demands according to real-time price signals.

- The study envisaged that energy trading had the potential “to replace net metering for a real-world revenue stream”.

- To quote from the report: “The research strongly suggested that such energy trading could help stabilise the grid without any tariff interventions of any kind at all.”

APPENDIX

A2. Exploring a Business case for Bengaluru

Consider the following cost details similar to the one presented above for exploring a business case for Bengaluru (the grid-related costs are relevant within BESCOM's jurisdiction):

Table 2 : Cost structure for Bengaluru, adopted from Table 1

Cost parameter		Notation	Cost (INR)	Comment
Grid-related	Current cost of electricity from grid for EV charging business[4]	X	5/kWh	Peak
	Current cost of electricity from grid for EV charging business	X	5/kWh	Off-peak
	DISCOM capacity charge	F1	~INR 9/ day	Assuming a 4 kW sanctioned load for a house-hold in Bengaluru (calculated as per KERC tariff structure)
		F2	INR 32 /day & per 10 kW sanc-tioned load[5]	Considering tariff for commercial consumers under LT-3 in Bengaluru at INR 95 per kW of sanctioned load[5]

[4]https://karunadu.karnataka.gov.in/kerc/Tarifforders2019/2-Bescom/Chapter-9_Proposal%20of%20tariff.pdf
[5]https://karunadu.karnataka.gov.in/kerc/Tarifforders2019/Tariff%20Order%202019/BESCOM/14-BESCOM%20-%20ANNEXURE%20-%204.pdf

APPENDIX

Cost parameter		Notation	Cost (INR/kWh)	Comment
Grid-related	Net metering tariff	Z	3.5	For all consumers[6]
P2P-trading-related	Online trading platform transaction fee	A		Needs to be assumed for now (In the current analysis, INR 0.5 per kWh traded is assumed)
	P2P energy rate	T		Set dynamically by the market
RTPV-related	LCOE from RTPV	Y1	4–4.5	For residential consumers
		Y2	3–3.7	For commercial and industrial consumers

[6] https://bescom.org/wp-content/uploads/2018/06/OMNew-SRTPV-tariff-for-entering-into-PPAs-from-01.04.2018-to-31.03.2019.pdf

APPENDIX

- Y1 or Y2 are cost of generation to prosumers, while X is the cost to consumers (EVCS in this case).

- In the above table, A is the additional price on prosumers and consumers to avail the service of the online trading platform; hence the above costs effectively is Y2+A

- Conditions for effective trading summarised from above points:

  a. Prosumers should be able to sell energy at a cost greater than the net metering and the LCOE (whichever is higher)
  b. Consumers should be able to purchase at a cost lower than that charged by the grid, minus the service fee charged by the trading platform
  c. Since both the buyers and sellers are connected to the grid, they need to overcome the fixed costs F1 & F2 imposed by the latter. Hence, the revenue from certain units of energy traded daily/monthly will account for these costs, beyond which profits can be availed. Let N1 and N2 be the required maximum number of energy units traded daily to overcome these fixed costs by the sellers and buyers, respectively.

The above statements can be stated mathematically as:

Conditions for viable P2P trading between RTPV owners (sellers) and EVCS business (buyers)

(i) $Y2+A < T < X-A$

(ii) $N1*Z > F2$ (or F1) ; for sellers (assuming Z will be the minimum selling price)

(iii) $N2*T > F2$; for buyers

Within the framework of the cost structure represented in Table 2, the conditions (i) to (iii) need to be satisfied for successful trading.

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