EWZ: Virtual Storage

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The software code which is part of this report is open source and available at <https://github.com/farzamfan/BIOTS18>

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INTRODUCTION

Blockchain, Big Data, Deep Learning, the Internet of Things… A lot of these topics are currently being discussed and may seem to be the solution to a lot of problems. Nonetheless, critical thinking about their real contribution to society, in the specific area of interest, needs to be done before implementing them. This report discusses the implementation of blockchain technology and the Internet of Things (IoT) to solve problems of Zurich based company ewz.

The main question that we want to tackle is how blockchain technology could help develop a reliable and efficient virtual energy storage solution, that gives ewz's customers the possibility to produce, store and use their own energy anywhere and anytime.

Currently, a considerable part of the households which ewz supplies are so called prosumers. Prosumers produce and consume energy, depending on the current production/usage rate they either feed energy into ewz's grid or use energy from that grid. The main production device to create renewable energy for these private households are solar panels and in this report we are focusing solely on that. However, the concept could be extended to any other type of renewable energy.

Nowadays, only about 60% (data provided by ewz) of the produced energy can directly be used by the prosumers. The remaining energy gets fed back into the grid. In order to save this surplus of energy and to fill up the residual 40%, there needs to be an implementation of a virtual storage system, which could possibly benefit from the advantages of blockchain technology. In this case, the energy not used by the prosumer should be virtually stored for later use. For the prosumer, storing energy virtually has the big advantage that he can access 100% of the energy he produces at any given time. Furthermore, it leads to more control and personal monitoring of his own produced energy. Knowledge about the personal production in combination with a clever incentive system could motivate the enlargement of the own production line of the prosumer and therefore enhance renewable energy production. Additionally, the virtually stored energy provides clear authentication for the renewable energy.

As there will be many transactions which could possibly be automated, the idea of blockchain and its smart contracts comes in. The Internet of Things will furthermore play a role in the authentication process by using smart meters connected to the solar panels.

Concept Overview

Our basic concept consists of a combination of blockchain technology and conventional methods which are the backbone of our incentive-system that we will introduce more thoroughly in the next chapter.

As already mentioned before, nowadays a prosumer can only use a fraction of the energy he produces. Typically, that is about 30% of his production. Physical storage systems, such as batteries or capacitors, can increase this number up to about 60%. The prosumer gets a compensation for the energy he feeds into the grid, but will most likely have to buy it back at a higher price, at times where his solar panels don't produce the desired amount of energy (winter, bad weather, after sunset).

The goal is now to offer prosumer a virtual storage which they can access whenever they need to. This is where the blockchain based token, the virtual energy storage token (“VES Token”) comes into play. The idea is that prosumers can fill up their virtual storage with VES Tokens when they feed their energy into the grid. The VES Token is always equivalent to the price of 1 kWh of energy, but is tradable to fiat currencies as well.

Furthermore, we want to encourage people to produce renewable energy, without considering their consumption. This is why we have invented the “ECO Point system”. Once gained, it will not be possible to spend these ECO Points. The goal is to incite people to buy and use new technology, respectively to enhance the already existing production facilities. Based on the amount of ECO Points, customers will be awarded additional benefits.

While the advantages for the customers seem pretty clear, the main reason for ewz to abandon the current system is the introduction of an automated transaction process. The lower effort for transactions results in lower costs for ewz.

INCENTIVE-SYSTEM

In this chapter we will introduce our Incentive-System consisting of the VES Token and the ECO Points. We will first take a look from the conceptual side before we continue with the implementation.

The VES balance

One of the unattractive aspects of having solar panels today, is that the prosumer is eventually forced to buy his own energy back with losses. Solar panels produce the most power during mid-day, when solar radiation is the highest. Often, in this period of the day energy is the cheapest and it is uncommon for the prosumer to use all of his locally produced energy during this time of the day. In this case the prosumer is offered the possibility to sell off surplus energy to the power provider at the current price. However, when the prosumer needs power later during the day, it has to be bought back from the provider at an often higher price due to the power price being tied to the time of day.

