Blocking the Grid: An Ethical Assessment of Blockchain Applications in Peer-to-Peer Energy Trading

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ABSTRACT

Peer-to-peer energy trading has arisen as a solution to rising demand for green energy and a desire to bypass the current model of centralized electrical utilities. Currently the field is unfocused, with many different approaches being tested in simulations and trials. Many such trials involve using a blockchain-backed element to some degree in order to ensure transparency and balance. However, the vast majority of these trials are being assessed purely on the bases of material efficiency and cost-value criteria, with very little attention being given to ethical implications of implementing such a system for an essential utility. This paper will discuss the benefits and consequences of using a blockchain-backed system for peer-to-peer energy trading, with references to some of these trials and the implications of their approaches.

KEYWORDS

Blockchain Technologies, Peer-to-Peer Energy Trading, Sharing Economy, Equality, Energy Prosumers, Microgrid Transactions, Price of Anarchy

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1 Introduction

The increase in the development of renewable energy has led to the rise of a new class of utility customer; the prosumer. While this group in theory would result in a grid made up more of green energy, in reality access to these technologies is concentrated among the upper class. In addition, current avenues for people to participate in trading of their energy resources can only be done through centralized and often monopolistic energy companies. Should a prosumer produce more than they consume, a common outcome is for the utility to pay the prosumer for the money, resulting in wealth accumulation in already high income households, with lower income households not benefitting from the network in any feasible way.

The current leading solution to this issue is developing a peer-to-peer energy trading model wherein prosumers consumers can participate in a marketplace with one another. This has in turn made the concept of smart grids and interacting microgrids an increasingly common goal for utilities and prosumers alike. Recreating a utility in such a way presents a unique set of challenges, such as where people will trade this commodity, how electrical load will be balanced, what type of currency will be used, and how the system will be kept secure.

One such solution includes using a blockchain backed marketplace, with some approaches having a blockchain-backed token acting as currency, and others having the load itself be traded using a blockchain-backed ledger system to maintain transparency. Blockchain has been increasingly selected as the backing record system for a variety of applications focused on decentralization, and while many see it as the future of transaction verification, blockchain has also occasionally been used in a way that replicates current power structures rather than disrupting them. Improperly utilized blockchain technologies run the very real risk of simply overengineering extant structures with the added downside of alienating those not already fluent in the technology itself. In something as essential as a utility, this can have dire consequences.

While all ventures in peer-to-peer energy trading are currently deeply theoretical at this point in time, the literature that exists largely focuses on structure and execution, with few if any pieces on the ethical implications of any model, let alone a blockchain-backed one. This paper will act as a review of several such ventures, and discuss the benefits and pitfalls of using blockchain as a basis for a peer-to-peer energy trading model.

2 The Peer-to-Peer Model

Recent years have led to increasing concerns about climate change, and with it an increasing interest in residential green energy generation. This has given rise to a new class of energy user called a "prosumer", who both generates power to and uses power from the grid. However, it does not seem that the opportunity to be a prosumer is equilateral.

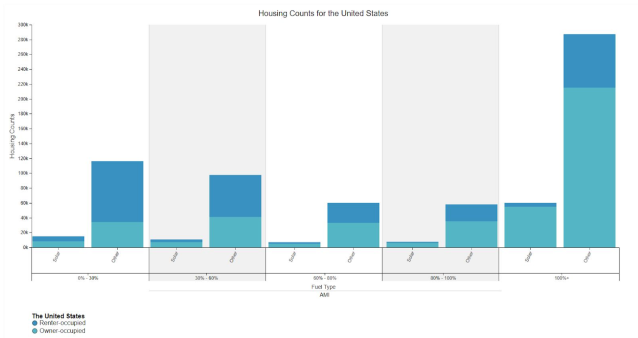

Figure 1: Owner/renter occupied buildings with solar and other heating fuel. [1]

Figure 1 shows information from the LEAD tool, illustrating the relationship between access to green energy for heating fuel and percent of the average median income. More housing units have solar alone as a fuel source in the 100%+ bracket than in all the lower brackets combined. Additionally, 81% of solar heating energy is coming from owner-occupied homes versus 53% of electrical heating energy.

