

# A Decentralized Autonomous Ecosystem for Peer-To-Peer Clean Energy Trade

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**Abstract**—One of the visions of our United Arab Emirates founding father, the late Sheikh Zayed bin Sultan Al Nahyan was to transform UAE into a sustainable country. Sustainability is not only environment related as popularly known, but also the economy and the people of the society. The UAE as a country has been focusing on sustainability from different aspects, mainly clean energy generation. UAE's ambitious road to sustainability is centralized on clean energy generation. The proposed *Decentralized Autonomous Digital Ecosystem* is an autonomous Blockchain based application framework that aims to accomplish UAE's target of reaching up to 25% clean energy generation by 2030. The digital ecosystem is an autonomous Blockchain based peer-to-peer clean energy trading platform between peers, where the excessive energy from small-scale decentralized energy resources including homes, office buildings and factories with capacity to generate clean energy using PV systems.

## I. INTRODUCTION

This paper introduces a Blockchain based autonomous application developed by American University in Dubai Engineering students to support the development of a peer to peer clean energy digital transaction platform using the concept of hybrid Blockchain technology. The aim is also to investigate the current status and developments in Blockchain based technology applications and its adaption to daily life of the residents in UAE. We also discuss characteristics and uniqueness of Blockchain as a transforming and disruptive technology destined to revolutionize the many modern-day regular business practices of public and private sector agencies. For several years we have been following the reports and research papers published in high ranking scientific journals to streamline and understand the progress of the continuously evolving Blockchain technology. Since the main focus of this research is on Blockchain applications for trading clean energy, we will also present a detailed review existing clean energy trading platforms with and without Blockchain technology. A decade ago, Blockchain technology was introduced to the world by Satoshi Nakamoto [1] as a distributed peer-to-peer, linked list like data structure.

## II. BLOCKCHAIN TECHNOLOGY

A Blockchain is a peer-to-peer network based on a shared distributed data structure. Since its inception in 2008, Blockchain emerged as a major innovative and disruptive technology that will revolutionize the way we interact, automate, and trace and track digital transactions. Currently Blockchain is being introduced in supply chain management, health care, identity management, autonomous vehicles, education and human resources management.

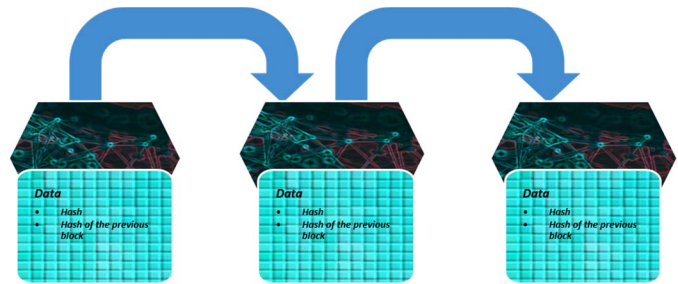


Fig. 1. Blockchain Figure to be included

Trust is the foundational character of Blockchain and uses digital signatures and keys to authorize and validate transactions, and positively identify the initiator [2] [3]. A Blockchain record can neither be manipulated nor removed (the immutability character of a Blockchain). New blocks created over time are digitally verified and appended to the chain, ensuring data integrity and creating a verifiable data structure trail where the shared and transparent blocks provide visibility to all participants, simultaneously. As discussed earlier, the digitally recorded data blocks are stored in linear chain where each data block in the chain is cryptographically hashed and time stamped [3]. Figure 1 illustrate a simple Blockchain concept.

The hashed data block will be linearly linked to the previous data block (which came before it) in the chain and this will ensure all data blocks in the Blockchain have not been tampered with or altered. This will help us understand that Blockchain is a completely decentralized and distributed network with no one entity controlling or regulating it. An important feature of Blockchain is that it provides secure and valid data structures through the process of distributed consensus. The consensus protocol of Blockchain is the ability of all anonymous network participants agreeing the network rules are followed by executing the consensus protocol algorithm. There are many established consensus protocols in Blockchain such as Proof of Work (PoW), Proof of Stake (PoS), Byzantine Fault Tolerance (BFT), Proof of Activity (PoAc), Proof of Burn (PoB), Proof of Elapsed Time (PoET), Proof of Capacity (PoC), Proof of Authority (PoA) and Proof of Importance (PoI) [4] [5]. To implement the Decentralized Autonomous Ecosystem (DAE) application, we are planning to combine the advantages of PoW and PoI along with a new protocol based on priority of blocks being generated. When a

new block is generated, based on the application, a priority index is assigned and the consensus protocol uses priority index for validation.