A solution to this problem is the Virtual Energy Storage (VES) balance. Whenever the prosumer feeds 1 kWh of electric power into the main grid he is awarded with one VES Token. VES Token are a blockchain based token which on one hand can be exchanged directly for a free kWh of energy from the main grid and on the other hand can be traded for fiat currencies. This token will therefore eliminate monetary losses the prosumer would otherwise face for buying his power back.

The Bonus System (ECO Points)

The goal is to create a bonus program that rewards production of clean energy, actions that benefit the environment and loyalty to ewz. The program can be compared to common frequent-flyer programs offered by airlines and loyalty programs offered by supermarkets, e.g. Cumulus from Migros. It is understood to be additional to the virtual energy storage (VES Token, i.e. a kWh-balance) and the participation is voluntary. A prosumer is free to only use the VES Token in combination of his solar plant. However, it is the goal of the electricity company to promote the attendance to this program by offering rewards upon certain progress. The bonus system is thought to be, among other aspects, an incentive for a potential user to buy the solar panels from ewz related sources.

The core of this loyalty and reward system are the ECO Points. There are multiple ways for the prosumer to collect them, but they are all based on the production of clean energy and enlargement of the prosumer network. The main way for the prosumers to gain ECO Points is to feed renewable energy, which was produced by their certified solar cells, directly into the power grid. This will cause the prosumer to firstly collect VES Token and simultaneously gain a certain amount of ECO Points per kWh of electric power fed into the grid. A different way to gain ECO Points is to further the cause with an investment in ewz's clean energy technologies and infrastructure.

Parallel to these two possibilities the prosumer will be confronted with smaller challenges on a weekly basis. Fulfilling the requirements will give the user an additional amount of ECO Points along with a randomly selected side benefits. Examples for these side benefits could

be an increased amount of VES Token gained or an ECO Point multiplier with varying intensity that pre-multiplies all ECO Points gained over a short period of time.

Furthermore, the prosumer should be incentivized to recruit more prosumers, therefore if a prosumer convinces another person to buy solar panels and join the network, that individual will be rewarded with affiliate rewards and gain additional ECO Points.

Likewise, as soon as there are 3 or more adjacent (in a 50 m radius) houses, they form a prosumer community. Communities get a collective ECO Point multiplier and a considerable cost reduction on ewz maintenance fees for their solar panels.

The benefits of ECO Points

The goal of the reward system is to give the prosumer a real profit from his production of green energy. The reward should be recognizable by the community to increase the extrinsic motivation as well as the intrinsic motivation of the prosumers. The advantages should be on short term, as well as on long term basis.

The benefits of the ECO Points, which mainly result due to large production of renewable energy, could be for example cheaper maintenance of the solar panels or even cheaper solar panels to further extend the production.

In order to keep the prosumers interested in enlarging their production, there are short term goals which give direct benefits to the user if he achieves them, such as cheaper costs of energy, as well as long term goals which should keep the prosumers interested in pursuing their renewable energy production .

