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The importance of classification in reducing the congestion price in peer-to-peer energy trading

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Abstract – Peer-to-peer energy trading is a model in which energy can be exchanged directly between energy producers and consumers. This model offers an innovative approach to energy markets. In traditional energy trading models, energy producers collect energy at a single point and then distribute it to consumption points. However, with peer-to-peer energy trading, energy producers can offer energy directly to consumers, thus reducing the costs of intermediaries and distribution networks. [1], [12]
The importance of the peer-to-peer energy trading model comes from several aspects: Energy Efficiency, Renewable Energy Incentives, Flexibility and Reliability etc.
Peer-to-peer energy trading allows the energy system to become more decentralized and more sustainable. However, an appropriate classification and regulation is necessary for peer-to-peer energy trading to work effectively. [2]
The most important of these classifications is the distance category. Distance and peer-to-peer energy trading offers a new paradigm for efficient and sustainable energy distribution. Compared to traditional energy distribution models, this new approach allows energy consumers to exchange energy among themselves. This aims to provide a more flexible, efficient, and environmentally friendly energy distribution. [3], [13]
In this study, I made simulations to see how the distance could have an effect on the energy trade between peers, and as a result of the simulations, the distance and arrangement of consumers from each other was examined. As a result, the regulation of consumers has proven to have an effect on trade, and the classification of consumers shows that it has a large effect on lowering the congestion price.

Keywords – Congestion Price, Peer-To-Peer Energy Trading, Classification, Order of Consumers And Producers, Distance In Energy Trade

I. INTRODUCTION

Congestions and fluctuations in the energy sector are a frequent challenge in traditional energy supply chains. [17] These problems arise from imbalances between demand and supply and can cause energy price spikes and productivity losses. However, an innovative model known as peer-to-peer energy trading in recent years offers an important solution to solve these problems and create new opportunities in the energy sector. Peer-to-peer energy trading is a system that allows direct buying and selling of energy between individual energy producers and consumers. This system provides faster, more efficient, and flexible energy trading by eliminating traditional intermediaries.[18] Regardless of congestion prices, peer-to-peer energy trading allows consumers to communicate directly with local energy producers to meet their energy needs and adopt a more sustainable approach to balance energy consumption and energy production. This innovative trading model is an important step towards a more stable and sustainable energy future by transforming the energy market. [6], [14]

In today's electricity networks, when a region's network fails, electricity is transferred from another region to that network, which is effective in raising the congestion price, but we can reduce this price by various methods. The shape of the consumers has an effect on the congestion price, and this effect proves when we classify the consumers.[7]

I did a simulation on the Grid singularity application in line with how the grid, or rather consumers' style, can lower the congestion price, and finally the results show us how the trade regulation affects the price of electricity.

II. METHOD AND PROGRAM

Grid Singularity's mission is to give individuals and the energy community ultimate freedom as to energy type, location, price or as a trading partner. The European Union and other regulators have endorsed a bottom-up, user-centered market design and recognized its various benefits. It simplifies the design of bottom-up markets by linking aggregators that connect energy assets.

There are two different payment methods known as "Pay-As-Bid" (PAB) and "Pay-As-Clear" (PAC) in the electricity grid. These methods have different approaches in terms of electricity consumption and pricing. [10]

A. *Pay-As-Bid (PAB)*

In the Pay-As-Bid system, It is customary for electricity suppliers to submit their electricity demands through an auction or bidding process. It is the responsibility of each supplier to submit its own demand and asking price. In order to balance supply and demand in the market, electricity consumption demands, and price offers are combined. In this process, the electricity price is determined based on the prices offered by each supplier. [8], [9]

B. *Pay-As-Clear (PAC)*

In the Pay-As-Clear system, electricity suppliers accept the unit price rather than offering a quote. In other words, suppliers submit their demands by setting a unit price. Then, electricity demands, and unit prices are combined and the demand and supply balance is achieved in the market. The electricity price is determined on the basis of these unit prices and electricity is consumed at the same price for all customers. [15]

According to the two methods I mentioned above, I simulated the effect of grid arrangement on the price via Grid Singularity.

