ubiq-e

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Figure 1: CC-BY-SA

All contributors contributed equally to this report. The software code which is part of this report is open source and available at "https://github.com/ETHBitos2018/ubiq-e". This project report was written as part of the spring 2018 course 'Blockchain And the Internet of Things (851-0591-01L)' run by M. Dapp, S. Klauser, and D. Helbing.

1 Introduction

1.1 Motivation

Once upon a time .. In the future not that far from now. Though, the world has changed dramatically.

You wake up as always. You go to your bathroom to do the routine you do every day. You turn on the lights. Huh, but nothing happens. It is still dark. Power outlets are dead. Not again, you say. You are experiencing yet another electricity shortage .. So common these days. You skip the routine, get dressed and go to work. By foot today. You wonder whether all the tech will work in the office or you will have to use paper and pen. More and more popular these days.

Yes, that is how the near future might look like. With power demand on global scale going up and natural resources being more scarce every day, we are heading into dangerous times of the mankind. The scenario visioned above might not be that far-fetched. It can easily happen, that centralised energy suppliers provide energy only a few days a week and only a few hours a day or they charge ridiculous amount of money per single 1 kWh. The current setup of having mainly centralised and monopolistic energy suppliers on the market is simply not sustainable.

According to a report[10], fossil fuel will be depleted in next 50 years. If we look at it in terms of pollution, then in 2014, approximately 78 percent of US global warming emissions were energy-related emissions of carbon dioxide. That presents huge waste of energy and environment damage. Moreover, not every person is the same in terms of their needs and functioning. In a huge portion of the world, people have been developing societies of individuals where own good is above all. Though this concept is often questioned, it is still widely believed that if everyone is well, whole society is well. Hence, providing every single individual with a customized energy plan to cover their needs is totally valid thing to do.

We believe that there is a huge call to disrupt the current system of energy supply and demand so it is more efficient, more reasonable and more sustainable. Since our goal should be to preserve our planet for our future generations to come.

Our team, hereby in the rest of the text, address the problem depicted above and offers a solution that might open a new chapter in our lives governed by energy.

1.2 Problem Statement

In the near future, it is expected that the energy system and the availability of renewable energy will increase. More and more users will have the possibility to create little renewable energy plants as the time goes and as better and different innovations, improvements and inventions regarding renewable energy production will come up, such that the regular people could make use of. The posed problem concerns how we can store produced energy from the EWZ customers in an efficient, reliable way with the help of the blockchain technology and the internet of things? Is it possible to transfer/exchange energy across the various periods throughout the year.

The challenge in this problem is to find a way to introduce the technology of blockchain and the internet of things for virtual energy storage for the customers of EWZ. We need to ensure that the customers can get their stored energy amount whenever they need it, so that virtual energy storage needs to be accessible for an user without being bounded to a specific time or place.

Our solution proposal should lay the foundation of a possible solution for a reliable and intelligent way to deal with this problem.

The rest of the text is structured as follows. Next section deals covers basic terminology, explains what blockchain and discusses literature regarding blockchain technology together with energy systems solutions. Then, we propose our conceptual model of how the energy system with virtual storage as the cornerstone should work. Then, we provide some details on the implementation part how we integrate and utilize blockchain technology within our concept. Last but not least, we conclude our text with a look at pitfalls (both tech- and concept related) we encountered during our work and then at potential future contribution.

2 Terminology & Literature

In this section, we set up some basic terminology[11] related to the blockchain technology. Moreover, we explain what the technology is all about and why it represents one of the most interesting pieces of technology for the coming future.

2.1 Blockchain

What is blockchain technology?

"The blockchain is an incorruptible digital ledger of economic transactions that can be programmed to record not just financial transactions but virtually everything of value."[1]

A distributed database

Information held on a blockchain exists as a shared — and continually reconciled — database. This is a way of using the network that has obvious benefits. The blockchain database isn't stored at any single location, meaning the records it keeps are truly public and easily verifiable. No centralised version of this information exists for a hacker to corrupt. Hosted by millions of computers simultaneously, its data is accessible to anyone on the internet.

