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Microgrid and Blockchain: Bringing Sustainable Electricity to Myanmar

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Abstract

Myanmar's limited electricity infrastructure presents an opportunity to privately develop microgrids that are separate from the existing centralized grid system. The technological breakthroughs in microgrid and blockchain systems enable private investors to develop blockchain-based microgrid systems that allow prosumers- consumers who also produce energy with household solar panels- to freely trade energy within the microgrid community. A blockchain-based microgrid system that incentivizes all parties to optimally produce and consume electricity according to the aggregate supply and demand is proposed to minimize the need for storage and ensure efficient allocation of energy.

Examples of the combination of blockchain and renewable energy already exist, such as SolarCoin, the first solar energy-based digital currency. A pilot project for a blockchain-based microgrid system is underway in Brooklyn Microgrid (BMG). These pilot projects are collecting data and adjusting their models to build a scalable blockchain-based microgrid model. More pilot projects are needed in Myanmar in order to identify the specific regional challenges and variables required for building an optimal, socially inclusive model.

Keywords

Blockchain, Microgrid, Renewable Energy, Electricity, Infrastructure, Prosumer

Disciplines

Business

MICROGRID AND BLOCKCHAIN:

BRINGING SUSTAINABLE ELECTRICITY TO MYANMAR

By

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Abstract

Myanmar’s limited electricity infrastructure presents an opportunity to privately develop microgrids that are separate from the existing centralized grid system. The technological breakthroughs in microgrid and blockchain systems enable private investors to develop blockchain-based microgrid systems that allow prosumers- consumers who also produce energy with household solar panels- to freely trade energy within the microgrid community. A blockchain-based microgrid system that incentivizes all parties to optimally produce and consume electricity according to the aggregate supply and demand is proposed to minimize the need for storage and ensure efficient allocation of energy.

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1. Introduction

Electricity supply in Myanmar has traditionally been hampered by the lack of infrastructure. Despite the central location in Southeast Asia bordering China, Thailand, Laos, and India, Myanmar has been troubled by internal political conflicts and the lack of external investment. Myanmar currently has a centralized grid system mainly for its two major cities, Yangon and Mandalay. Most of the suburban or rural areas do not have access to the centralized grid system, however, and the urban areas experience frequent power outages and delays due to the seasonality of its electricity supply and the poor maintenance of the grid system. Expanding the existing centralized grid system is both costly and unsustainable, and the government does not have the financial resources or the political stability to support an expensive, long-term infrastructure project. International agencies such as the World Bank have given loans to support the expansion of the centralized grid system, but they have been ineffective due to the government's heavy energy subsidy that depresses the energy price.

Myanmar, however, is a rapidly emerging economy that requires a significant boost in its energy production. The country's demand for electricity doubled between 2012 and 2018, showing a dramatic increase in energy demand from the increase in economic activities[1]. Given the explosive demand in electricity and the government's inability to financially support the grid expansion, this presents an opportunity for private sector energy development in Myanmar. This opportunity coupled with a rapid development and innovation of blockchain technology suggests a possibility of creating a decentralized, private grid system with microgrids both consuming and

[1] Dapice, David. "Electricity Demand and Supply in Myanmar." *Ash Center*, Dec. 2012, ash.harvard.edu/links/electricity-demand-and-supply-myanmar.

producing energy without relying on a centralized, government-sponsored grid.

A system of using the blockchain technology with microgrid has been suggested as a potential solution to increase efficiency in electricity distribution. In this system, households that consume and produce renewable electricity- also known as prosumers- are connected to each other as part of a microgrid and participate in a trade of excess electricity. This system increases the private sector involvement in energy production and gives more autonomy to the microgrid operators and the individual households. A blockchain focusing on renewable energy production is already in use, such as SolarCoin, as discussed later in this paper. A pilot project for connecting households to form a microgrid is underway in Brooklyn, New York, to test the commercial viability of this system. Both blockchain and microgrid technologies are relatively new and not widely implemented yet, and they present a number of challenges that need to be addressed.

