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3rd International Conference on Innovative Academic Studies

September 26-28, 2023 : Konya, Turkey



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# The Effect Of The Number of Units On Peer-to-Peer Energy Trading

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***Abstract*** – In recent years, there has been a significant and rapid expansion in the energy sector. Renewable energy sources have made substantial inroads into the electricity grid, resulting in their substantial contribution to the overall energy mix. This shift towards renewables has introduced new complexities into energy estimation and trading, particularly in the electrical energy market, where the reliance on meteorological conditions is significant. Developing effective energy trading strategies has become paramount to ensuring the efficient functioning of smart grids, as they play a crucial role in alleviating system stress. Nevertheless, the burgeoning number of smart grid users has presented substantial challenges for maintaining stability and efficiency in energy trading operations [1], [12].

Furthermore, amidst the escalating global energy crisis, which has been linked to geopolitical conflicts and the dominance of powerful nations in fossil fuel reserves, many countries are pivoting towards clean and sustainable energy sources, accompanied by the implementation of new legal frameworks. One such legal development pertains to commercial laws in the electrical energy sector [2].

This study, centered on the electricity trading landscape, conducted a comparative analysis within the Emir community. It was observed that the number of households on the consumer side has a significant impact on cost escalation. To mitigate this rising cost trend, it becomes imperative to enact legislation that delineates construction criteria to be adhered to by communities [3], [13].

In this study, the introductory section highlights the importance of electricity trading, followed by an examination of peer-to-peer energy trading. The research investigates how the quantity of residential units affects trade dynamics and resulting profitability. The concluding segment of the study presents the findings and provides recommendations for future directions [4].

*Keywords – Peer-To-Peer Energy Trading, Number Of Units, Residential Units, Trade Dynamics, Profitability, Energy Market*

## I. INTRODUCTION

Peer-to-peer energy trading has emerged as a promising solution to address the challenges posed by traditional centralized energy distribution systems [17]. In recent years, the growing awareness of climate change and the increasing demand for renewable energy sources have spurred the development of decentralized energy systems that empower individuals and communities to generate, consume, and share electricity locally [18]. This paradigm shift has given rise to peer-to-peer energy trading platforms, which enable energy producers and consumers to engage in direct, transparent, and decentralized exchanges of electricity [5].

One of the critical factors that influence the effectiveness and scalability of peer-to-peer energy trading platforms is the number of units participating in the trading network. This number can encompass a wide range of stakeholders, from individual households with rooftop solar panels to larger commercial and industrial entities with substantial energy production and consumption needs. Understanding how the number of units affects peer-to-peer energy trading is paramount, as it has profound implications for the economic, environmental, and social aspects of energy systems [6], [14].

This innovative study delves into the effect of the number of units on peer-to-peer energy trading, aiming to shed light on the various dimensions of this complex interaction. By investigating the dynamics of energy trading in networks with varying numbers of participants, we seek to provide insights that can inform policymakers, utility companies, and communities interested in implementing and optimizing peer-to-peer energy trading platforms [7].

## II. Materials and Method

Grid Singularity is dedicated to empowering individuals and the energy community with unparalleled freedom in choosing their energy sources, determining their energy's origin and price, and selecting trading partners. This mission aligns with the European Union and other regulatory bodies' support for a market structure that prioritizes users' preferences and needs. To achieve this vision, Grid Singularity streamlines the creation of user-centric energy markets by facilitating connections between aggregators that link various energy assets.

Two distinct payment methods are prevalent within the electricity grid: "Pay-As-Bid" (PAB) and "Pay-As-Clear" (PAC). These methods diverge significantly in their approaches to managing electricity consumption and determining pricing structures [10].

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

In the Pay-As-Bid system, electricity suppliers typically participate in an auction or bidding process where they submit their individual electricity demands along with their proposed prices. The responsibility for submitting both the demand and the asking price rests with each supplier. To achieve a balance between supply and demand within the market, the system aggregates electricity consumption demands, and price offers. Consequently, the final electricity price is calculated based on the pricing proposals submitted by each supplier [8], [9].