Blockchain Durability and robustness

By storing blocks of information that are identical across its network, the blockchain cannot:

1. Be controlled by any single entity.

2. Has no single point of failure.

Transparent and incorruptible

The blockchain network lives in a state of consensus, one that automatically checks in with itself every ten minutes. A kind of self-auditing ecosystem of a digital value, the network reconciles every transaction that happens in ten-minute intervals. Each group of these transactions is referred to as a "block". Two important properties result from this:

1. Transparency. Data is embedded within the network as a whole, by definition it is public.

2. It cannot be corrupted. Altering any unit of information on the blockchain would mean using a huge amount of computing power (more than 50 percent) to override the entire network.

The idea of decentralization

By design, the blockchain is a decentralized technology. Anything that happens on it is a function of the network as a whole. Some important implications stem from this. By creating a new way to verify transactions aspects of traditional commerce could become unnecessary. Stock market trades become almost simultaneous on the blockchain, for instance — or it could make types of record keeping, like a land registry, fully public. Additionally decentralization is already a reality.

The Blockchain & Enhanced security

By storing data across its network, the blockchain eliminates the risks that come with data being held centrally. Its network lacks centralized points of vulnerability that computer hackers can exploit. Today's internet has security problems that are familiar to everyone. We all rely on the "username/password" system to protect our identity and assets online. Blockchain security methods use encryption technology. The basis for this are the so-called public and private "keys". A "public key" (a long, randomly-generated string of numbers) is a users' address on the blockchain. Bitcoins sent across the network gets recorded as belonging to that address. The "private key" is like a password that gives its owner access to their Bitcoin or other digital assets. Store your data on the blockchain and it is incorruptible. This is true, although protecting your digital assets will also require safeguarding of your private key by printing it out, creating what's referred to as a paper wallet.

Smart Contracts

Contracts allow us to formalize a relationship and form the basic building block of the market economy. A smart contract uses computing power, networks and algorithms to increase the efficiency and reliability to execute contracts. This principle is not new and was already published in the mid nineties. Smart contracts reduce the human and computational transaction costs incurred by the contracts participants, principals as well as third parties, as they negotiate, commit, perform or adjust contracts.

This "smartness" is achieved by embedding the contractual clauses, terms and conditions in the hardware and software of contract participants, in such a way as to make the breach of contract expensive

[1] Don & Alex Tapscott, authors of Blockchain Revolution (2016)

for the breacher. A simple example of a smart contracts, as described in 1997 by Nick Szabo, who is considered being one of the inventors of smart contracts is the vending machine. In return for coins, via a simple mechanism, the machine dispenses change and product according to the displayed price. The machine is sufficiently secure to protect the coins and content from attackers, to allow profitable deployment of vending machines in different areas.

The internet and further development of global computer networking has provided a range of new possibilities to effectively deploy smart contracts. However, the internet remains limited to the distribution of data. It does not transfer values or assets. This is the known as the double spending problem. The internet is very good at copying data to various recipients by various applications (e-mail, web, bulletin boards) and protocols (TCP/IP, FTP etc.). However copying shall be prevented when dealing with assets, known as the "double spending problem". When transfer assets, such as money, it shall be prevented that money is spent twice, a key principle for any asset or currency to function. This double spending problem is a key issue that modern distributed ledger technology, or blockchain, can avoid.

Blockchain has a unique capability to record, track and trace transactions in an immutable and auditable way such that the above "double spending" problem is avoided. It uses consensus algorithms, cryptography and distributed computing power to enable this. With the advent of blockchain, a new environment now exists to uniquely enable smart contracts to be applied in daily life and economies.

2.2 Literature

Most applications related to blockchain technology for energy systems are particular in trading energy [12, 8, 6], however for virtual energy storages there is an implemented solution with blockchain[5] and a paper related to a possible virtual energy storage concept[9] and many other commercial solutions without clear indication of which technology is used [7, 1, 2].

