

Energy Trading Market Simulator Blockchain-based

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Abstract - Solar energy devices in homes and businesses eliminate the energy supplier-consumer divide. Energy prosumers have new roles. Blockchain technology allows prosumers, consumers, energy, and amenities to exchange energy in a low-cost, safe, and novel way using cipher encoding and wide-ranging arrangement proof. This job builds and operates an unknown and exact Agent-Based Modeling (ABM) model and Geographic Information System (GIS) to handle energy dealing in a domestic neighborhood market for Qatar's Education City Community Housing. (ECCH). The method for reproducing minor market spatial and timing aspects collects and analyzes energy usage data. These models help you build an automated energy trading system and understand trading markets. GPS data and an agent-based design can be used to study community-based property market deals by quickly changing parameters. High-performance calculations will improve large-scale simulation prototypes with many legislators, providing more accurate results and an accessible environment to study the energy blockchain community's impact on Qatar's economy, society, and technology.

Keywords - Blockchain, Energy Trading, GIS, Agent-based modeling, Social Simulation, Real-time mapping, Spatial process

I. INTRODUCTION

1.1 Energy Trading Markets

Conventional markets trade energy through an organized system with multiple mediators, like the eighteenth-century electric power grid. However, energy usage and population rise demand new forms that better serve growing cities. Decentralized systems are 50% more productive and flexible than regulated systems [1]. The central plan needs more money and produces a safer and more stable energy delivery system. Supporting autonomous options locally requires studying the energy market's norms and actors. Photovoltaic (PV) companies and residential uses are blurring the energy provider-user split. Prosumers are energy users who generate energy to save money and the environment [2]. Net metering and feed-in tariffs allow prosumers to sell or use their energy. Utilities can't afford infrastructure repair without charging more to regular customers and lowering regulatory perks for prosumers (like lower Feed-In Tariffs) when prosumers stop using their energy. Higher consumer costs and lower prosumer regulatory incentives cause a "death spiral" loop when more users leave the grid.

1.2 Energy Blockchain

Electricity markets host daily bids at a set price to sell energy. Energy is supplied at the market-clearing cost regardless of the number of offers and bids at any given hour. Sales will decide which makers can meet rising energy demand at the lowest cost. Energy blockchains enable open involvement, zero-cost trades, and safe, automatic energy delivery [3]. A blockchain is a dynamic digital data model with a growing list of time-stamped and cryptographically logged events. Each "smart contract" code is linked to a transaction record and defines the conditions for a transaction. Blocks contain deals.

The Power Ledger Network and Brooklyn Microgrid are blockchain-based power generation reconfiguration tools.

- Power Ledger System uses Sparkz, a smooth power market money, to enable energy apps. It is autonomous, openly available, and extensible. Users can swap money for kWh on the site. It has two-coin networks. (POWR and Sparkz). The network lets prosumers and domestic users' trade energy, and the POWR supports the ecosystem. On Sparkz's network, local money can be exchanged for POWR [4].
- Transactive Grid's Brooklyn Microgrid uses P2P energy sharing to build a green energy network from public rooftop solar projects. LO3 Energy claims Transactive Grid automates real-time customer interactions with energy providers. April 2016 beta testers included five prosumers and five loyal clients [5]. Private Blockchain powers Tendermint. Interactive smart meters handle traditional meters with blockchain coins.

Both trials imply a blockchain system could create and sustain a local energy market. These projects/pilots did not require physical grid constraints or an "in-chain" tool to check the accuracy of TE market regulation and management data. Blockchain-based transactive energy networks have significant flaws.

1. Often missing from these systems is an "in-ledger" method for verifying transactions through tangible monitoring.
2. There is still a lack of tangible security, and they are not geared toward facilitating business between governments.

3. They don't use standard IoT standards, so they don't always work well with other devices.
4. Inadequate scaling is a common problem because permission less ledgers are used.

Both freely outlined autonomous choices fail to handle centralized grid administration's data verification, access, and security issues. Our blockchain-based data security design will enhance encryption and use device-to-device data-sharing methods for business IoT networks to aggregate and verify data seamlessly.