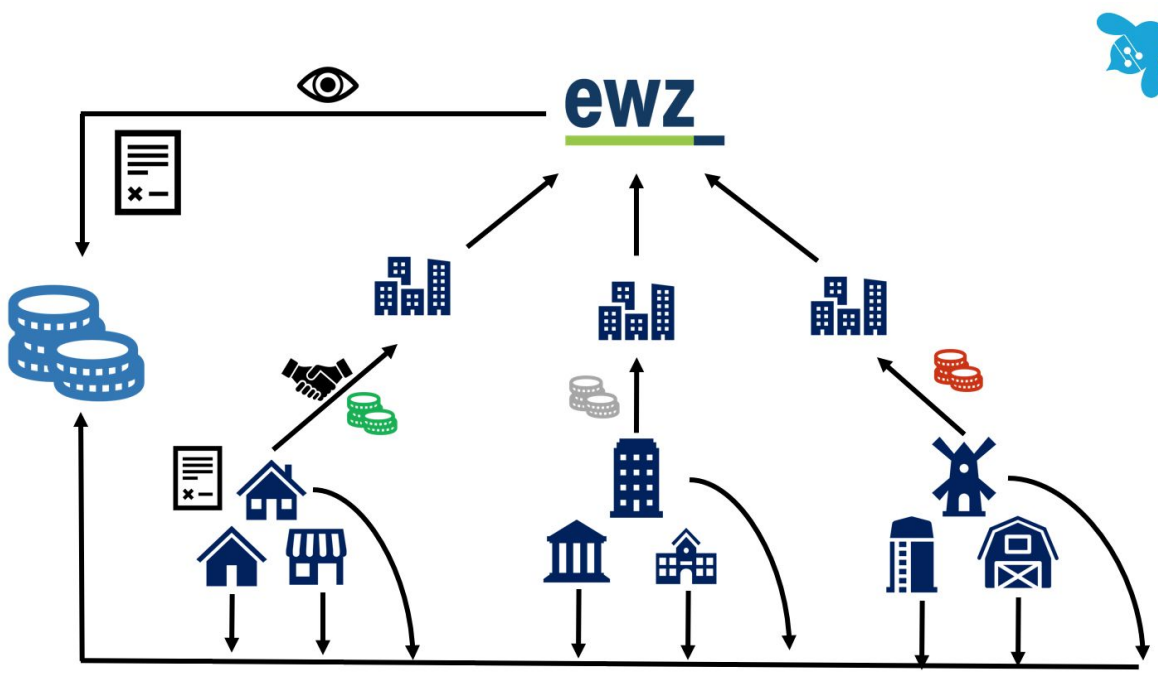
Additionally there will be exclusive parties and events for prosumers who reach a certain amount of ECO Points, which motivates the production of renewable energy even more and those events can be put in the press to advertise the concept of benefits of ewz.

IMPLEMENTATION OF THE INCENTIVE-SYSTEM

Implementation of ECO Points

Since ECO Points are a user-specific value that does not decay and cannot be traded, it makes little sense to aim for a blockchain based implementation for the following reasons: Running a decentralized blockchain consumes a lot of energy, since changes in the state of the object the blockchain is tracking involve a large percentage of the networks computing power. For ewz who aims to minimize power waste this approach is not feasible. Furthermore, ECO Points are like a status for the user and there should not be any possibility for independent entities to trade their score. Current solutions should therefore completely suffice.

Implementation of the VES Token



The architecture of the proposed VES Token system is shown in the above figure. The VES Token infrastructure has 3 layers and a separate entity. On the lowest layer are the prosumer. They can consume and produce energy and inject their additional renewable energy into the electricity grid. At the next layer, are the “Kreis grid managers” (kreisGM). The task of such entities is to collect the information from the lower layer (prosumers in their Kreis), integrate them, if necessary do some checks, and in fixed periods, report the data to the upper layer. At the highest layer, is the ewz main management system. This is the main entity in charge of managing the energy demands, performing random checks on prosumers to make sure of the authenticity of the data, and arrange for buy/sale of the appropriate certificates. The separate entity shown on the left, is the token manager. The token manager issues token to the prosumers for the energy they inject into the grid, and burns them when

the prosumer uses grid energy. The token manager is owned by the owner of the grid (in this case ewz). The proposed architecture has several benefits:

1) The hierarchical structure of the system, hides the complexity of the lower levels from the higher level entities.

2) Distributing the computational tasks across the network helps with the efficiency of the calculations, as well as them being done in a timelier manner.

3) Designating local and kreis level managers, helps with a better fine-grained control as well as community building at the local level.

4) ewz still has control over the smart meters and can randomly performs checks on them to make sure they are reporting the correct data.

5) By use of private blockchains, the privacy of the participants and clients is assured. The only entity in the network that can match the addresses to actual addresses, is ewz.