I) Scenario 1 (pay as bid)

The test results of the peer-to-peer energy trade created through Grid Singularity will be examined. As seen in Figure 1, the community formed in Bahçelievler location of Istanbul city, consists of 5 houses. The priority of this test is to simulate the function of a peer-to-peer energy community envisaged to be established in Turkey. As a result, it is clear that a community open to development has been created. In Figure 2, there is a view of the community on the map from different angles. In the community, there are 5 loads with a total value of 2646 kWh, 3 PVs with a total value of 25 kWh and 2 batteries with a total value of 10 kWh. The share of community electricity consumption provided by its own renewable energy assets increased to 82.5% as a result of simulating the community for 7 days, which reduces the dependency on the electricity grid. It supplies most of its electricity from the grid. The electricity produced by the generating consumers in the community is mostly self-sufficient, and most of the residences operate largely independently of the grid. The community was initially established with a diameter of 900 meters and in other scenarios this diameter will be further expanded to show the effect of distance on energy trade.

Our simulation results indicate that the community is priced with using the Pay as Offer and Pay Net market mechanisms. The information obtained within 15 minutes is evaluated. This information is obtained by determining the exchange status of the consumer's demand situation and the amount of electricity produced by the producing consumer with other residences.

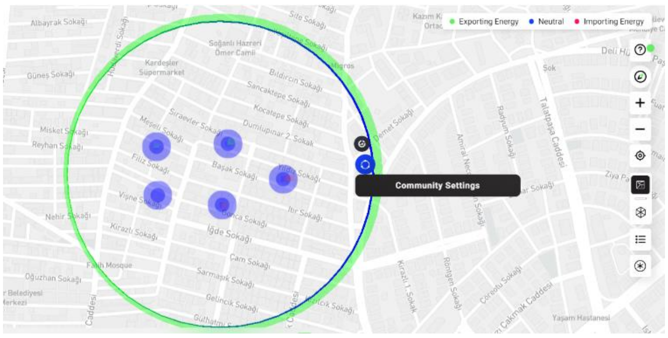

Figure 1. Images of the community on the map (pay as bid)

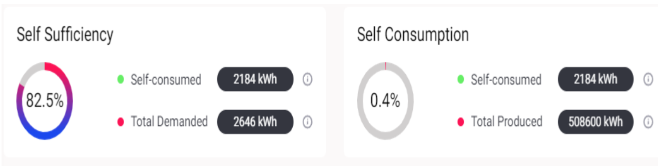

Figure 2. Self-production and self-consumption rate of the community

Table 1. Energy bills and net energy traded for the community (Pay as Bid)

	Bought		Sold		Total Balance	
Assets	**Energy KWh**	**Paid (€)**	**Energy KWh**	**Revenue (€)**	**Energy KWh**	**Total (€)**
Home	121,25	36,01	169051,75	72,79	168930,5	36,78
Home 2	112	33,03	169128	49,1	169016	16,07
Home 3	70	20,74	169275	39,09	169205	18,35
Home 4	252	46,07	0	0	252	46,07
Home 5	981,75	173,97	36,75	10,24	945	163,74
Grid Market	506416,5	0	462	138,6	505954,5	138,6
Total	507953,5	309,81	507953,5	309,81	0	0

II) Scenario 2 (pay as clear)

In the second scenario, the pay-to-net method was traded, but in the end, the values changed very little, in Table 2, there is a difference of 12 KWh in the energy sold and received at the community size in a week in total, with a difference of 10 euros in cost.

Table 2. Energy bills and net energy traded for the community (Pay as Clear)

	Bought		Sold		Total Balance	
Asset	**Energy KWh**	**Paid (€)**	**Energy KWh**	**Revenue (€)**	**Energy KWh**	**Total (€)**
Home	123,5	36,78	169054	63,23	168930,5	26,45
Home 2	112	32,99	169128	51,31	169016	18,31
Home 3	70	20,74	169275	47,07	169205	26,5
Home 4	252	45,75	0	0	252	45,75
Home 5	991,75	177,13	46,75	13,02	945	164,11
Grid Market	506416,5	0	462	138,6	505954,5	138,6

III) Scenario 3 (pay as bid after layout change)

In the 3rd scenario, I changed the layout of the houses and increased the diameter of the community by 10 Km. I simulated the newly created community with a two-sided payment system and a pay as offer system.