At this point, we would like to focus on the established understanding of Blockchain technology that data blocks in Blockchain have built-in ability to execute algorithms independently to process transactions and propagate them across the chain. Normally data-blocks or chain nodes contribute to network consensus by including transaction data in a block. An important feature of Blockchain is that there is no central data-block processing or distributing the data, but every block has the ability to execute algorithms independently and transmit information to the chain. The independent processing capability of Blockchain provides us ways to integrate Machine Learning algorithms in every block that is being generated [6]. A block with Machine Learning capability will be able to process data and also take decisions on certain matters related to the user, thus, such a block can be called a decentralized machine learning block. Today, Blockchain is a continually evolving and innovative technology supporting the growing application in business, healthcare and academics. Different types of Blockchain networks are being developed to meet the growing requirements of the business needs and data management such as [4]:

- *Public Blockchain* which is also called permission less Blockchain, contains no restrictions. It allows anyone to contribute data to blocks with all participants processing an identical copy of the block, for example, bitcoin network.
- Private Blockchain is permissioned Blockchain which allows only invited users to join the network. These Blockchain networks are controlled by a single or a group of designated administrators. In essence, private Blockchain network allows distributed identical copies of data blocks, but only to a limited number of users. This network topology is suitable for application requiring speed and greater transparency.
- Hybrid Blockchain is semi-decentralized and has characteristics of both public and private Blockchains. It could also be a consortium of different Blockchain networks with public and private characteristics with group of organizations controlling it. Administrators of each organization has the authority to allow or restrict the rights of the users in accessing the blocks and also restricting the ability blocks to executing the consensus protocol, since all blocks need not have such rights due to the hybrid nature of the network

### III. DECENTRALIZED AUTONOMOUS ECOSYSTEM

The decentralized autonomous design platform is designed and developed using the hybrid Blockchain technology. In this paper, we will demonstrate digital ecosystem for peer-to-peer clean energy trading application using decentralized solar energy resources. However, the digital ecosystem as a design platform is not limited to energy trade, but also to use other home and industrial applications in the areas of healthcare and

banking sectors. For this reason we decided to develop the *Hybrid Blockchain* technology where our customers have the flexibility to protect private data and release public data related to the trade and transactions that are being executed in the blocks that are assigned to them.

### IV. PEER-TO-PEER ENERGY-TRANSFER: ENERGY-CHAIN DEMONSTRATION

The peer-to-peer clean energy transfer is a digital ecosystem demonstration platform where green energy is generated and traded with potential customers who are energy deficit and already part of the digital ecosystem network. Energy-Chain started as peer-to-peer clean energy trading platform where clean energy from a small-scale distributed energy source such as a home or an office building in Dubai with solar power generation capability, is trading among the local energy prosumers and consumers [7] [8] [9]. Energy-Chain was introduced in Dubai a year ago at the EXPO 2020 startup program and selected for EXPO 2020 Startup-University Innovation grant. The motivation behind introducing Energy-Chain in Dubai is based on the vision of United Arab Emirates founding father, the late Sheikh Zayed bin Sultan Al Nahyan to transform UAE to be a sustainable economy. Sustainability is not only environment related as popularly known, but also the economy and the people of the society. The UAE as a country has been focusing on sustainability from different aspects, mainly clean energy generation and de-carbonization. Having sustainability in the UAE, centralized on clean energy generation, E-Chain works to accomplish UAE's target of reaching up to 25% clean energy generation by 2030.

Being an active member of the Solar Decathlon Middle East (SDME) project, representing the American University in Dubai's technical team for energy management and home automation [10], the team worked with several students and professionals from different industries to design and construct a fully solar powered house. AUD's house generated power more than it consumed, thus, the excess energy was sent back to the Dubai energy provider grid (DEWA). After the successful completion of SDME contest, the idea of sharing or trading the excess energy generated to neighboring houses or buildings using Blockchain technology took shape. The digital ecosystem project is based on the concept of clean energy self-sufficiency in Dubai, where a house or a building with solar energy generation capacity will act as a distributed energy source, called an Energy-Chain Home [11] [12] [13] [14]. Buildings or villas that have the solar power system installed will be able to generate, consume and trade the excess energy produced with others that do not generate sufficient energy either clean or not. Every house or building validated in the system is considered as an Energy-Chain digital ecosystem Node or Block, which is able to access the public information from digital ecosystem network about the excess power generation and power required for the homes and buildings with insufficient generation capacity or no generation setup.