This paper explores the possibilities of applying the blockchain-based microgrid system for a sustainable electricity supply in Myanmar. More households in Myanmar are relying on private renewable electricity generation, often using cheap solar panels from China. The proposed blockchain-based microgrid system has the potential to link these households and create private microgrid systems throughout the country and lessen the need to rely on the government's efforts to expand the centralized grid system. This paper presents background data from publications on blockchain and microgrid, and analyzes the risks and challenges associated with implementing this system in Myanmar through comparing with the existing microgrid projects, and how this new system will make the electricity distribution in Myanmar more efficient.

2. <u>Background – Myanmar</u>

Myanmar continues to experience extreme poverty and lack of infrastructure mainly due to the ongoing political unrest. There has been minimal investment activity in the energy infrastructure of Myanmar, supported by a collaboration between the Myanmar government and international agencies and aid organizations. The recent industrialization and technology investment, however, are causing the electricity demand in Myanmar to grow rapidly, at approximately 14% annually.[2] The current energy supply is extremely limited and is not meeting the growth in demand, leaving approximately 70% of the population without reliable access to electricity.[3] The current grid system only supplies power to the major urban areas and does not reach the communities in the rural areas. Furthermore, the centralized grid system results in frequent power outages due to poor maintenance and the seasonality of hydropower, combined with the lack of storage capacity for excess electricity.

Current Electricity Generation System & Household Usage

The government of Myanmar relies heavily on seasonal hydropower to supply electricity to its grid system. Hydropower accounts for 68% of the grid electricity, but Myanmar lacks the storage infrastructure to evenly supply electricity throughout the year without the effect of seasonality[4]. This seasonality in electricity supply and lack of storage capacity are the main

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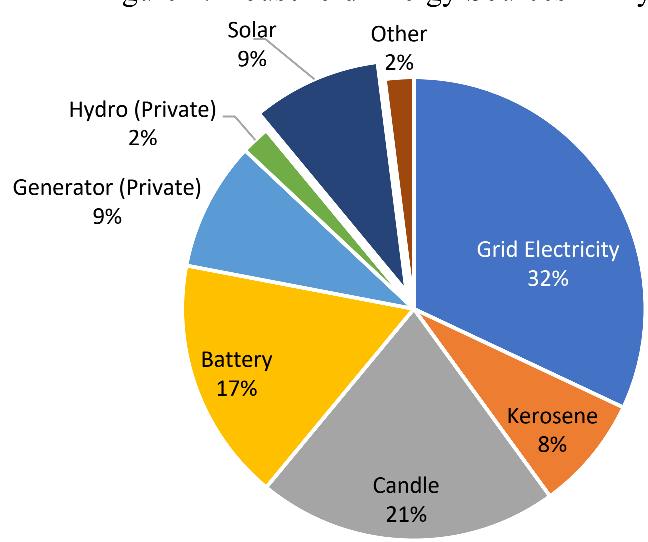
[2] Energy and Extractives Global Practice East Asia and Pacific Region. *International Development Association Project Appraisal Document on a Proposed Credit in the Amount of SDR 286.9 Million (US$400 Million Equivalent) to the Republic of the Union of Myanmar for a National Electrification Project*. Rep. no. PAD1410. N.p.: World Bank, n.d. Print.

[3] "Electricity to Transform Rural Myanmar." The World Bank, n.d. Web. 18 Nov 2017.

[4] Energy and Extractive, *International Development Association Project.*

causes of the frequent power outages in urban areas. Almost all businesses report experiencing power outages and 76% of them own private generators to continue their operations in case of a central power outage[5]. The households, however, mostly do not have the resources to install private generators and are forced to live without electricity and rely on other inefficient, outdated, and environmentally harmful energy sources, such as kerosene or candles. The figure below shows the portion of each type of energy used in households in Myanmar.