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

In the Pay-As-Clear system, electricity suppliers do not provide individual price quotes; instead, they accept a predetermined unit price. In this approach, suppliers express their electricity demands by specifying a unit price. Subsequently, the system aggregates these electricity consumption demands and unit prices to establish a balance between supply and demand within the market. The resulting electricity price is then determined based on these unit prices, and all customers consume electricity at this uniform price [15].

Using Grid Singularity, I conducted simulations to assess how grid arrangement impacts pricing under the two methods mentioned earlier.

### *C. Scenario 1 (Two-Sided Payment and Payment-as-Offer Method)*

We have conducted an examination of the test results for peer-to-peer energy trading facilitated by Grid Singularity. In Figure 1, we can observe the formation of a community in the Bahçelievler area of Istanbul, consisting of 5 houses. This test primarily aims to simulate the functionality of a peer-to-peer energy community envisioned for establishment in Turkey. The results clearly demonstrate the establishment of a dynamic and evolving community.

Figure 2 provides a map view of the community from different angles. Within this community, there are 5 loads with a total electricity demand of 2646 kWh, 3 photovoltaic (PV) systems generating a combined total of 25 kWh, and 2 batteries with a total capacity of 10 kWh. Through the simulation of this community over a span of 7 days, we observed that the share of electricity consumption sourced from the community's own renewable energy assets increased to 82.5%. This reduction in grid dependency signifies a significant achievement, although a portion of electricity is still supplied from the grid.

The electricity generated by the community's prosumers (those who both produce and consume electricity) allows most of the residences to operate independently of the grid. The initial community had a diameter of 900 meters, and in subsequent scenarios, we plan to expand this diameter to investigate the impact of distance on energy trading.

Our simulation results indicate that the community employs the Pay as Offer and Pay Net market mechanisms for pricing. Information is collected and evaluated every 15 minutes, which includes assessing the exchange status of consumers' electricity demand and the electricity production levels of generating consumers within the community.

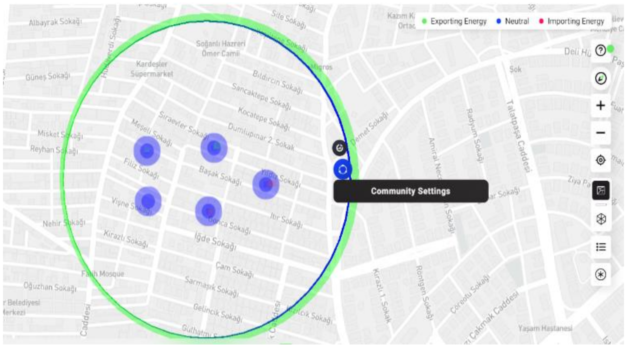


Figure 1. Images of the community on the map (pay as bid)

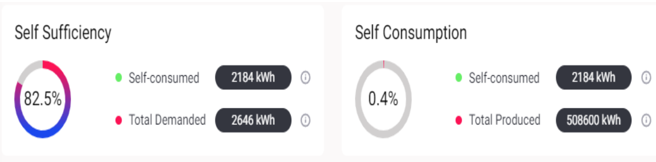


Figure 2. Self-production and self-consumption rate of the community

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

| | **Bought** | | **Sold** | | **Total Balance** | |
|---|---|---|---|---|---|---|
| **Asset** | **Energy (kWh)** | **Paid (€)** | **Energy (kW h)** | **Revenue (€)** | **Energy (k Wh)** | **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 |

**Energy Export** **Energy Import** **Neutral**

### *D. Scenario 2 (Two-Sided Payment and Net Payment Method)*

In the second scenario, trading was conducted using the Net Payment method; however, the results showed minimal differences. As illustrated in Table 1, there is a 12 kWh difference in the total energy sold and purchased within the community over the course of one week. Additionally, there is a cost difference of 10 euros.