The platform accepts not only prosumers with clean energy provision but also the non-clean energy consumers. Therefore, one does not need to have clean energy system to be able to

<pre> Hashes: 30 Block Hash: d395151bd721c7f9d12616d4533b800efb2ec4e347b84779043f39d10cf4500a BlockNo: 1 Block Data: House 1 Day 1: Production = 49.96245000000004 Watts Consumption = 266.39000000000004 Watts Net Power = -216.42755000000005 Watts House 1 Day 2: Production = 444.76431 Watts Consumption = 268.5 Watts Net Power = 176.26431000000002 Watts House 1 Day 3: Production = 421.83335999999997 Watts Consumption = 285.36 Watts Net Power = 136.47335999999996 Watts  Total Net Power = 63.42012000000011 Watts Credit (Grid) = 0 AED Credit (Solar) = 6.342012000000011 AED Credit Total = 6.342012000000011 AED ----- </pre>	<pre> Hashes: 34 Block Hash: 1704cc5cf3f9fd7ca8ddcef043709c183f811835d75c5fb46fed7de345ae514 BlockNo: 2 Block Data: House 2 Day 1: Production = 18.735927 Watts Consumption = 217.26 Watts Net Power = -198.524073 Watts House 2 Day 2: Production = 166.78661 Watts Consumption = 219.65 Watts Net Power = -52.863390000000001 Watts House 2 Day 3: Production = 158.18742 Watts Consumption = 228.20000000000002 Watts Net Power = -348.170042999999974 Watts  Total Net Power = -348.170042999999974 Watts Credit (Grid) = -95.97657910632617 AED Credit (Solar) = -5.64962259115839 AED Credit Total = -101.62620163544202 AED ----- </pre>	<pre> Hashes: 7 Block Hash: 67179ccad83a94685d59e82d2f60440d57e97e429a95aa0f6a6a136bc782 BlockNo: 3 Block Data: House 3 Day 1: Production = 0 Watts Consumption = 134.93 Watts Net Power = -134.93 Watts House 3 Day 2: Production = 0 Watts Consumption = 136.42 Watts Net Power = -136.42 Watts House 3 Day 3: Production = 0 Watts Consumption = 145.06 Watts Net Power = -433.51 Watts  Total Net Power = -433.51 Watts Credit (Grid) = -119.50139779367373 AED Credit (Solar) = -7.034401470884183 AED Credit Total = -126.53579926455791 AED ----- </pre>
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Fig. 2. Power activity and sharing using Blockchain

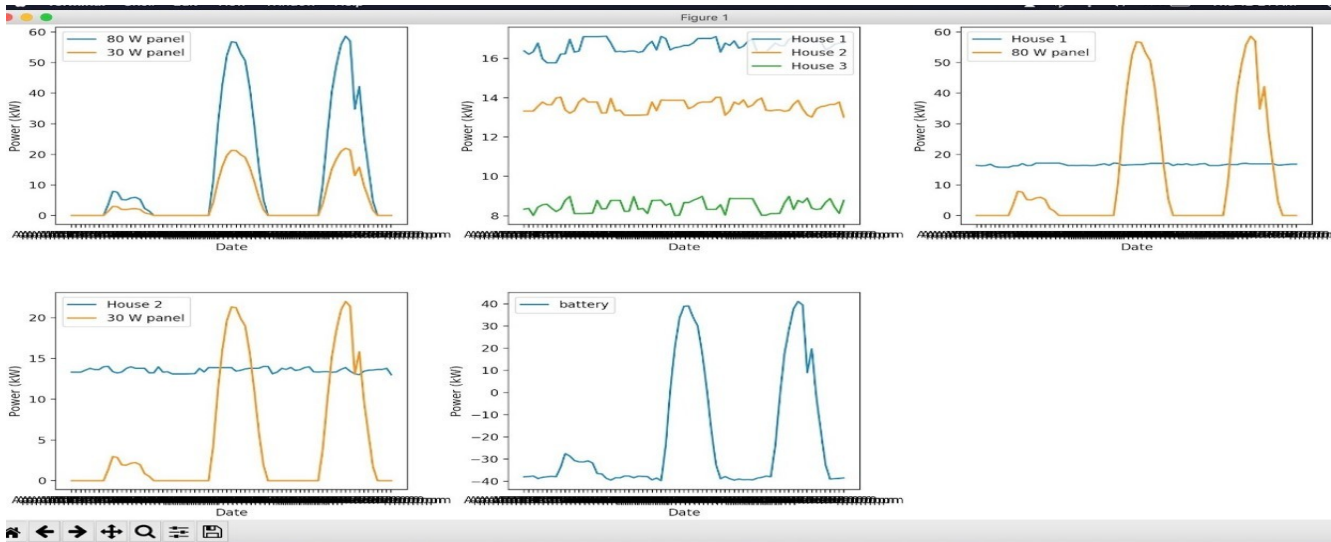


Fig. 3. Production and Consumption of Power

use clean energy. The event and transaction of trading energy through digital ecosystem will be as simple as just using any other mobile application. The decentralized machine learning models installed in Energy-chain blocks will be pre-trained to execute peer-to-peer energy trade on day-to-day bases. The user need not get involved in this business model, since the blocks are designed to be autonomous to initiate smart contracts. When the data generated by blocks analyze the data gathered from energy generation and the management module takes decisions using the machine learning algorithms integrated inside the blocks. The sensors and smart grid in the solar generation setup interact with the Block to gather data from power generation, home energy consumption, and energy saved as illustrated in Figure 2. This information will be placed in public section of the digital ecosystem Blockchain for other customers who are in need of energy can place an order to generate a peer-to-peer energy transaction.