Figure 1: Household Energy Sources in Myanmar



(Source: 2014 Census)

Many households outside of the two most major urban centers of the country still do not have access to the basic appliances due to the lack of constant supply of electricity. According to the national energy consumption survey conducted by Asian Development Bank, 8 out of the 13

[5] World Bank Group, UKAID, and MINPED. "Myanmar Eneterprise Survey 2014: Early Findings." *Myanmar Enterprise Survey 2014*. The World Bank Yangon Office, n.d. Web. 24 Oct 2017.

surveyed townships had no access to space cooling and 7 townships had no access to refrigeration. Most townships, however, had access to television, mostly using the electricity from private generators run by fossil fuels. This shows the prioritization of energy use among households in Myanmar, and how the lack of sufficient electricity supply to power essential appliances is preventing further economic growth of the country. The table below shows the further breakdown of household appliance usage.

Figure 2: Household Appliance or Application Availability by Township

Available	Households	Cooking (%)	Lighting (%)	Space Cooling (%)	Water Heating (%)	Television (%)	Refrigeration (%)	Pumping (%)	Other (%)
Ngaputaw	85	100	100	0	100	25	0	2	0
Kyauktada	40	93	100	73	98	95	88	98	15
Dala	61	100	100	2	100	57	31	0	0
Phae Khone	72	100	100	0	0	47	0	1	0
Kyaukpataung	149	100	100	1	5	42	2	10	3
Mandalay	35	100	100	40	43	100	80	66	0
Magway	61	100	100	0	0	36	0	0	5
Theinni	69	91	100	0	0	43	0	0	0
Taungkoke	75	100	100	0	0	20	0	0	0
Di Maw Soe	61	100	100	0	10	67	2	21	2
Platwa	95	100	100	0	0	13	0	0	0
Chaung Sone	78	99	100	0	0	85	3	3	1
Hlaing Bwe	86	100	100	1	0	26	0	0	0

(Source: Asian Development Bank)

Government Plans and International Support

To address this issue, the government of Myanmar has launched the National

Electrification Plan (NEP) with a 400 million USD loan from the World Bank[6]. This plan aims to expand the grid system and reach universal electricity access by 2030, installing more reliable, efficient, and large-scale generators through several stages. The NEP is an ongoing project, however, and has not yielded any significant results despite the ambitious goal of universal electrification. The households, especially those in the rural areas, live the same lifestyle without a consistent supply of electricity and rely on unsustainable generators that require fossil fuels.

The government has also been heavily subsidizing the current electricity production, incurring massive annual deficit and eliminating room to invest in further expansion of the grid[7]. The electricity generated from both public and private powerplants are sold to state-owned distribution companies with an offtake agreement, which locks in rates of future electricity productions. The Myanmar government has been subsidizing electricity distribution through these offtake agreements since the beginning of electricity infrastructure development, and it is accumulating losses as the national electricity demand increases. In 2016-2017, Ministry of Electricity and Energy (MOEE) reported a loss of 337 billion Myanmar Kyat, equivalent of 250 million US Dollars. MOEE expects the country's electricity demand to reach 3,100 megawatts in 2018, which will incur losses amounting to 376 billion Kyat, equivalent to 279 million US Dollars.[8] Considering that the total amount loaned from the World Bank for the National Electrification Plan is 400 million US Dollars, addressing these massive losses from the government subsidy is crucial in creating room for further investment in the grid system.