Literature review

Sikorski et al. [12] introduced a concept fitting for the industry 4.0 by using machine to machine (M2M) communication in order to establish an autonomous electricity market. For the concept the producer will publish an exchange rate for energy and the consumer is the one trying to adapt its energy demand to minimize energy cost. For implementation they used three virtual machines hosted on Windows 10 and used MultiChain [3] as blockchain and Aspen Plus for process modelling and optimisation of the plant.

Menglekamp et al. [8] introduced a concept consisting of a double-sided market (peer to peer), designed for a large number of agents by using the Ethereum blockchain protocol. Their concept of a local energy market (LEM) is based on double auction with discrete closing times as then a uniform clearing price is determined for each time step. Surplus or lack of energy in a LEM will be traded with an energy provider. After clearing, the market will post information about the traded energy amount, market price for all agents participating. Then they simulated over a year discretized with a time step of 15 minutes using 100 prosumers and optimized the LEM self-consumption. In order to optimize smart meter were used for forecasting an agent's demand and supply at a time step and then send to its blockchain account. If an agent does not fulfil his contract he will be penalized.

Imbault et al. [6] look into the implementation of blockchain technology with Predix [4] for the case of green certificates, which represents renewable generated energy and has been implemented in the district of Rueil-Malmaison in France.

Mihaylov et al. [9] proposed an NRGcoin which represents locally produced with renewable energy. The NRGcoin does not represent a constant energy, because its generation rate is specified through a function based on local energy balance and also on the amount provided by smart meters. Energy supply and demand is regulated thorugh an open currency exchange market for NRGcoins, which incentivizes prosumer to balance energy supply and demand for their own self-interest. For modelling several functions are needed. A prosumer P generates an electric feed x into the grid and gives this information on the blockchain where a function f(x) generates NRGcoins. Substation S connected to prosumer P can measure total local production tp and consumption tc and feed it to another function g(x, tp, tc) and exchanges NRGcoins with the balance of the Distribute System Operator. This $g(\dots)$ function acts as a price function for production and consumption. A proposed function for $g(\dots)$ is a bell function, where its maximum is reached when supply and demand are equal. Based on smart meter measurements in 15 minutes interval rewards are then calculated. For the consumer price $h(\dots)$ is a function of requested energy amount y, total local production tp and consumption tc and additional parameters. Both functions g(...) and f(x) represent the earned amount of NRGcoin for a prosumer. From this concept there are many modifications possible. All functions and their parameter can be modified and applied to different economic theories and optimized on specific goals.

Start up and current solutions

LO3 Energy are working with Siemens Digital Grid and next47 are working on a smart microgrid in Brooklyn. LO3 Energy provided a blockchain platform where energy transactions are on stored on blockchains, Siemens Digital Grid provided solutions for a microgrid and next47 was financier and supporter of this project. This microgrid with blockchain technology is based on Siemens' microgrid development from a village Wildpoldried in southern Bavaria that has been operating since 2014. [5]

Different utilities have launched a virtual storage for prosumers. Two of those solutions are from Germany and one from Switzerland. IWB the energy utility has launched since the start of 2018 a virtual storage for prosumer with photovoltaic [7]. E.ON with the product SolarCloud [1] and SENEC with SENEC.Cloud [2] offer also virtual storage. E.ON additionally offers customers to withdraw their own energy for electric cars in over 4'000 stations in Germany. For all these solutions the working principles of their virtual storage system cannot directly be deduced from their website, it may be proceeded from the utility rather than on the blockchain.

3 Conceptual model

3.1 Set rules and environment

Firstly we need to introduce the set rules and environment in which our concept may take place. Currently, here in Switzerland, the energy pricing is regulated by the local energy distributor EWZ, which has constraints given by the national authority. The price is set to not fluctuate over the year, this means that the price of 1 kWh in May is the same as in December. Furthermore, additionally to being a consumer, it is nowadays still difficult to also become a producer. Let alone being a producer for other homes, since real-time, peer-to-peer energy transactions are not yet allowed by the government. Still we wanted to set our system in a time, in which every household can consume and produce as much as they like. We therefore expect production to be higher in summer than in winter, due to solar panels. The households will therefore have times of overproduction and times of need and will want to transfer this energy from one season to another.