This process is in which a peer-to-peer energy trade is envisioned in two different ways for Energy-Chain users.

The first model is on-grid model using a specially designed smart-grid. The Blockchain collects data continuously from the generation setup and monitor the consumption at home on a daily basis. The machine learning algorithm based on reinforcement learning methods will work towards optimizing the energy utilization and data generated through this process will be stored in the blocks with a private token initiated by the chain. Once the blocks identify excess energy, it will place this information for trade in public section of the hybrid Blockchain which is transparent to other blocks (users) in the chain. Let's say Block A as illustrated in Figure 2 has excess power and placed it for trade. At this point any other blocks in the chain who is in requirement of power can place a transaction to buy the excess power placed for trade in block A. Once the transaction is completed, block A will release the

power to grid and billing will be adjusted with the support of the energy provider of the city.

The second model is off-grid model and it requires large investment to install huge storage capacity and power transmission infrastructure. This model is applicable to rural areas where there aren't regular service providers for energy distribution, thus, not applicable to a city like Dubai. However, we are also developing off-grid model distributed energy source for peer-to-peer energy trade to be used in under-developed countries, where the infrastructure for power generation and distribution is not well developed.

The Figure 2 illustrate the content of blocks in Energy-Chain. Currently all validated blocks will have the information of prosumers and consumers. The annexed Figure 2 shows that status of 3 blocks out of which two prosumer blocks and one consumer block. The blocks provide information about the total power generation, consumption, and excess power available for trade and a positive identification of prosumers. The DAE-Blockchain (BC) ecosystem is designed in a way to provide smooth experience in performing peer-to-peer energy transaction between prosumer and consumers. As discussed in section III, the current DAE-Blockchain architecture also proves energy management solution using Machine Learning techniques such as unsupervised and reinforcement learning algorithms to predict the expected worst-case energy conception and home energy management with the help of other connected IoT home automation devices. The DAE-BC platform also has graphical user interface (GUI) where a user can visualize the Blockchain information as illustrated in Figure 3, showing the solar panels production, houses consumption and battery storage. The GUI is useful in a large-scale Energy-chain platform where the user can monitor the excess energy on trade and also used for data analytics and decision-making process.

The digital ecosystem-Blockchain network architecture is in its beginning stage and still a long way to go to achieve its goal. According to the project plan, digital ecosystem-Blockchain is a holistic Blockchain platform where a home or business owner can use it to coordinate and control daily activities including energy, education, transportation, health and finance transactions autonomously. The number of projects and trails in this area has significantly increased recently all around the world such as Sonnen Community, Summer Watts, PeerEnergyCloud, Vanderborn [15] etc. However what makes the digital ecosystem-Blockchain different is that, it aims to provide complete and customized solutions to its prosumers and customers. Dubai being advanced in technology and resources, I believe Energy-Chain is a perfect solution to the growing energy requirements, health and transportation of a city-state like Dubai. Energy-Chain team also plan to extend its capability to Energy-Chain electric vehicle charging units across United Arab Emirates. This will provide another level of flexibility for prosumer to trade excess energy to neighboring home usage or to their electric car charging.

## V. CONCLUSION

In comparison to existing Blockchain applications, the digital ecosystem-based Energy-Chain architectures is ahead in ideation and technology development. However, there are many gray areas we still need to figure out and perform to keep-up our research on integration of Artificial Intelligence, Machine Learning and Blockchain. One other issue currently in the line of action is about the immaturity of Blockchain technology itself. Blockchain is a new and transforming disruptive technology. It needs to address several issues before achieving larger adoption to the common public. One major challenge is that of scalability and developmental cost to maintain the required properties of decentralization and not compromising on its immutability character. Dubai being a progressive city and positioned itself in a leading role on improving its infrastructure and creating more sustainable solutions to the needs of growing population. The main three elements that we always give importance in our design and development of the digital ecosystem are decentralization, digitization, and decarbonization. It is indeed a difficult task to achieve all three requirements. However, the policies and strategies adopted by Dubai Government and EXPO2020 encouraged us to expand our research programs.

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