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

| | Bought | | Sold | | Total Balance | |
|---|---|---|---|---|---|---|
| Asset | 1) Energy (kWh) | Paid (€) | 2) Energy (kW h) | Revenue (€) | 3) Energy (k Wh) | 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 |

Energy Export  Energy Import  Neutral

*E. Scenario 3 (Multi-Consumer Community with Two-Sided Payment and Payment-as-Offer Method)*

In the third scenario, the number of households was increased from 5 consumers and producers to 10 households (with the same criteria). The newly formed community was simulated using the two-sided payment system and the payment-as-offer method.

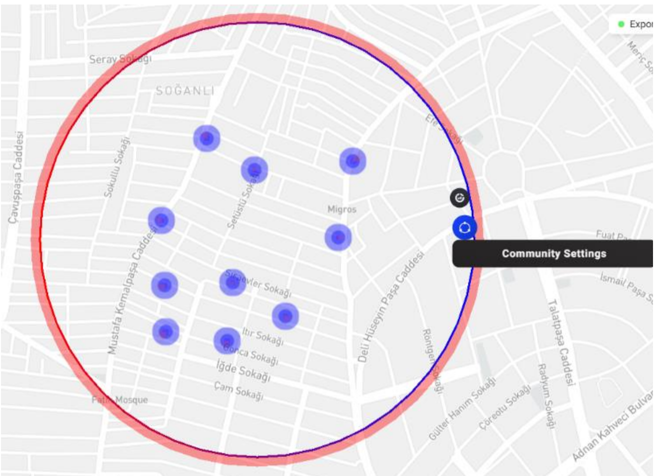


Figure 3: Visual Representation of the Community on the Grid Singularity Map

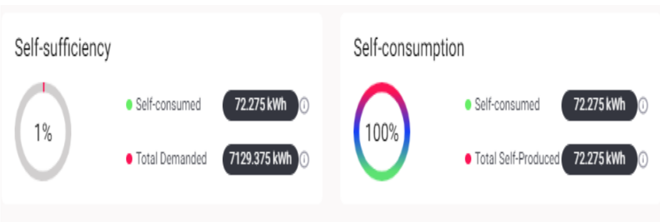


Figure 4: Self-Generation and Self-Consumption Rate of the Community (Grid Singularity)

Table 3: Energy Invoices and Net Energy Traded for the Order Community

| | **Bought** | | **Sold** | | **Total Balance** | |
|---|---|---|---|---|---|---|
| **Asset** | **Energy (kWh)** | **Paid (€)** | **Energy (kW h)** | **Revenue (€)** | **Energy (k Wh)** | **Total (€)** |
| Home 1 | 1669,67 | 500,55 | 0,5 | 0,14 | 1669,17 | 500,41 |
| Home 2 | 1333,67 | 399,74 | 0 | 0 | 1333,67 | 399,74 |
| Home 3 | 829,67 | 248,53 | 0 | 0 | 829,67 | 248,53 |
| Home 4 | 672 | 201,21 | 0 | 0 | 652 | 201,21 |
| Home 5 | 2520 | 755,72 | 0 | 0 | 2520 | 755,72 |
| Home 6 | 9,56 | 2,87 | 3,08 | 0,46 | 6,47 | 2,4 |
| Home 7 | 9,56 | 2,87 | 3,08 | 0,46 | 6,47 | 2,4 |
| Home 8 | 16,8 | 4,93 | 0 | 0 | 16,8 | 4,93 |
| Home 9 | 9,56 | 2,87 | 3,08 | 0,46 | 6,47 | 2,4 |
| Home 10 | 9,56 | 2,87 | 3,08 | 0,46 | 6,47 | 2,4 |
| Grid Market | 0 | 0 | 7067,23 | 2120,17 | 7067,23 | 2120,17 |
| Total | 7080,06 | 2122,16 | 7080,06 | 2122,16 | 0 | 0 |

**Energy Export  Energy Import  Neutral**

*F. Scenario 4 (Multi-Consumer Community with Two-Sided Payment and Net Payment Method)*

In the fourth scenario, trading was conducted using the Net Payment method, but the results showed very minimal changes. When compared to Table 3, it is evident that although there is a higher volume of energy traded, this energy is obtained at a higher cost. This can be attributed to the increased energy demand resulting from the higher number of households and energy loss due to the community sourcing its energy from the external grid.