Efforts have been made to address the subsidy issue but were met with strong

[6] Energy and Extractive, *International Development Association Project.*
[7] Dobermann, Tim, London School of Economics, University of Oxford, and UKAID. "Energy in Myanmar." International Growth Centre, n.d. Web.
[8] Chern, Kang Wan. "Solving Myanmar's Power Problem." *The Myanmar Times*, 1 Aug. 2017, www.mmtimes.com/business/27048-solving-myanmar-s-power-problem.html.

oppositions. The Assembly of the Union, the Myanmar equivalent of the congress, voted in 2014 to raise the electricity prices by as much as 42.8% for both households and businesses[9]. This decision, however, was met with a strong nationwide opposition from both the households and the business owners whose operations depend on the low cost of electricity. Due to this ecosystem that was built around the heavy subsidy by the government, Myanmar is still struggling to minimize the loss and invest more in infrastructure. The vicious cycle of heavy subsidy and lack of funds to expand the electricity infrastructure continues, and the majority of the people in Myanmar are forced to live with an inexpensive, but unreliable supply of energy.

This low quality of government-distributed electricity is forcing many Myanmar households to look to privately managed renewable energy as an alternative. Solar power has been gaining popularity due to the influx of inexpensive solar panels from China, which borders Myanmar. More than one million households are using these inexpensive solar panels, and the movement from using generators that use traditional fossil fuels with health hazards to using sustainable solar panels is accelerating rapidly. This increase in solar panel distribution and individual household electricity generation presents an ideal opportunity to implement the decentralized blockchain-based microgrid communities.

Interest in Renewable Energy Microgrid

These shortcomings of the centralized grid system led to the increasing interest in private renewable energy market. ABB, a Swedish-Swiss multinational corporation specializing in robotics and power, is heavily involved with the grid development in Southeast Asia, including

[9] Htike, Zaw, and Ei Toe Lwin. "Electricity Price Hike Set for April 1." Myanmar Times, 24 Mar. 2014. Web.

Thailand, Cambodia, Laos, and Myanmar. ABB is leading the international interest in implementing microgrid technology in underdeveloped areas such as Myanmar and is vocal in the need for both private and public interest in developing decentralized grid systems. Chaiyot Piyawannarat, the regional managing director of ABB Southeast Asia, notes that microgrids can now be built and installed "much more cheaply compared to ten years ago."[10] He recognizes that the "technology is there… it all has to do with how fast and easy things can get done," pointing to the policy support from the government and private funding for scalability.

Pilot projects are already underway to test the commercial viability of the microgrid model in Myanmar. The Ministry of Agriculture, Livestock and Irrigation (MOALI) implemented eight microgrid pilot projects in selected villages in rural areas with the technological help from the World Bank, Asian Development Bank, and Germany's Gesellschaft für Internationale Zusammenarbeit (GIZ)[11]. MOALI set a target of electrifying 35,000 households with microgrid systems and an additional 460,000 households with home solar panels by 2021. This government investment in microgrid systems signals its support for private investments and significantly decreases risk for any international investment in the area.

Interest from the private sector is also increasing, led by international consortiums that fund joint ventures with local companies. Yoma Strategic Holdings, a Singapore-based investment fund headed by a Burmese businessman Serge Pun, partnered with a Norwegian investment fund Norfund, International Finance Corporation (IFC), and the Canadian government to launch Yoma Micro Power[12]. Yoma Micro Power raised 28 million US Dollars in

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[10] Chern, Kang Wan. "Solving Myanmar's Power Problem." *The Myanmar Times*, 1 Aug. 2017, www.mmtimes.com/business/27048-solving-myanmar-s-power-problem.html.
[11] Thant, Htoo. "Off-grid projects to jump-start rural electrification." *The Myanmar Times*, 12 May. 2017, www.mmtimes.com/national-news/nay-pyi-taw/25957-off-grid-projects-to-jump-start-rural-electrification.html.
[12] Htwe, Chan Mya. "Yoma Strategic-backed outfit to produce and supply power in rural Myanmar." *The Myanmar Times*, 4 Apr. 2018, www.mmtimes.com/news/yoma-strategic-backed-outfit-produce-and-supply-power-rural-myanmar.html

debt and equity to install micro power plants and mini-grids to power rural villages and telecom towers. It plans to scale up to more than 2,000 plants by 2022 to provide microgrid electricity to the rural population.