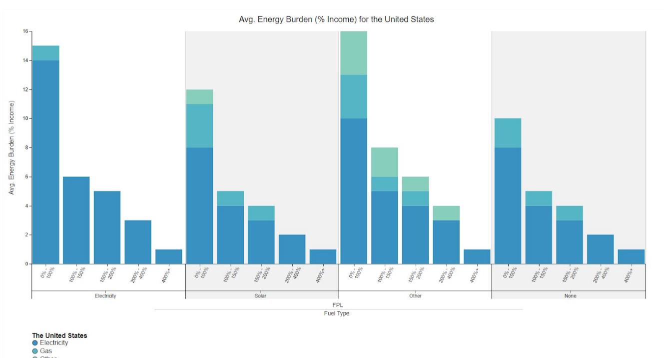

Figure 2: Average Energy Burden across Federal Poverty Level groups and heating fuel type [1]

Figure 2 shows data about financial burden on various rungs of the Federal Poverty Level divided into energy sources. Solar energy is correlated with the second-lowest financial burden among those at 0-100% of the FPL, next to those who have no fuel source for heating at all (and generally lower financial burden across the board).

2.2 Smart Grids and Microgrids

This rise in prosumers has created a need for power infrastructure to work in a very different way than they had before; now power flew into and out of the grid. This situation created an interesting problem for power companies in terms of forecasting. Power grids are subject to Kirchhoff's rule, which states that the power that flows into a system must be equal to the power that flows out. Companies could either choose to depend on the output of prosumers, potentially not being able to meet demand in case of a prosumer's equipment malfunctioning, or choose not depend on this output, likely resulting in wasted generation. Since then, smart grids have been implemented which provide more robust data for forecasting, with excess energy being stored or traded.

This balancing can be done more reliably when organized into a series of interconnected microgrids rather than one large contiguous system. Zhang et al theorizes that the most likely way the grid will be organized in the future is that there will be three tiers of microgrids interacting at increasing scales[2]. However, transferring energy at long distances results in energy loss, so coordination between these microgrids is vital.

This coordination and balancing could be done by a central agent, but this frequently has little benefit to those in lower income groups. Peer-to-peer energy markets make energy a collaborative effort; while it will not install solar energy for lower income people outright, it redistributes the savings in green energy to those in the microgrid. One such approach in order to make this model accomplishable is to have the load and transactions between peers managed by a distributed ledger system via blockchain.

3 Benefits of Blockchain Applications

Blockchain presents many attractive solutions to the hurdles presented by a peer-to-peer system. This system has seen a rapid increase in popularity in computer science circles of late, and it has tremendous benefits for those aiming to move away from centralizing groups for services. Decentralized transactions introduce the concern of "double spending", an occurrence wherein a unit of nonstandard currency can be used several times more than intended during a transaction, causing inflation. In something like a peer-to-peer energy trading network, where this currency could theoretically be electrical load itself, this is unacceptable. Blockchain uses a collected distributed ledger system to solve this problem, where any transaction not found in over 51% of the system is considered invalid. Johanning et al have this to say about blockchain as a peer-to-peer energy solution: "They are the foundation for creating digital assets. Since they also solve the double-spending problem, technology and disruptive potential through 'the creation of a market using a smart contract' is decisive here"[3].

3.1 Ledger Approach

Blockchain makes use of a distributed ledger system to keep track of transactions. Accordingly, many blockchain-backed implementations include using this ledger to track load currently in the system. The fact that this ledger gets distributed allows those with access to it to be conscious of the current supply and demand. Additionally, the ledger allows everyone involved to see the past transactions, which also assists in load forecasting and transparency. Similar, the microgrid approach allows forecasting to occur on a more granular level, increasing the overall accuracy within each group. This results in less wasted generation, which is better both for the environment and savings.