Other set rules that are relevant are listed below:

- Battery storage systems continue to be expensive. Even if they become cheaper, there are concerns about their environmental impact.
- Customers would like to get the benefits of their energy production systems even when they are away. If there is such an option they will be incentivised to purchase such systems.
- Feed-in tariffs are not enough, and will further drop in the future. A new incentive system is required.
- The increase in distributed energy source is a threat to the utility because it might push customers off grid, or minimize their usage of the grid.
- Large generators may become inefficient and may lose business
- If the producers stay on-grid then it may lead to congestion, due to total overproduction
- Not everyone wants to be part of a new energy system

3.2 Process

Our general idea is to use smart contracts and a energy token to solve the problems of a virtual energy storage. These tokens are representative for the stored energy of a user.

The idea came after several considerations from a group discussion, but we all agreed that we wanted to introduce a token as a representation of the produced and consumed energy by the user. Furthermore, from a users point of view, we thought it necessary that the storage of energy has to be lossless[2] as well as that the availability of access has to be independent of time and place. Our solution was using the technology of the internet of things in smart meters, which would enable the least dependent access. We iterated the idea that there could be sophisticated token system with reward or penalty system depending on how cooperative the customer is. With blockchain and the internet of things it would be possible to use an oracle and use predictions for that token system and that data could be used to maximize the share of renewable energy on the grid.

With this framework, we designed our storage system to be like a bank account connected to the internet of things with smart meters and build upon a blockchain. With such data it is then possible to balance production and consumption of energy over the grid. Certainly this system assumes cooperativity of the customer, which we get with a reward/penalty system. Cooperativity in this sense means the willingness to share his/her data about usage, production etc. Based on his/her behaviour, rewards can be calculated by algorithms and incentivise customers and producers to be favorable. Possible behaviours a customer can have:

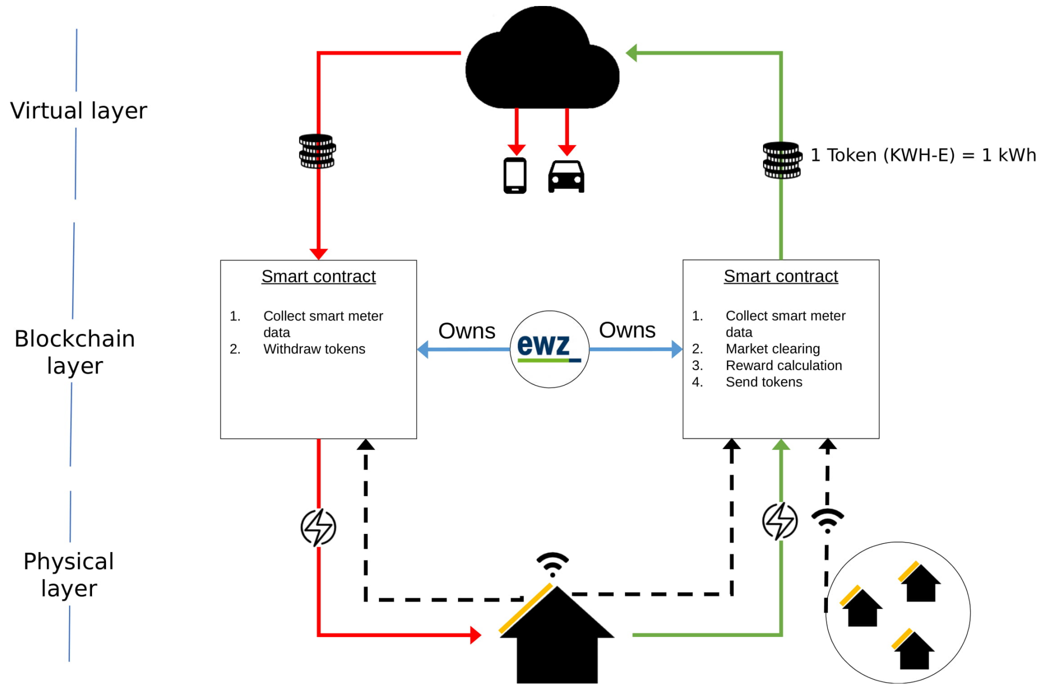
- share information
- contribute to the grid
- behave optimally for the system
- produce/want to consume renewable energy