Table 4: Energy Invoices and Net Energy Traded for the Order Community

| Asset | Bought | | Sold | | Total Balance | |
|---|---|---|---|---|---|---|
| | **Energy (kWh)** | **Paid (€)** | **Energy (kW h)** | **Revenue (€)** | **Energy (k Wh)** | **Total (€)** |
| Home 1 | 1669,67 | 500,55 | 0,5 | 0,14 | 1669,17 | 500,41 |
| Home 2 | 1333,67 | 399,74 | 0 | 0 | 1333,67 | 399,74 |
| Home 3 | 829,67 | 248,53 | 0 | 0 | 829,67 | 248,53 |
| Home 4 | 672 | 201,21 | 0 | 0 | 652 | 201,21 |
| Home 5 | 2520 | 755,72 | 0 | 0 | 2520 | 755,72 |
| Home 6 | 9,56 | 2,87 | 3,08 | 0,46 | 6,47 | 2,4 |
| Home 7 | 9,56 | 2,87 | 3,08 | 0,46 | 6,47 | 2,4 |
| Home 8 | 16,8 | 4,93 | 0 | 0 | 16,8 | 4,93 |
| Home 9 | 9,56 | 2,87 | 3,08 | 0,46 | 6,47 | 2,4 |
| Home 10 | 9,56 | 2,87 | 3,08 | 0,46 | 6,47 | 2,4 |
| Grid Market | 0 | 0 | 7067,23 | 2120,17 | 7067,23 | 2120,17 |
| Total | 7080,06 | 2122,16 | 7080,06 | 2122,16 | 0 | 0 |

**Energy Export** **Energy Import** **Neutral**

## III. RESULTS

For example, in the first scenario, Residences 1, 2, and 3 have made a profit from energy trading, while in the fourth scenario, other residences have obtained their energy from the grid within seven days, meaning that the community has not been able to generate its own energy. This shows that the community is at a loss. Looking at the overall figures, when the community had a demand for 7,129.375 KWh of energy, it was only able to supply 72.275 KWh. These figures are quite different from the first scenario, where the community produced 508,600 KWh of energy when the demand for energy was 2,646 KWh, indicating that the community is efficient and profitable at a high level [20].

## IV. DISCUSSION

According to the reviews, as the number of residences increases, the volume of energy trade naturally rises, leading to higher costs. At the same time, an increase in the number of residences also leads to a higher dependence on the external grid[5],[19]. In other words, more residences require the community to obtain energy from external sources, reducing the community's profits and making it more dependent on external sources. Additionally, it indicates an increase in energy loss due to transformers and other conversion devices[4], [16].

## V. CONCLUSION

According to the results of the research, there needs to be a certain number of residences in the electricity markets. This implies the need to progress towards achieving reasonable profits and reduced dependence on external sources. Peer-to-peer energy trading is a method that enables less reliance on the main grid and higher profitability. In order to achieve these goals, the number of residences for communities engaging in trading should be determined from an engineering perspective.


## ACKNOWLEDGMENT

This work was written based on my experiences in my professional career and the knowledge I gained at Yıldız Technical University.


## REFERENCES


[1] Mohammad Khodoomi, Hadi Sahebi, Robust optimization and pricing of Peer-to-Peer energy trading considering battery storage, Computers & Industrial Engineering, Volume 179, 2023

[2] Hadi Sahebi, Mohammad Khodoomi, Marziye Seif, MirSaman Pishvaee, Thomas Hanne, The benefits of peer-to-peer renewable energy trading and battery storage backup for local grid, Journal of Energy Storage, Volume 63, July 2023

[3] Xubin Liu, Xinyu Chen, Tianyu Jin, Zhangjie Liu, Yonglu Liu, Mei Su, Canbing Li, Qiuwei Wu, Network-Constrained Peer-to-Peer energy trading for multiple microgrids considering zoning pricing, International Journal of Electrical Power & Energy Systems, Volume 147, May 2023