1.2.1 Simulating Energy Ecosystems (Blockchains)

Another innovative feature of this research is using a Complex Adaptive System (CAS) to create a simulated world in which users of the Blockchain Solar Environment can try and evaluate secure and equitable energy exchange. Semi-independent parts perform CAS. CAS is an invention of ABM. When combined, their distinct actions produce highly complicated adaptive systems [6]. The simulation of energy exchange networks in the CSA/ABM has developed.

Equilibrium models, game theory, human subjects' research, and agent-based models have all been applied to studying autonomous energy marketplaces [7]. Since they don't consider human nature, balance systems are incapable of simulating energy blockchain network infrastructures. Since game theory only applies to specific marketplaces, it is too inflexible to use a dynamic energy blockchain. Researching human subjects is time-consuming and difficult without prior knowledge of the industry, but the results can be insightful.

More people are increasingly turning to ABM strategies because they solve these problems. The complicated, ever-changing behavior of energy market networks can be predicted by agent-based modeling (ABM). Smart contracts enable the sharing of energy on a regional scale. Using Byzantine agreement and ABM, they have developed a blockchain-based financial exchange.

A novel model for transactive energy markets has made significant headway in its analysis and validation using these and other CSA/ABM techniques. However, these initiatives are typically insignificant and founded on structural assumptions relevant to other markets but not to Qatar. Adaptive business modeling is used to construct a versatile system for verifying and evaluating a blockchain ecosystem for the energy sector in Qatar's technological, economic, and societal setting.

Thanks to blockchain technology, energy suppliers, prosumers, and end consumers can now engage in safe, low-cost energy trading. Energy trade applications streamline direct energy operations using immutable distributed ledgers and consensus-based transaction authorization. By cutting out the middleman, digitization of contracts streamlines business transactions and reduces business prices.

Thanks to cryptography, transactions, and personal information are safe from prying eyes. Hackers are deterred from accessing sensitive transaction data through distributed systems and consensus-based processes like proof-of-work [8].

Microgrids using crypto-based energy systems are being trialed in Australia and the United States. Work is currently being done in other nations. Global energy blockchain networks are expanding. This initiative is being undertaken to prepare Qatar's decentralized green energy capability for emerging energy technologies and marketplaces. Use bitcoin's photovoltaic power in a decentralized economy with a decentralized societal structure and policy framework.

Community Solar marketing strategies are needed to increase commercial and residential PV usage using energy blockchain solutions. Community solar refers to solar energy devices held jointly by a group and a third entity.

Users can save money on their monthly electricity bills by sharing solar assets. Businesses and homeowners can now use PV systems and energy production through community solar. Current and prospective PV users can rest easy knowing that this technology will help them with energy revenue, PV cost of ownership, and implementation advantages. The installation of community solar panels in the United States increased by 200% per year from 2015 to 2017, reaching 1,500 kilowatts by 2018.

ABM has seen increased application in simulating the independent electricity market in recent years. Energy market environments are modeled as complicated adaptive systems with agent interaction, and ABM is used to forecast their future behavior. New adaptable energy market models have benefited from this and other CAS/ABM approaches. Agent-based modeling also has the advantage of depiction. "Agents" can understand complex data patterns and aggregations of any scale and period. An agent will represent the system. Reducing the complexity of the reference system is a crucial step for modelers. The ABM idea is rarely completely implemented in models. Most agent-based models focus on a single, or at most multiple, interaction levels and a simplified geographic representation. This is due to the lack of a suitable computational modeling approach. There is still a shortage of locally active agents and GPS tasks. We suggest a novel modeling approach for constructing understandable geographic models to address this problem. Assessment and preparation are aided by data processing and Satellite technology.

This investigation replicates energy trade amongst community members and analyzes blockchain transactions using a novel and creative Map layer for a distributed generation trading prototype. The following is a synopsis of this study. Section 2 explains how the suggested approach could incorporate geographical knowledge about physical locations into the ABM. Methods, both theoretical and

practical, are discussed in Section 3. Model truth is assessed in Section 4.

2. PROPOSED MODEL

Distributed vitality from PV usage defies utilities' position as energy dealers by fuzzing the lines between power sources and consumers. Distributed database designs based on consensus-based verification and cryptography encoding can help prosumers, customers, energy, and utilities cut down on transaction costs and increase security by streamlining direct energy operations. With the aid of a supple energy blockchain, this task will facilitate the exchange of solar energy in Qatar in a way that is both secure and transparent while also being environmentally friendly. Figure 1 shows the different situations and participants used in this research to put the trading model to the test.