There was also a discussion about other token mechanisms, as replacement of the current certificate system for the way of energy production or using different tokens for different places of production, so that regional dependencies might be solved. This would allow to give differently produced energy, a relative value. This diversity of tokens would allow a whole new energy market. A decay feature for the token was discussed as well, but it countered our idea of the token always representing the same amount of energy. The idea for a decay mechanism came from the user being able to hoard tokens, which might break the system.

During the whole process, we constantly were confronted with economical aspects of the project. Unfortunately we could not dive too much into it due to time issues, but we discussed the basics. First of all we wanted a 24 hours live pricing so that we can achieve an autonomous peak equalisation of energy usage during day. In addition we can foster demand response with dynamic energy pricing. Furthermore there will be a new certificate market, which will incentivise especially utilities to either trade certificate tokens or produce renewable energy itself. As discussed with a person from EWZ, companies are interested in such certificates, as they are enforced by the law to have a certain amount of renewable energy certificates. In the end we had to make decisions concerning the user interface.The process and results are commented further below[3].

[2] Meaning that you should always get the same amount of energy for your tokens, independent of the price market.
[3] In the implementation part

3.3 Final Concept



Our concept is divided into 3 layers.

The virtual layer consists of a symbolic energy storage for each user, which retains her/his tokens (1 Token (KWH-E) = 1 kWh).

The blockchain layer is the controlling entity of our system and ensures security and transparency. It uses computer protocols named smart contracts to set the rules of deposition and withdrawing of tokens from the physical layer into the virtual layer and vice versa. In our case the owner of the smart contracts is EWZ, due to legal issues. The system can also work without an owner.

The physical layer is every energy measurement, consumption and/or production unit in the system. The significant part are the measurement units or sensors, which collects how much energy a user produces and consumes, to inform the smart contracts.

3.3.1 Salient features

- Reward mechanism
- Dynamic energy pricing
- Lossless energy storage
- Flexibility in usage of stored energy
- Sharing economy for green energy

4 Implementation

This sections provides details of our implementation, i.e., how we used the blockchain technology to convert the concept given above into a real-world application. Note, that at the time being, our app only provides limited functionality as we aim rather to offer a proof of concept implementation.

4.1 Goals

Designing our app, we focus on fulfilling following criteria.

We want to enable big energy providers as EWZ to create a token system for their smart grid and to easily integrate a certified sensor to their system.

We want the token system to have a settable price, which follows the underlying rules of the energy market. Moreover, our token system needs to be in the ERC 20 standard for the better operability.

Last but not least, we want the user to have an overview of its energy production/consumption data given by the sensors. Besides, the user should be able to manage the sensors in their household and pay for energy usage either with previously collected tokens or money.