In practical senses, the system works as follows: The smart meter from the prosumer keeps record of the amount of energy consumed/produced during fixed time intervals. For each kWh of energy, a token is either issued or burned by the request of the prosumer. The prosumer requests the token manager for tokens to be issued (for energy put into the grid), or burned (for energy used from the grid). Each prosumer as well as the token manager keeps track of tokens on their own blockchain. This prevents any false information or claims from either side. After fixed time intervals, each prosumer sends the summarized token data to the kreisGM. The kreisGM checks the data with the token manager and if the data matches, adds it to its records. This helps with managing local affairs as well as community pricing / arrangements. Similar patterns can be seen in the organization of governments and local municipalities. KreisGM's, after fixed intervals, inform ewz of the summarized record of their kreis. ewz can check for the authenticity of the data, and if the data matches, it proceeds to acquiring appropriate certificates and request payments from the prosumers or pay them according to their records.

The code of this implementation is on github.

AUTHENTICITY

Authenticity of energy origin

For the whole system proposed above to work properly, the electricity company has to rely on the authenticity of the energy origin. Solely the production of clean and renewable energy, e.g. the solar panels, should contribute to the ECO Points and VES Token balance. Should a malicious user cheat, e.g. by connecting a cheap gas generator, the electricity company must be able to detect the fraud.

In order to ensure that only the energy produced by the solar panels increases the balances, there are three different control mechanisms proposed in this chapter.

Neighborhood comparison

The first possibility about how the issue of authentication could be tackled, is an intelligent system that recognizes anomalies in energy production in comparison to the local neighbors. Data of the electricity meter of every prosumer is collected on a server hosted by the electricity company (ewz). Each data set contains information about the energy production over one single small time period (e.g. 4 to 8 hours) in that household, the unique address of the meter and its geographical location. Naturally, the electricity produced is not only dependent on the current weather, but also strongly depends on the size of the solar panels. While the current weather for all houses in a neighborhood is roughly the same, the size of the respective renewable energy producing solar plants are not. Therefore, the amount of energy is normalized (set in relation to the area which the renewable energy is produced on) and then compared to the values of the neighbors. Due to the fact that proximate houses get roughly the same amount of sun energy, abnormal single peaks can be detected and there can be further checks whether this irregularity may involve fraud.

This method, however, allows quite a large range of cheating. Additionally, it does not detect a whole neighborhood committed to cheating. For this purpose, the following method could be added, additionally.

Public meteorology

A lot of weather bureaus, including the National Meteorological Services, provide a lot of public data about the weather in a certain area. Especially the number of sunshine hours in a specific area could be of interest to the electricity providers. Based on empirical information collected from older solar panels, and the current data sent by the electricity meters, the electricity providers could determine whether the amount of energy produced is realistic or not.

Both methods combined, however, do not consider the fact that solar production depends on more factors than the sunshine hours per day. Simply unfavorable shadowing from trees, snow on top of a roof, or tall buildings in the proximity limit the validity of these techniques. Further, the different efficiencies of different solar panels are to consider. Therefore, it seems to make sense to see these two methods only as a rough boundary for what could be a realistic amount of energy produced, and what could be fraud.

Smart sensors

The third and most important proof of authenticity comes from the so-called *smart sensors*. The electricity company provides solar panels with a built-in smart sensor directly connected to the solar cell, which can communicate via the internet to ewz's server and measure the produced electric energy. These *smart sensors* are registered and designed such that the sensor itself cannot be manipulated. They are protected mechanically by predetermined breaking points in case somebody tries to manipulate the sensor, e.g. by taking them off, or connecting another power line to it.

Implementation

For the implementation of the authentication process we use IoT. Since there will be a massive load of data transfer required for this implementation, blockchain is not suitable for this problem, because there would be huge transactions costs for the gas. Additionally, this kind of data is not secret, which means we do not have to encrypt it.

The smart sensors collect data, which they send directly per Wi-Fi to a server, where ewz gathers and stores the data collectively.

BUSINESS MODEL & ECONOMIC IMPACT

This chapter gives a summary about the business model and the environmental impact of our suggested system. We believe that with the implementation of VES/ECO systems as well as the authentication control based IoT, there will be a new structure of business that transcends the existing ones. In addition, we also briefly review the potential economic impacts of our system in the sense of promoting renewable energy and enhancing energy market efficiency.