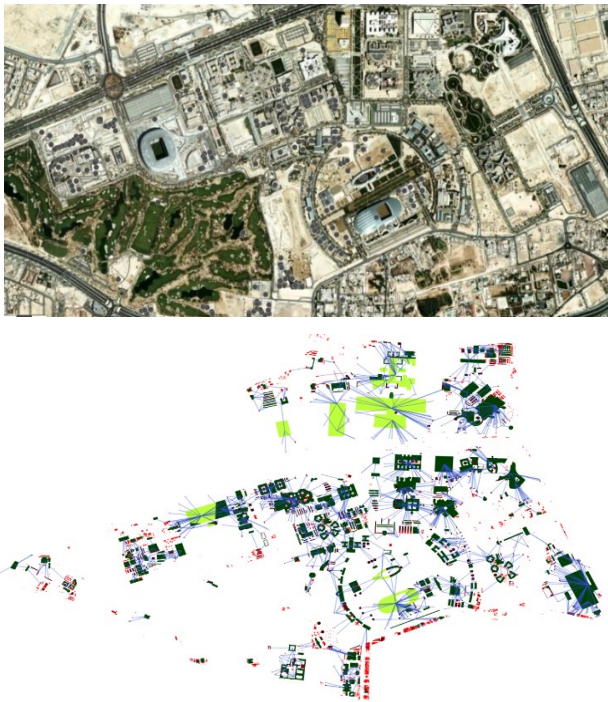


Figure 1. ECCH lots #1 (right) and #2 (left). The data used in this project is for Qatar Foundation housing compound (#lot1 and #lot2). This compound contains 623 homes from different types (villas and flats).

For the ECCH network, we were among the first to create a multi-agent system built on blockchain technology to manage DER and TE [9]. In the current paradigm, each building is viewed as a passive energy agent player, and there is a possibility that its proprietor will "buy" or "sell" the excess solar energy produced on its rooftop to nearby properties. Each energy worker would be in charge of a group of instruments and devices linked to the grid, such as batteries, turbines, solar panels, fuel cells, and other changeable burdens. Using the energy blockchain software, consumers can purchase distributed or central grid power. The smart meters that make up the energy blockchain network record the regional demand and supply. Help desk agents at

KAHRAMAA have access to blockchain transaction data for resolving issues like fixed pricing with peer energy data [10, 11].

Community-based solar energy exchange is assessed in this approach. Population density (the probability that each cell has a house), customer count, and prosumer count are all factors the model considers when assessing potential trade outcomes. The suggested model accounts for traders' interactions with their peers, and exposure to market factors varies depending on their trading experiences. The system evaluation influences the agent's decisions, the market energy price, and the friend reviews. A player's trade past determines how they engage with their peers and how economic principles impact them in the suggested model. The system evaluation impacts the agent's decisions, the market energy price, and the agent's friend information. Our answer is a preliminary concept that consists of three sub-pairs: 1) a sub-layer, 2) API GIS-ABM software/technique, and 3) Blockchain participants. Adjustments will be made to the blockchain infrastructure to allow for practical ECCH implementation.

3. DATA & METHODS

Collecting data, treating it, predicting it, analyzing it, verifying it, and evaluating its success are the five phases of the proposed design. In this article, we describe the first set of computer trials designed to examine how the trading behaviors and outlooks of the characters in our model evolve. To begin, we construct a customer agent community consisting of people who have requested energy trades. We simulate a domestic market with as many as 700 individual consumers. Energy users can make educated choices regarding their electricity consumption.

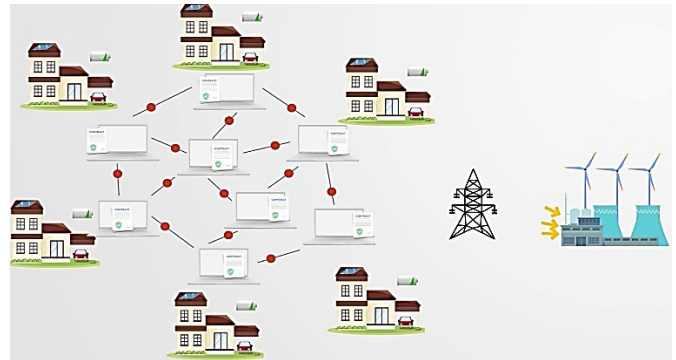


Figure 2. ECCH lots #1 (right) and #2 (left). The data used in this project is for Qatar Foundation housing compound (#lot1 and #lot2). This compound contains 623 homes from different types (villas and flats).