4.2 Architecture

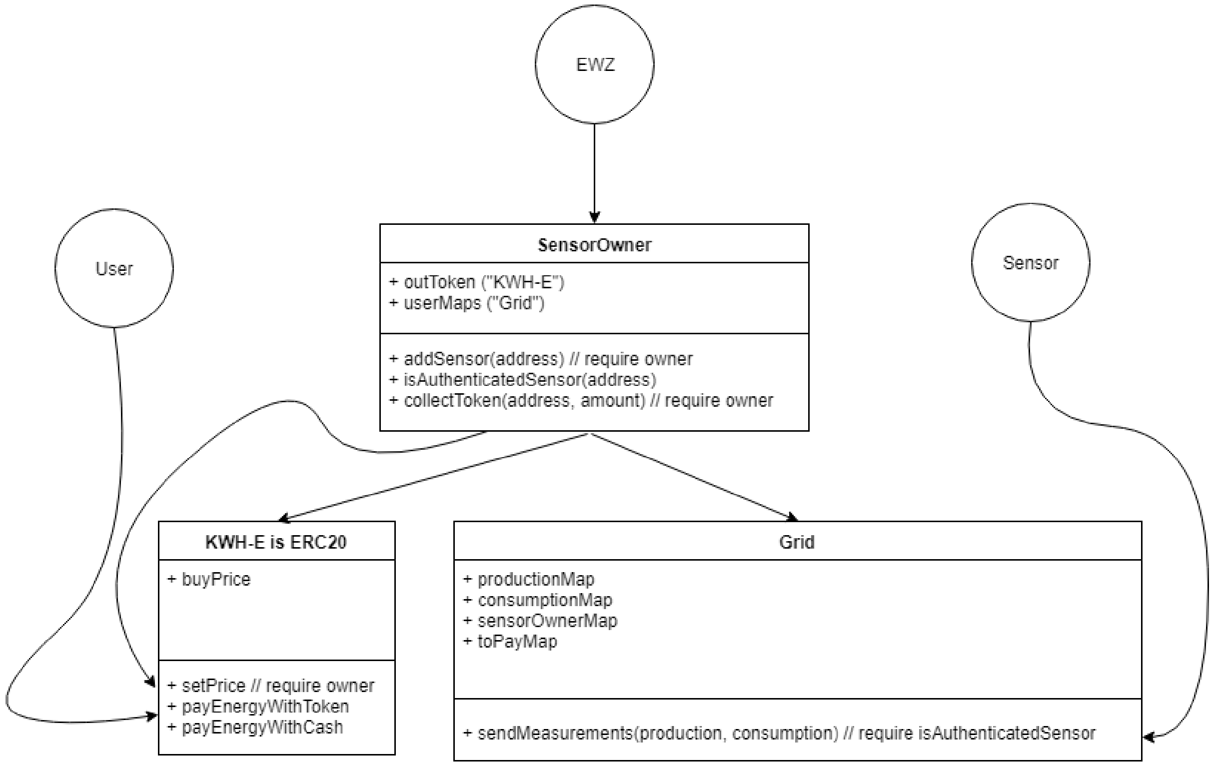
As the blockchain technology dictates, a building block of our app is a smart contract. Our architecture consists of three smart contract (over two files SensorMonitor.sol and ubiqToken.sol) and a simple graphical user interface. These three contracts are laid out as follows:

- Contract SensorOwner in SensorMonitor.sol works as controlling instance overwatching the whole system.
- Contract Grid in SensorMonitor.sol stores all the relevant information: consumption, production and payed, or to be payed values for every user.
- Contract UBIQBiots18 in ubiqToken.sol is ERC 20 KWH-E Token itself and allows user to trade tokens and pay for the energy usage with the tokens or money directly.

The graphical user interface is essential to making the product management viable for the service providers (e.g., EWZ). It needs to be easily usable by the intended customers and as such provides a transparent and real time access to the:

- Market evaluation of the token to be able to make better trading/storage decisions and also make predictions.
- A comprehensible summary of their last transactions and current wallet status as a list.
- A comprehensible overview of its real time energy production/consumption given by the smart meters in the form of a pie-chart.

The login page looks as shown below where after a secure login, one is able to get data from and write to the blockchain. This is enabled using a meta mask Chrome/Firefox extension which allows one to run our Ethereum dApp in our browser without having to run a full Ethereum node. It injects a javascript based web3 object into every website one loads. We then interface our smart contract using the smart contract unique address and ABI generated by the javascript file. Any modification in the smart contract changes its address and ABI so complete trust and security is ensured between the smart contract issuer and the customers. The many callback functions for using the various functionality provided by us are specified in the Javascript code. The UI is made using HTML and CSS.



ubiq-e architecture visualization

4.3 Features of smart contracts

A closer look at the smart contracts might bring some more insight. The features of the smart contracts are best described by going through the functions, which are more or less each equal to one feature and comparing those with the picture of the architecture above.