Business Model

With the implementation of our system, ewz surpasses the role of a pure electricity company by taking the function of providing energy related data service such as the authenticity control of energy origin, energy transaction optimization between the firm and prosumer (or even among the prosumers) along all levels, and potentially establishing an energy security market linking renewable energy to innovative financial derivatives. The core concept here is that by making better use of the huge amount of exclusive data generated by the system, the firm can go from merely providing concrete infrastructure and energy products to delivering data analysis services. A whole set of related business can be derived to meet the changing demands of prosumers by adopting the cutting edge of new technologies.

Our proposed model would give ewz an edge in the highly competitive energy supplier market. Generally speaking, for commodities, such as electrical energy, only the price is of importance to the customer. With the implementation of the VES Token and a long-term based customer-relationship tool, such as the ECO Points, ewz has the opportunity to bind customers for long periods of time. For the prosumer it is an advantage to partner with ewz, because of the ECO Points benefits and the trading economy of the VES Token.

For prosumers, who in the bottom line produce more than they consume, the currency of VES Token, which is strictly bound to a kWh of energy, takes away any reason to partner with other grid providers, as they will always get their energy demands covered at no additional costs.

Economic Impact

The first impact of the new system comes from the promotion of renewable energy: more renewable energy will be produced and used due to the benefits obtained from the VES Token and the ECO Points system which not only enables the prosumer to virtually store their excess energy production for later use, but also provides the customers of ewz with rewards for caring about the environment and being loyal to the company. Renewable energy plays a crucial role in mitigating climate change as well as enhancing energy efficiency. For example, the use of solar power can effectively reduce the emission of greenhouse gases that causes the global warming, it would also reduce environmental pollution caused by burning of fossil fuels and improve public health, reduce premature mortalities due to pollution and save associated health costs. Despite the huge benefits, only 19% of the global energy consumption comes from renewable energy as of year 2016. High cost is the biggest reason preventing the production and consumption of renewable energy. But there’s a clear trend in the reduction of the cost due to a continuous growing business. In

this sense, incentivizing the consumers to use renewable energy is the key point in expanding the market, reducing the costs and in the end benefiting the environment.

Increasing energy market efficiency is the second economic impact of our system. Thanks to blockchain, the employment of smart contracts and VES Token makes it extremely simple to handle energy transaction information at all levels. In addition, the contracts are not only restricted between the electricity company and prosumers. It can also be extended among prosumers when the infrastructures allow. And as the nature of the cryptocurrency, there's also potential for VES being traded on a global exchange to promote its liquidity and thus increasing the corresponding energy market efficiency through a bigger free market. However, if done so, the VES Token could not be fixed to a certain value anymore, but rather be in a possible range, which still would have to be bounded, so that fluctuation could be avoided.

EVALUATION

Disruption

The implementation of the VES Token changes the delivery system of energy, as known nowadays, fundamentally. Today, prosumers can solely benefit from a fraction of their produced energy. With the implementation of our VES Token, the prosumers can benefit from one hundred percent of their produced energy as there exists a virtual storage system, even without having to rely on large physical storage, such as batteries.

Additionally, the trading process can be much faster, as the amount of paperwork is reduced and there is no need for a third-party company such as a bank to be involved in the transactions. The whole automatization process can save a lot of money, as there is no need to buy and exchange certificates from different companies manually like nowadays.

The proposed architecture with its hierarchical structure will increase the efficiency even more and private blockchains ensure the clients privacy.

Furthermore, by using smart electricity meters which directly send the data to the ewz servers, attempting to manipulate the meters will be extremely difficult. These smart meters have a unique identifier, so that the stored data can be identified on the server and is directly linked to the prosumer. In comparison to the incentive model from nowadays, the ECO Points system gives the prosumers an extrinsic motivation objective. Today prosumers act solely based on intrinsic reasons, such as fighting global warming. Extrinsic motivation such as cheaper energy costs will be more interesting for those others who are less interested in supporting the renewable energy sector for environmental reasons.