Challenges of Microgrid System in Myanmar

Developing infrastructure often impacts the livelihoods of the people already living in the area. The Myanmar government has faced challenges with the displacement of the local population, especially in case of hydropower development. Myanmar has traditionally developed around Irrawaddy River, the country's largest river and the most important commercial waterway. Expanding hydropower capacity means building dams that will have environmental damage in the area and displace the villages that have historically been in place.

Another challenge in developing a sustainable, decentralized microgrid system is the volatility in energy supply. Solar power may be affected by the cloud cover and is subject to volatility on a daily basis. The distinct monsoon seasons of Myanmar might also create seasonal volatility with solar energy production. Developing infrastructure for solar energy production requires a significant storage capacity to smooth out the seasonal supply and demand peaks. Myanmar currently does not have the storage capacity for its hydropower energy production and building enough capacity in addition to developing the microgrid systems will be a major challenge. This issue, however, can be mitigated by the blockchain technology explained in the next section.

3. Blockchain Model for Electricity Generation & Distribution

Background – Blockchain Technology

Blockchain technology is transforming the way we engage with centralized systems. Bitcoin first disrupted the global payment system by creating a virtually untraceable crypto-currency that allows people to make decentralized, peer-to-peer transactions without having to go through a centralized agency, such as a bank. More crypto-currencies, including Ethereum and Ripple, are following suit in making global transactions faster, cheaper, and more seamless. Blockchain technology, however, also has many applications outside of the payments industry and can be applied to decentralizing any of the traditionally centralized system. Blockchain startups are disrupting many industries by implementing a decentralized model to industries controlled by a few centralized parties.

The foundation of blockchain relies on coin generation based on different methods of mining. For an example, Bitcoins are generated when a computationally difficult puzzle is solved purely by the size of the computing power. The more computing power one has, the faster one can mine bitcoins; the rate of Bitcoin mining is directly proportional to the size of computing power and the amount of electricity consumed. Similarly, each type of coin has a different way of mining that is determined by the value represented by the generated coins. FileCoin, for instance, generates coins based on the amount of individual storage space shared with the cloud[13].

Traditionally, electricity generation has been controlled by a few central companies that

[13] https://filecoin.io/

are often government owned or controlled. Most developed countries have a centralized grid system that gives no autonomy to the people producing their own renewable energy. Myanmar's unique position of having the microgrid technology available before developing the country's grid system gives the advantage of creating a truly decentralized, cost-efficient energy distribution system. The increasing number of households with their own solar energy generation systems, the interest in microgrid technology, and the need to balance seasonal supply and demand fluctuations place Myanmar in an ideal setting to take advantage of the blockchain technology to enhance its microgrid system.

Blockchain-based Microgrid Model in Myanmar

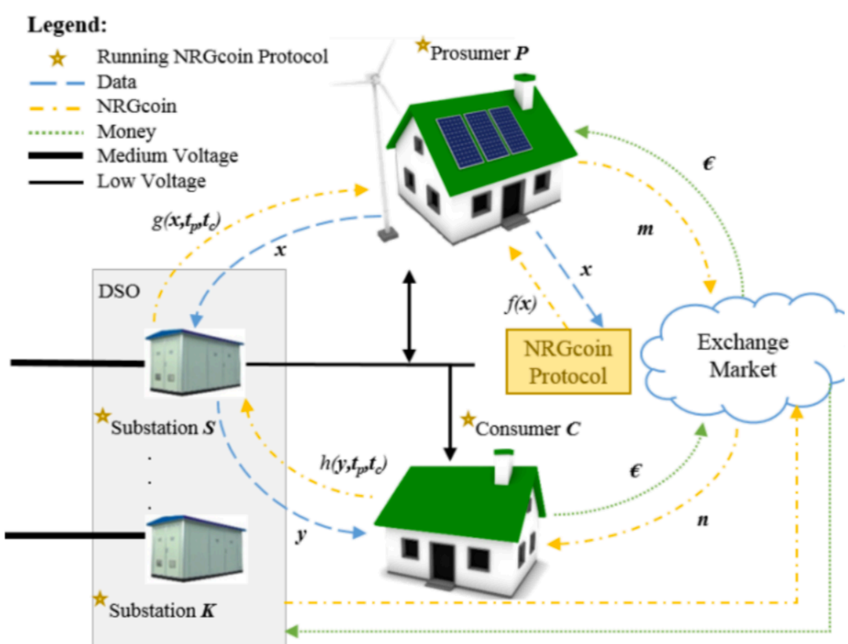
Currently, households with solar panels that consume and produce their own energy trade their energy either by selling it back to the centralized grid or through an auction. Neither of these systems, however, provide an efficient market where price is determined by supply and demand. The prosumers selling the energy back to the central grid have to take the price offered by the grid operator, which is not based on the actual demand. The auction system is more efficient in a way that it matches the sellers with the highest bidder, but the bids represent the buyers' expectation of future price of electricity, not the real-time aggregate demand. Both methods require increase in storage capacity, either as part of the centralized grid or under individual ownership. Incorporating blockchain technology, however, can distribute electricity more efficiently and minimize the necessary storage capacity expansions.