4.3.1 Sensor Owner

- Constructor sets up the other two contracts in place, sets the owner of this contract as the creator of this contract and allows the Grid contract to trade with the tokens
- addSensor(addr) allows the creator to add an authenticated sensor (stored in local map)
  - requires isOwner
  - isAuthenticatedSensor(addr) returns if a sensor with addr is authenticated
- Other functions allow the contracts to communicate to each other passing their addresses

4.3.2 Grid

This smart contract is a group of maps (= data structure to associate a value with a key) that store relevant data.

- productionMap: stores how much energy a user has produced
  - can be resetted by the user themselves (by setters and getters)
  - is updated by sensors through sendMeasurement function
  - note: the setter is actually never used by our system
- consumptionMap: stores how much energy a user has consumed
  - can be resetted by the user themselves (by setters and getters)

  - is updated by sensors through sendMeasurement function
  - note: the setter is actually never used by our system

- sensorOwnerMap: stores which sensor belongs to which user
  - an user can add their sensors themselves (with setOwnerOfSensor and getSensorOwner)

- toPayMap: stores how much an user has to pay to the system
  - can only be updated through sendMeasurement by sensors or from token address, when the user pays their energy to the token contract
  - can still be seen by the user with getters

As can be seen above, there is one function that is crucial to our design.

- sendMeasurement(int production, int consumption)
  - should be called periodically
  - calls a method isAuthenticatedSensor() on ourSensorOwner, which stores the address of the SensorOwner contract and checks therefore, if the sender is an authenticated sensor
  - after checking the caller it adds his consumption and production to the blockchain
  - note: The amount of energy the user has to pay is equal to his consumption and the amount of tokens the user gets us equal to his production
  - note: since the Grid is allowed to do transactions, it can directly trigger the "giving out" of the tokens

```
//sends measurements on blockchain
//only a authenticated sensor can call this method
function sendMeasurement(uint256 production, uint256 consumption) public {
    require(ourSensorOwner.isAuthenticatedSensor(msg.sender));

    address user = getSensorOwner(msg.sender);

    consumptionMap[user] += consumption;
    productionMap[user] += production;

    toPayMap[user] += consumption;
    ourToken.transferFrom(ourSensorOwner, user, production);
}
```

4.3.3 KWH-E

Our Token is compliant to the standard ERC 20 functions and has some additional functions, which are described further down. The ERC 20 standard is not necessary for our project. However it allows trading with other currencies and supports certain tools, like Etherscan or Metamask, which might be useful in the future.

As for now the contract creates 1‘000‘000 tokens and gives it to the SensorOwner contract (more precisely it gives the tokens to the one creating this contract).

The functions are:

- Standard ERC 20 functions
- The buyPrice field has its getter and setter function. Note: The setter function can only be called from creator token, which is in our case the SensorOwner contract.

- payEnergyWithTokens and payEnergyWithCash are the main two additional functions. It might be worth looking closer into the payEnergyWithTokens function. On the other side payEnergyWithCash is not yet implemented, since we would need a way for a bank to communicate securely with the user and the blockchain.

payEnergyWithTokens:

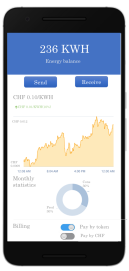
- First it gets the identity of the user, the amount the user has to pay and his/her balance from the Grid contract.
- Then it takes as many tokens as needed or available from the user and uses it to reduce the amount the user has still to pay.
- It transfers the tokens to the owner of the contract, which again, in our case, is the SensorOwner contract.

```
//Way for user to pay energy bill with tokens
//called by user
//returns balance
function payEnergyWithTokens() public {
    uint256 toPay = ourUserMaps.getToPay(msg.sender); //gets the amount the user has to pay
    uint256 balance = balanceOf(msg.sender);       //see balanceOf

    //pays with all the tokens the user has and subtracts them of the amount the user has to pay
    //transfer these token to the owner of the contract
    if(toPay > balance) {
        ourUserMaps.setToPay(msg.sender, toPay - balance);
        transfer(owner, balance);
    } else {
        ourUserMaps.setToPay(msg.sender, 0);
        transfer(owner, balance - toPay);
    }
}
```

4.4 Features of the Interface of our App

To facilitate the use of our app we aim to make it as simple as possible and have the important traits an ebanking app offers. It will therefore show your current token balance and price, a diagram of your produced and consumed energy and your transaction history. An additional feature is the possibility for the user to choose whether he wants to pay his bills with money or with tokens. This is our interpretation for an app accessible and usable for everyone, as it will not overwhelm users with too much information.