The model uses the correlation between the different structures' types, distances, sizes, surfaces, and levels to describe the commercial exchange process. If you want to save money on your electricity bill, you can buy it from the utility or your k closest neighbors. Our ABM software integrates many figures, such as power grid data, hourly

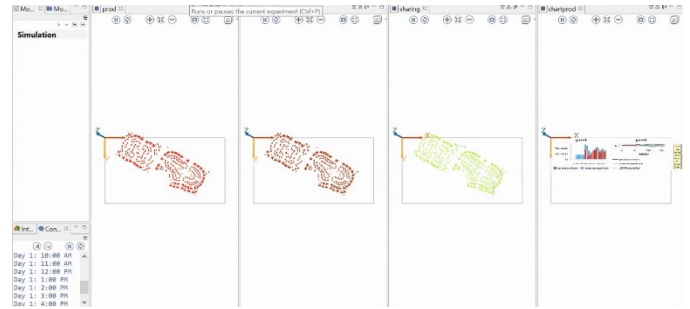
production capability profiles, energy generated from rooftop PV panels, and building figures. In Figure 1, we show the entire area (including node shapefiles and the road) used for the study. The research also made use of ECCH's OSM figures provided as shapefiles. The roadway shapefile was pre-processed to create the node shapefile.

Our prototype aims to depict how individuals in a neighborhood interact with one another (see Figure. 2). It caters to various dwellings and provides a wide range of layout options. This allows us to observe how the agents' actions evolve in reaction to different conditions by analyzing the characteristics of local electrical transfers. The structure also shows how agents interact by incorporating geographic vector information and considering each geographical object as an agent. Therefore, the agents can depict anything in the ECCH spatial data collection, including a road, a structure, or anything else. The various entities that make up the suggested model are described in more detail below.

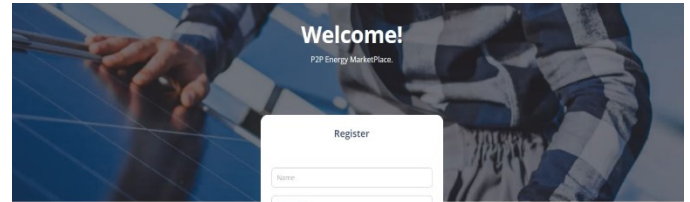
- **People:** 623 families who call this place home are included. Each agent is guaranteed to watch for another agent using an agent-based model to make a power buy or sale through the energy exchange system. It's a truth that people have different needs throughout the day, and they properly disperse their queries about satisfying those needs across the city. Agent's duties may include gathering information about potential energy customers in the area. They also put together a buy request and choose the lowest-priced prosumer.
- **Users** have fluctuating electricity needs throughout the day based on variables like expense and other internal and exterior factors.
- **Utilities:** a company that supplies energy to customers and allocates the resulting balance of costs for the following day
- **Producers:** Power is supplied by "Producers," who charge a set rate per kilowatt hour.
- The producers have the final say on how much electricity they will generate at any particular time.

4. EXPERIMENTAL RESULTS

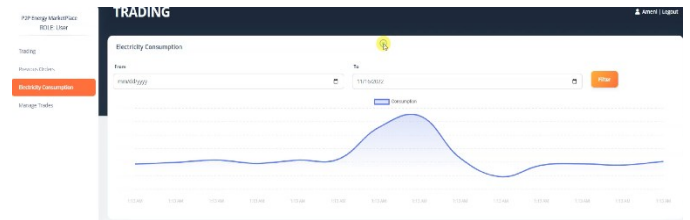
The research also introduces a novel way to test and validate secure and equitable energy trading across Decentralized Technology Ecology users by constructing a real GIS environment. By combining geographic vector data from section 3 with a multi-level categorization strategy, we can respond to the requirements of the medium- to large-scale dealing market and observe fundamental market changes and advances. Second, the system suggests ways in which GIS data and agent-based modeling can be combined to produce more sophisticated blockchain-based applications. Compounds from the ECCH lot#1 and lot#2 groups play central roles in the model.