Leveraging Myanmar's existing hydropower infrastructure and the potential to expand using the nation's river network, this paper proposes a microgrid system centered around hydropower plants that also connect to the prosumers who use and produce solar energy. The blockchain technology will allow all parties to freely generate and trade energy, including both the hydropower plant operators and the solar energy prosumers. Having each hydropower plant connected to smaller solar-based microgrids allows electricity generated from hydropower to complement the solar energy generation, minimizing seasonal effects from both solar and hydropower. This combination of different renewable energy forms using the same blockchain mechanism will help Myanmar create a truly decentralized, market-based energy infrastructure driven by private investments. In order to successfully implement this system, the blockchain mechanism should be designed with a careful consideration of incentivizing each party involved through coin generation and matching supply with demand.

1. Coin Generation and Usage

Prosumers, after using the generated electricity for their own usage, can pump the excess energy back into the microgrid to receive coins that they can use later to purchase energy from other prosumers. When a prosumer transfers the energy into the microgrid, new coins are generated to keep the value of the coins from being deflationary. In addition to the new coins generated, the prosumers are awarded coins that match the amount of electricity transferred to the microgrid, adjusted for the total supply and demand. The prosumers can then use these coins to purchase electricity for their consumption at a real-time price determined by the total electricity supply and demand within the microgrid. The prosumers can also trade the coins in an external market for government currency (also known as fiat currency), at a price determined by the supply and demand of the external market. This mechanism is visually explained in the diagram below:

Figure 3: Schematic Setup of Blockchain-based Microgrid



(Source: Mihaylov et al.)

In the model proposed by Mihaylov et al., Prosumer *P* feeds *x* amount of excess energy into the microgrid and receives *f(x)* and *g(x)* amount of newly generated coins. The amount of energy injected into the grid and the coins received are broadcasted to all parties. Prosumer *P* can then use the coins to buy electricity in the future or sell *m* amount of coins on the external exchange market for fiat currency, denoted as € in the diagram. A consumer *C* buys *n* amount of coins from the exchange market and pays *h(y)* coins to purchase *y* amount of electricity from the microgrid. The substations *S* and *K* are connected to the microgrid to store and distribute electricity and collect data on the total electricity production and consumption within the microgrid.

2. Supply & Demand Matching

This model optimizes the aggregate supply and demand of electricity within the microgrid more efficiently by autonomously controlling the price of electricity. This is done through designing the electricity pricing models *f(x)*, *g(x)*, and *h(y)*. The individual microgrid operators can design these functions to fit the unique production and consumption patterns of the community, but an optimal blockchain-based electricity microgrid system will require the three functions that reflect the change in total production and consumption.