The ledger forecasting also allowed for coalitions to be formed on the basis of generation and usage. While typically some amount of user anonymity is maintained in these trials, the blockchain can potentially recommend users to one another in order to maximize the net social efficacy of the exchange as well as to maximize utility within the system as a whole, as seen in Sid et al's efficiency assessments[4].

3.1.1 Transparency

The major promise of transparency via blockchain can sound contradictory at a glance. As a system, it advertises transparency, but it also claims to be a "trustless" system. The distributed ledger allows all transactions within the chain to be viewable by all engaged in the network, which is transparent, but these systems also typically anonymize the participants in some way, restricting the knowledge exposed about each user to solely their transactions. In this way, a form of trust is formed, but based solely on the behavior documented and not on externalizing factors. Per Wulf, "by establishing a network of transacting parties that trust each other despite anonymity, the technology enables unbiased transactions and eliminates prejudices against minorities[5]". In this way, blockchain can act as an equalizer, protecting marginalized communities from discrimination that may otherwise take place in a peer-to-peer environment.

3.2 Building Resilient Communities

It is also argued that using blockchain in this model will lead to more resilient grids and communities. Microgrids backed by blockchain make managing load relatively simple, which logically leads to fewer brown-and-blackouts. To the same end, power primarily comes from the community itself, meaning sources are localized and easier to access and repair than the remote generation and equipment generally encountered in traditional centralized models.

Additionally, by having blockchain-backed microgrids, communities are encouraged to invest in themselves rather than in centralizing agents. As seen in Figure 2, people at 0-100% of the Federal Poverty Level carry the most financial burden in terms of energy spending, which also means they gain the most proportionally from the lower energy prices and decreased waste that blockchain allows. Increasing the financial independence of lower-income communities in turn allows them to be more financially resilient as well. By shielding marginalized communities from discriminatory trading practices while also increasing the overall wealth in said community, a blockchain-based model shows a lot of promise in terms of the ethical and social implications of peer-to-peer energy trading.

4 Concerns of Blockchain Applications

To the general population, blockchain is not terribly well understood, especially when one disentangles it from cryptocurrency applications. While one of the goals of such a model involves a trustless network of users, the users themselves still need to be able to have to trust in the network itself for the model to have any validity. This is doubly true for a basic utility such as power, so at the very least a widespread implementation of a blockchain-backed model would require adequate education of those engaged, a point that was not brought up in any of the case studies reviewed when discussing potential for a wider rollout. .

Trial runs for peer-to-peer are still in their infancy, especially in regards to blockchain. In a comparative review of such trials, Park et al claimed that "it is still difficult for individuals to freely trade electricity, and the scale is also rather small"[6]]. While the blockchain-specific trials have typically made it easier for transactions to occur, this approach still presents several concerns for engineers to tackle.

4.1 The Blockchain Trilemma

Figure 1: The Blockchain Trilemma. [7]

In a way, blockchain is at odds with itself. The Blockchain Trilemma was a concept introduced by the founder of Ethereum, Vitalik Buterin, to describe the issues blockchain technologies had with balancing their goals in regards to scalability, security, and decentralization. While the concept was originally introduced to describe cryptocurrency environments, these issues expand to the core of all blockchain-backed technologies.

Scalability typically refers to the number of transactions a blockchain can process in a certain amount of time. Namely, due to the distributed ledger network, the more nodes are in a given blockchain means more distributed ledger copies need to be updated for each transaction.

Security refers to the distributed safety of the network in general. Due to its structure, blockchain is susceptible to something called a 51% attack. Part of blockchain's fraud resistant nature means that if less than 51% of nodes register a transaction, it is considered invalid and wiped from the distributed system. However, should a specific entity have control over 51% of nodes in a network, fraudulent transactions could easily be entered into the ledger without any issue. One can avoid this issue by having a diversified node population, but this leads to issues with scalability mentioned above.

Decentralization focuses on the core of blockchain - the trustless distributed ledger network. Blockchain technologies are supposed to allow participants to not have to trust in a centralizing body to validate transactions. However, in order to be cognizant of security concerns and flaws in the blockchain, a centralization agent of some form is frequently required. For instance, a common solution to security concerns involves having multiple blockchains essentially managing the same data, but this would then require some additional body to cross check the two ledger systems and decide which one is at fault during an attack.