Concluding, the implementation of VES Tokens and ECO Points leads to a more autonomous and efficient energy delivery system. Prosumers get a financial incentive for doing something good to the environment and are ensured that they can fully profit from their own produced energy. Finally, the implementation of smart meters provides the authenticity for renewable energy.

Limits of blockchain technology

Even though the potential of blockchain is enormous, it is important to understand that there are limits to blockchain technology. An important fact to consider, is that the blockchain itself consumes great amounts of energy, when the *proof of work* algorithm is used, which at the moment is an industry standard. For these reasons, one needs to spend a careful thought on whether it is reasonable to use blockchain technology or not.

An example where the implementation of blockchain technology did not seem reasonable is the balance of the ECO Points. Since only data needs to be stored and no transactions are carried out, a conventional database will suffice.

Another concern of blockchain technology is the double-sidedness of privacy. All the data on the blockchain is usually shared publicly with everybody else in the system. To avoid that problem, we use private blockchains in our architecture.

Especially during the transitional period, the compatibility has to be given at all times. So we have to implement the blockchain, while we have to make sure that the system still runs when the system is only partly overhauled.

With closer consideration of blockchain technology further issues arise. On one hand, there is only one suitable way of communication with the blockchain, namely smart contracts. These are, once accepted from both parties, irreversible. On the other hand, anyone with the encryption key can read the encrypted data if the key is made public.

In addition, gathering information from the blockchain is complicated, since there has to be an extra implementation of a search index to be able to search the blockchain.

Challenges

In this short chapter we will explain the challenges we faced. Some of them are solved partly or fully, others need to be further investigated.

One of the challenges of implementing the proposed system is the restructuring of the business plan of the power provider. At first sight, the benefits seem to lie clearly on the customer's side. Since we had a financial expert in our team, we dedicated a chapter to how a possible business model could look like.

Naturally the whole system does not work if the prosumers lose interest too quickly in the program. Therefore, the progress system should have a healthy balance between achievable short-term and long-term milestones with interesting rewards. An affiliates program should also be put in place to create communities of prosumers further spreading interest in the program.

Another challenge is that the reward system should not make tampering the power sensors (smart meters) a possible option for gaining VES Token and ECO Points. ewz would have to provide the solar cells with a sensor that measures the amount of power generated by the solar cells, together with the other solutions provided in the authenticity chapter this should guarantee the genuineness of the renewable energy fed into the system.

A possible way to implement this would be to integrate these smart meters directly into the solar cells with an mechanical mechanism, which will break the smart meters if any tampering occurs to the smart meter. However, the real challenge here is to practically achieve that and add smart-meters to already existing solar cells as well.

Further the forced implementation of every detail of this program with blockchain technology does not make sense. Blockchain technology is not optimized for storing data and consumes a lot of energy. By sending lots of data on the blockchain, the resulting transaction costs are enormously high. It follows that for example implementing the ECO Point system on a Blockchain is hard to justify, since there are no transactions between independent entities and current solutions such as a central server would completely suffice to store the ECO Point balances.

A final challenge to consider is the usage of VES Token beyond the reach of the Zurich for example for charging your electric car. The question whether the VES Token should become a global energy token or currency depends strongly on the intended business model.

CONCLUSION

The question we wanted to answer was how blockchain technology could help develop a reliable and efficient virtual energy storage system.

We realized that trying to implement blockchain technology in every field cannot be justified. Blockchain has a set of advantages and disadvantages that cannot be expanded that easily. We came across examples where initially we thought that a blockchain implementation would be plausible, but after a more careful consideration the opposite was agreed upon. An example for that would be the ECO Point system. It must also be said that Solidity has to be handled with care. It is buggy and certain features are not implemented correctly yet, such as libraries. At all times one has to be careful, that a malicious smart contract is not submitted to the blockchain, as the action is normally irreversible.

However, blockchain also has a lot of benefits and could indeed help to develop an efficient virtual energy storage system. Using blockchain and our VES Token, ewz would benefit from completely automated transactions and take a leading role in a changing energy supplier market. Consumers on the other side get an innovative incentive for producing renewable energy, and partnering with ewz in a long term.