First, *f(x)* coins are newly created and awarded to the prosumer *P*. These coins are proportional to the generated energy *x* and are created to prevent further deflation of the coin. The microgrid operator may determine the rate at which *f(x)* is generated, according to the size of the microgrid community and the rate of distribution of coins.

In order to match the supply and demand as closely as possible, it is important to design the production function to incentivize prosumers to produce more electricity during peak demand and vice versa. The production function can be shaped as a bell curve to motivate prosumers to inject just the right amount of electricity into the microgrid. The production price function *g(x)* can be defined as:

$$g(x, t_p, t_c) = \frac{x * q}{e^{\frac{(t_p - t_c)^2}{a}}}$$

The production price is a function of the amount of electricity generated *x*, the total amount of energy produced t_p, and the total amount of energy consumed t_c, where *q* is the maximum price defined by the microgrid operator awarded to the prosumers when the total supply t_p matches the total demand t_c, and *a* is the scaling factor when the total supply does not match the total demand. This function creates a bell curve that awards the highest price to the prosumers when the total supply matches the total demand, which incentivizes the prosumers to continue producing electricity until the demand is met and produce less as soon as the supply exceeds the demand.

The consumption price function should be designed to incentivize the consumers to minimize electricity usage during low demand, and vice versa. This is key to mitigating the daily fluctuations of solar energy from the change in weather, and the seasonality effect from the hydropower generation. In order to efficiently distribute electricity with a minimal investment in storage capacity, the demand must follow the supply during times of low electricity generation. The consumption price function can be defined as:

$$h(y, t_p, t_c) = \frac{y * r * t_c}{t_c + t_p}$$

The consumption price is a function of the amount of electricity consumed *y*, the total amount of energy produced t_p, and the total amount of energy consumed t_c, where *r* is the maximum price defined by the microgrid operator charged to the consumers when the energy supply is below a threshold set by the operator. When the supply matches the demand, consumers are charged the price of r/t_c per kWh. The price approaches 0 as the total production exceeds total consumption, incentivizing the consumers to use more electricity during peak supply and minimize usage during low supply. The production and consumption price functions balance the supply and demand within the microgrid by incentivizing both the prosumers and the consumers to match each other's output and usage.

3. External Trade of Coins

It should be noted that the prosumers get different amount of coins for the same amount of electricity generated, depending on the time of generation. This price is entirely independent of the market value of the coins in the external exchange market. The value of the coins in fiat currency is only determined by the supply and demand of the exchange market, which is determined by the aggregate supply and demand of all microgrids that use the blockchain system. The external trade of coins through a separate market exchange provides an incentive for further expansion of the blockchain-based microgrid system, as the generated coins have a real financial value.

In the context of Myanmar, the individual prosumers will primarily produce solar energy, but the microgrids will be connected to a larger hydropower plant that connects to several microgrids. The external exchange market can serve as a mechanism to efficiently adjust for seasonality in a larger scale, helping both the microgrid operators and the individual prosumers. When hydropower is generating a large amount of seasonal electricity, the prosumers can purchase coins from the exchange market to take advantage of the cheap electricity from the excess of hydropower. Also, if the hydropower operators produce too much electricity and the prosumers are sufficient with the electricity generated within the microgrid, they can sell the coins in the exchange market to recoup the costs of generation or for a potential profit.

The exchange market is reliant on the system's scalability and will benefit from the expansion of the microgrid networks. It sets the financial value of the coins, and the price will increase as the system expands throughout the country and the coins become a widely accepted form of currency for energy. This will attract private investments and the system will scale even faster, as many existing businesses in Myanmar own private renewable generators that they can use to not only support their operations in times of a power outage, but also create profit.

Existing Examples & Concerns

1. SolarCoin

SolarCoin is the most widely used blockchain-based solar energy initiative in the world. Created in 2014, SolarCoin aims to reward coins to verified renewable energy prosumers that they can trade freely in an external exchange market. 97.5 billion SolarCoins have been created to be granted to energy producers until 2050, with 38 million currently in circulation[14]. SolarCoin rewards one coin for each megawatt-hours of electricity produced. SolarCoins can be used as a digital currency or exchanged for fiat currency.