The trilemma is of vital concern to peer-to-peer energy trading. One of the main benefits of such a model would be to take full advantage of the decentralization blockchain allows and move away from having to get power through a utility. However, several proposed models depend on interactions between microgrids to deal with scale[8][4]. If each microgrid works off of its own blockchain, then decentralization must be ceded where these grids overlap. These smaller microgrids also introduce security issues, as it's very possible for a rental company to own a high proportion of properties within a certain geographic area, opening up a possibility for a 51% attack. If the entire grid works off of one chain, scalability issues come into play, which could lead to humanitarian issues in cases of blackouts where many transactions may occur at once.

While most of the case studies reviewed for this project attempted to fix one of these problems, none of them did it without falling victim to the trilemma and worsening another issue.

4.2 Price of Anarchy

The price of anarchy is a measurement used to assess how well a system functions assuming a certain amount of selfish behavior within a group. Sid et al. [4] focused their analysis of blockchain-backed peer-to-peer energy trading on taking data from a real world trial and using various cost splitting methods across coalitions to determine the total utility yielded. Equal split meant that all agents paid the same amount regardless of consumption, proportional split meant that agents paid proportional to their consumption, and egalitarian meant that everyone paid the amount needed for them to all receive the same amount of utility.

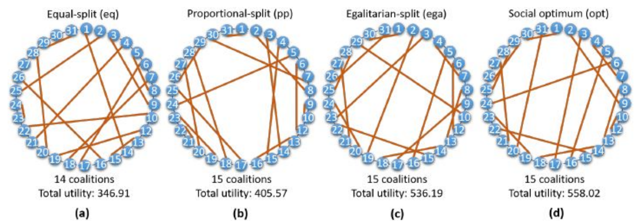

Figure 1: Figure X: Total utility output with a variety of cost sharing methods [4].

The outcomes are shown above, with the last graphic indicating the optimized coalitions. The loss of utility between the various methods from this social optimum helps us understand the price of anarchy in each situation. In order for the model to be socially efficient, and therefore ethical to implement, coalitions must be formed in a sensible way to minimize the price of anarchy. However, this ideal coalition forming would impede the freedom of agents to select the peers with whom transactions occur, counteracting the freedom of choice peer-to-peer would ideally allow. It could also be argued that this process of guided coalition forming is too close to ceding the decentralization that makes a blockchain-backed approach attractive in the first place.

5 Conclusions

The peer-to-peer energy trading model has a lot of potential as a means of better serving energy prosumers as they become more prevalent. Increasing community access to green energy, which is frequently only accessible to those in higher income brackets, is good for the population as a whole and may possibly lead to more conscious energy consumption. Implementing such a model with blockchain would then also allow for transparency of transactions and an easy way to view the state of the grid as a whole. This would in turn ideally result in lower energy waste, requiring less generation in general, and also allow for communities to be more independent without the need for a centralizing agency.

Enacting this model with blockchain technology would theoretically allow communities to bypass the need for a third party to manage electrical load, but would also introduce a bevy of concerns. While bypassing centralizing agents such as utility companies has a tendency to benefit marginalized communities, a grid solely dependent on blockchain lacks many of the measures in place to assist those who need the help the most.

As a technology, blockchain is not well understood by the general populous, and asking a group to trust it for something as essential as an electric utility without proper prior education is unreasonable. Additionally, the peer-to-peer model is dependent on external batteries to help manage nighttime load, which is not financially feasible for many. Blockchain also has inherent issues with privacy, security, and ability to scale.

While case studies have not ignored many of these issues, they are generally viewed more as stumbling blocks to implementation rather than as ethical issues. Out of interest of furthering the peer-to-peer model, many studies only coincidentally mentioned social repercussions. While not warranting a condemnation of a blockchain-backed peer-to-peer models, further case studies need to assess the barriers to entry such an approach would have to the general public and how to better cope with these issues without falling victim to the blockchain trilemma.

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