(a)



(b)



(c)

Figure 3. (a) A snapshot of the energy trading platform simulating the trading behavior of the 623 households in ECCH lot #1 and lot #2. The application provides demand and supply forecast profiles for each household during the energy, (b) a snapshot of the peer to peer online platform where a user can submit his “bids/asks” request and (c) tracking the real-time energy consumption plot of households.

The model analyzes the potential financial and legal implications of residential PV swapping in light of current energy costs, neighborhood norms, and grid status. Domestic PV trading is highly encouraged by the power sector pricing of PV at immediate t in Qatar. It can be facilitated further by including the addresses of houses currently involved in bid/ask transactions. In Figure 3. (a), we see a simulated trajectory. The average dealer's sentiment is depicted here, and the agents' opinions are unstable throughout 65 instruction stages. This can be attributed to the high-frequency consumer agents interacting in a particular region. To illustrate how companies compete for 100 simulated periods. Figure 3. (a) depicts three phases of a typical exercise day. All balancing offers are accumulated at the balancing moment, and the ones

with the lowest prices are used first. The output and consumption are compared after every 12 minutes. The model and its associated components are made available through an online web-based application where a user can submit his asks/bids requests. The platform allows a real-time tracking of households 'energy profiles.

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5. CONCLUSION

This paper focuses on the scalability issues associated with energy deals in the decentralized technology trilemma. It uses the decentralized technology trilemma's elements to rate decentralized technology for peer-to-peer electricity exchange. To evaluate and verify the energy infrastructure in the ECCH microgrid that supports 623 residential units, this study focuses primarily on the model study. If the gap grows too large, the regulation will be changed. Each update lasts for 60 minutes. The balance is determined by the amount spent in the previous month. Hourly requirements, available loads, and productive capacity are all displayed in Figure 2.

The outcomes demonstrate that the suggested prototype can now handle trading markets, enabling us to witness genuine market growth and enhancing modeling outcomes through GIS choices like hierarchical definition with ABM and spatial vector information utilization. GIS information and agent-dependent prototyping are combined to develop more sophisticated automated trading schemes. Results and future actions are discussed.

REFERENCES

- [1] Nsikak J. Blockchain can revolutionize the energy industry in Africa. In World Economic Forum 2018 Nov (Vol. 29).
- [2] Page MM. Energy transitions, intermediaries and home battery storage in Australia (Doctoral dissertation, Macquarie University, Faculty of Arts, Department of Geography and Planning).
- [3] Andoni M, Robu V, Flynn D, Abram S, Geach D, Jenkins D, McCallum P, Peacock A. Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Renewable and sustainable energy reviews*. 2019 Feb 1; 100:143-74.
- [4] Sadaye RA. Enabling Peer to Peer Energy Trading Marketplace Using Consortium Blockchain Networks. Arizona State University; 2019.
- [5] Orsini L, Kessler S, Wei J, Field H. How the Brooklyn Microgrid and Transactive Grid are paving the way to next-gen energy markets. In *The energy internet 2019* Jan 1 (pp. 223-239). Woodhead Publishing.
- [6] Heath BL, Hill RR. Some insights into the emergence of agent-based modelling. *Journal of Simulation*. 2010 Sep 1; 4:163-9.
- [7] Marks R. Market design using agent-based models. *Handbook of computational economics*. 2006 Jan 1; 2:1339-80.
- [8] Williams SP. *Blockchain: The next everything*. Scribner; 2019 Mar 26.
- [9] Boumaiza A, Sanfilippo A. Data Forecasting with Application to Blockchain-based Local Energy Markets. In *2022 13th International Renewable Energy Congress (IREC) 2022* Dec 13 (pp. 1-5). IEEE.
- [10] Ameni Boumaiza, Mazhar Sajjad, Antonio Sanfilippo, Nassma Mohandes, "Designing an Agent-based Energy Exchange Simulation Framework for Modeling Blockchain Systems," *International Conference on Sustainable Energy-Water-Environment Nexus In Desert Climate, Doha, Qatar*, 2-5 Dec 2019.
- [11] A. Boumaiza and A. Sanfilippo, "AI for Energy: A Blockchain-based Trading Market," *IECON 2022 – 48th Annual Conference of the IEEE*