The main difference between SolarCoin and the proposed blockchain-based microgrid system above is that the participants in SolarCoin cannot use the rewarded coins to purchase electricity, and that the coins are awarded at the same rate. Although SolarCoin is an easily scalable model and it has shown a rapid global penetration rate, its value is inherently different from the proposed blockchain-based microgrid system.

Although SolarCoin is gaining popularity as the leading digital currency mined through generating electricity, it cannot be used in the blockchain-based microgrid system in Myanmar. The microgrids in Myanmar must have their own digital currency in order to keep the supply and demand matching mechanism and maintain a reasonable price in the external exchange market.

[14] SolarCoin. "SolarCoin Policy Paper: A blockchain-based solar energy initiative." 4 Apr. 2014,

Adopting SolarCoin in Myanmar will incentivize larger players such as businesses or affluent households to use SolarCoin generation as a speculative profit-earning method. This goes against the initial goal of creating a sustainable, balanced microgrid system that uses incentives to minimize costs for added capacity.

2. Brooklyn Microgrid (BMG)

Brooklyn Microgrid (BMG) is a pilot microgrid project operated by LO3 Energy located in Brooklyn, New York. It tests the commercial viability of forming communities of prosumers who can freely trade electricity peer-to-peer. BMG was developed in areas especially vulnerable to grid failures to address the energy needs in Brooklyn in case of power outages resulting from severe weather events. As the first pilot project of its kind, BMG has built a virtual layer of blockchain-based energy trading mechanism on top of the existing grid system owned and operated by Con Edison, Inc.

BMG uses a blockchain model similar to the one suggested above that incentivizes prosumers and consumers to adjust their production and usage according to the aggregate supply and demand. BMG has successfully developed a private blockchain system using the Tendermint Protocol[15]. The participants of BMG project use TransActive Grid blockchain architecture and smart meters, which are developed by the project's operator, LO3 Energy.

BMG project is operational, but still faces significant challenges. The dynamic pricing mechanism similar to the proposed model needs to be tested and modified to reflect any unexpected changes. For an example, the BMG pricing model takes socioeconomic

[15] Mengelkamp, Esther, et al. "Designing Microgrid Energy Markets." Applied Energy, vol. 210, 2018, pp. 870–880., doi:10.1016/j.apenergy.2017.06.054.

characteristics into account; the weight of such variable in the pricing model or the methods of identifying such characteristics can only be identified by trial and error, given the novelty of this model. The pricing model also needs to take account how this model will adjust when it scales into a larger project, including critical facilities such as hospitals. A flat rate can be used for such critical facilities, but more data needs to be collected and prices tested.

4. **Conclusion**

Myanmar's unique position as a developing country without an extensive energy infrastructure presents an opportunity for private involvement with infrastructure development. Inexpensive solar panels from China have already started to dominate the private renewable energy market in Myanmar, but energy distribution is still inefficient and only in its starting stage of development. The increasing interest in microgrid from both local and global investors is creating a momentum in microgrid development in Myanmar.

Myanmar has an existing network of hydropower plants that it draws its centralized grid energy from. Using these hydropower plants, a blockchain-based microgrid system can be implemented to encourage the prosumers with household solar panels to produce and trade energy according to the aggregate supply and demand. This system can help minimize cost of investing in storage capacity by incentivizing optimal production and consumption and gives more autonomy to the individual prosumers.

The challenges exist, however, that need to be addressed through pilot projects. The pricing model for rewarding and using coins needs to be improved to include variables such as socioeconomic characteristics or critical facilities. The model needs to be flexible enough to accommodate the different regional characteristics, especially in case of Myanmar where the variables that need to be implemented are not as visible due to the underdeveloped nature of the society.

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