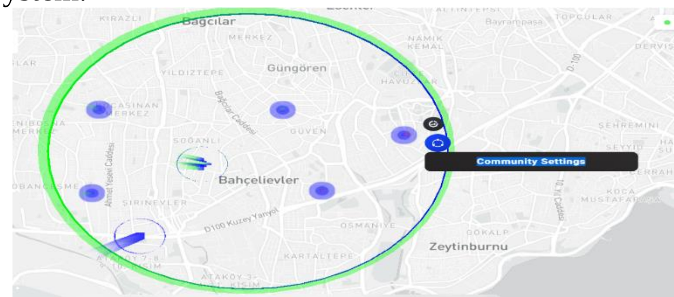

Figure 3. Images of the community on the map (pay as bid)

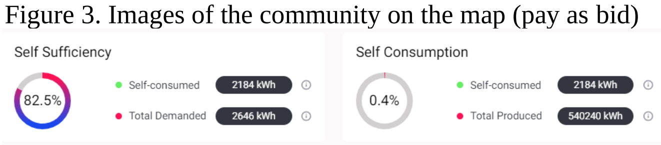

Figure 4. Self-production and self-consumption rate of the community

Table 3. Energy bills and net energy traded for the community (Pay as Bid)

	Bought		Sold		Total Balance	
Asset	**Energy KWh**	**Paid (€)**	**Energy KWh**	**Revenue (€)**	**Energy KWh**	**Total (€)**
Home	117,75	35,01	179528,25	51,3	179410,5	16,28
Home 2	112	33,13	180008	55,19	179896	22,06
Home 3	70	20.57	179555	53,52	179485	32,95
Home 4	252	45,92	0	0	252	45,92
Home 5	987.25	175.73	42,25	11,77	945	163,96
Grid Market	538056,5	0	462	138,6	537594,5	138,6

In the 3rd scenario, while the total demand of the community was 2646 KWh, 2184 KWh of energy was consumed, which means 82.5% of the demand. On the other hand, while the community produced 540240 KWh of energy, it consumed 2184 KWh on its own, and sold the rest and earned income for the community. The total community has maintained its balance in the community by trading at a cost of

310.37 euros, meanwhile, Home, Home 2 and Home 3 earned income from this trade, while Home 4 and Home 5 paid for the energy they consumed, that is, they bought energy from the market.

IV) Scenario 4 (share as clear after layout change)

Table 4. Energy bills and net energy traded for the community (Pay as Clear)

	Bought		Sold		Total Balance	
Asset	**Energy KWh**	**Paid (€)**	**Energy KWh**	**Revenue (€)**	**Energy KWh**	**Total (€)**
Home	127.25	38	179537.75	60.53	179410,5	22.53
Home 2	112	32.95	180008	47.17	179896	14.23
Home 3	70	20.79	179555	54.94	179485	34.15
Home 4	252	46.02	0	0	252	46.02
Home 5	977	172.4	32	8.91	945	163.49
Grid Market	538056,5	0	462	138,6	537594,5	138,6

III. Results

The only difference in the two types of payment is that in scenario 1, energy is sold to the highest offer of each consumer, but in scenario 2, consumers are sold to the highest bid in total.

When we compare Table 1 and Table 3, there is an increase in the energy volume in the energy trade of the community and the total cost has increased in proportion to the energy volume.

In scenario 4, trade was made using the pay-to-net method, but the values changed very little in the end. Compared to table 2, the traded energy volume is higher, but this volume of energy is traded at a lower cost. The higher the energy volume is due to the longer distances and is an indication of energy loss.

In my research and simulation, the price based on KWh varies between 25 cents and 30 cents, and the following simulations have been evaluated based on two payment methods (pay-as-bid and pay-as-clear), whereas the research conducted in England only examined the pay-as-bid method and varies between 6.1 c/KWh and 49.24 c/KWh. Two studies have demonstrated that energy losses cause energy prices to rise, but in my simulation, prices have changed more steadily.[20]

IV. Discussion

According to the results we found in this study, the location and arrangement of consumers in an electricity grid is effective in peer-to-peer energy trading. [4], [16]

In the current system, energy is distributed from a dam or nuclear power plant to a large area, which means more expensive energy for the consumer, but with distributed renewable power plants and energy storage systems, we can minimize the distance and distribute cheaper energy. [5], [19]

V. Conclusion

According to my comparison, the farther the distance between the residences, the higher the volume of energy in trade, causing higher costs. In my opinion, the size of the communities should be determined before electricity markets are formed, and this should be determined in the laws, because according to my research, as the diameter grows, that is, when energy trade is carried out in a wide area, there is a loss of energy, and this loss causes the consumer to pay for the energy, and this does not benefit the network and the community, but perhaps also causes harm.

As a result of the study, it makes more sense for communities to trade on a small scale, and the consumer will then obtain energy cheaper and more independently.

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