Mockup of our user Interface

4.5 Github

All code we have developed can be found under GitHub repository: ubiq-e

5 Evaluation & Conclusion

5.1 Evaluation of the Concept

During all discussions we came up with different ideas on how to bypass the physical layer of this problem as well as the current regulations of the authority. Of course we adjusted our concept as much as possible, but there are still a few issues to think about. First of all there is a possibility to hack or manipulate smart meters. This might be a issue for the correctness of the data as well as for the security and anonymity of a customer. Secondly we might have people who hoard their tokens. Even though we assume, hoarding is unprofitable according to the new dynamic energy market, this may backlash on us. Furthermore there are issues about the grid, like maintenance of the grid and equalisation during a shortage. This might look like a deficit on first sight, but the facts that people out of the system still need energy and that EWZ have much better ways of storing more energy more efficiently could compensate these expenses. In addition there are physical matters about the grid. it was out of our focus but we still heard of a possible unstableness of the grid, either due to the number of users or because of peaks of energy, which means a harshly over- or underproduction, on the grid. We thought about self-equalisation through online energy pricing.

An additional feature of our concept we wanted to have, is a automatic trading platform for energy tokens. This market would store the price and quantity of propositions from users and other users would then be allowed to buy those tokens. The idea of the market, also asks for more detailed description of the user specification, concerning the possibility of buying and exchanging tokens.

Expanding our system to multiple countries, the issue that would come up is the locality of the energy price, since a 1 Kwh needs to be cheaper in a well connected town, than in a desert for example. This can fixed by local tokens, for every region.

The last challenge might come up, due to the availability of smart meters. Without smart meters our system will not be able to work, since we need to measure the production and consumption of every user correctly.

5.2 Evaluation of the Implementation

Unfortunately we were not able to run our Code at time of its submission. We assume that the program did not work, since the token smart contract was not correctly initiated. The trading of addresses between contracts might be an issue. Further issues with the implementation are:

- We were not able to test the connection between the smart contracts and the user interface.
- No thorough tests were done and no further implementation for the security of our Token was done. We do not prevent against any abuse right now.

Due to these issues, we were not able to give a complete assessment of our program. We did however take one precautions for the safer usage if these contracts. There is a "collectMoney" function, which allows the creator of the smart contracts to collect all the tokens, if the system fails. Additional improvements in system stability and scalability may include:

- A way for EWZ to add tokens can be introduced, since now they only have an amount, which is set at the start. This was not implemented since it is not important feature for the demo.
- Not all user data is needed on the blockchain. Only the amount a user has to pay, is necessary to guarantee security in our system.
- It may be a bad idea to connect the Pay function with the Token itself. Both contracts allow trading and payment, however the Token therefore also needs to store the state of all users
- The user data and buyPrice (= Price in the current Token of the blockchain for one of our Tokens) need to be set periodically at a fast pace so that the contract have the correct data. This unfortunately uses a lot of updates on the blockchain. There are probably better ways to solve this, like an input stream for the buyPrice or redirecting the pay function to also fetch the user data instead of storing all of them.

- At last we also need to connect the buyPrice to an actual interface, so that it is editable as described by its future specifications.

5.3 Conclusion

There is still a lot of research needed in different areas to make such a concept reality. Firstly the technology of blockchain is still being experimented with and may never be scalable enough to store what we expect it to. Furthermore we only touched the physical aspects and issues of storing energy. Even with technological progress, the government of the population might still be against a change of system, which our concept really is. There will be voices in favor and against a new system. We therefore do not expect our version to be implemented in a future time but rather wanted to test a new concept and find certain issues, which are described throughout this report.

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