[4] Yuanxing Xia, Qingshan Xu, Yu Huang, Pengwei Du, (2023), Peer-to-peer energy trading market considering renewable energy uncertainty and participants'. individual preferences, International Journal of Electrical Power & Energy Systems, Volume 148, June 2023

[5] Martin Tegnér, Rune Ramsdal Ernstsen, Anders Skajaa, Rolf Poulsen, Risk-minimisation in electricity markets: Fixed price, unknown consumption, Energy Economics, Volume 68, Pages 423-439, October 2017
[6] Ijaz Hussain, Sajjad Mohsin, Abdul Basit, Zahoor Ali Khan, Umar Qasim, Nadeem Javaid, A Review on Demand Response: Pricing, Optimization, and Appliance Scheduling, Procedia Computer Science, Volume 52, Pages 843-850, 2015
[7] Ross May, Pei Huang, A multi-agent reinforcement learning approach for investigating and optimizing peer-to-peer prosumer energy markets, Applied Energy, Volume 334, 15 March 2023
[8] Yiğit, E., Özkaya, U., Öztürk, Ş., Singh, D., & Gritli, H. (2021). Automatic detection of power quality disturbance using convolutional neural network structure with gated recurrent unit. Mobile Information Systems, 2021, 1-11.
[9] Chengkuan Zeng, Guiqing Qi, Zixuan Liu, Jiafu Tang, Zhi-Ping Fan, Chongjun Yan, Auction-based approach with improved disjunctive graph model for job shop scheduling problem with parallel batch processing, Engineering Applications of Artificial Intelligence, Volume 110, April 2022
[10] Michel Zade, Sebastian Dirk Lumpp, Peter Tzscheutschler, Ulrich Wagner, satisfying user preferences in community-based local energy markets — Auction-based clearing approaches, Applied Energy, Volume 306, Part A, 15 January 2022
[11] (2022) The epiaş website. [Online]. Available: http://www.ieee.org/www.epias.com.tr
[12] Esteban A.Soto, Lisa B.Bosman, EbisaWollega, Walter D.Leon-Salas, Peer-to-peer energy trading: A review of the literature, Applied Energy, Volume 283, 1 February 2021
[13] Dufo-Lopez R., Bernal-Agustin J., "A comparative assessment of net metering and net billing policies. Study cases for Spain," Volume 84, Page 684-697, Energy, 2015
[14] Chenghua Zhang, Jianzhong WuYue, Zhou Meng, Cheng ChaoLong, Peer-to-Peer energy trading in a Microgrid, 2018, Applied Energy, Volume 220, Pages 1-12, , 15 June 2018
[15] OFGEM, Promoting Choice and value for all gas and electricity customers, Pay-as-bid or pay-as-clear pricing for energy balancing services in the Balancing Mechanism
[16] E.M. Mosconia, S. Poponia, C. Silvestri, Insights into congestion costs and financial risk management: the electricity market, The 5th International Conference on Sustainable Energy Information Technology (SEIT 2015)
[17] Xiuhan Lin, Luhao Wang, Hang Xu, Ming Yang, Xingong Cheng, Event-trigger rolling horizon optimization for congestion management considering peer-to-peer energy trading among microgrids, International Journal of Electrical Power & Energy Systems, Volume 147, May 2023
[18] Yuanxing Xia, Qingshan Xu, Yu Huang, Pengwei Du, Peer-to-peer energy trading market considering renewable energy uncertainty and participants' individual preferences, International Journal of Electrical Power & Energy Systems, Volume 148, June 2023
[19] Wei Zhou, Yuying Wang, Feixiang Peng, Ying Liu, Hui Sun, Yu Cong, Distribution network congestion management considering time sequence of peer-to-peer energy trading, International Journal of Electrical Power & Energy Systems, Volume 136, March 2022
[20] Jaysson Guerrero, Bunyim Sok, Archie C. Chapman, Gregor Verbič, Electrical-distance driven peer-to-peer energy trading in a low-voltage network, Applied Energy, Volume 287, 1 April 2021.