Waste2Block

One Man's Trash Another Man's treasure

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Abstract Many countries in the European Union and in the world struggle to find effective measures and systems to successfully reach the environmental goals set by the European Union for the upcoming decades.

One of the major problems throughout Europe, but particularly in some countries like Portugal is the very low recycling rates and adherence to the practic of recycling in general.

This is caused by a plethora of reasons, in particular the lack of trust of the populations in the process and the lack of incentives for those who recycle as well as a lack of descrimination for people's behavior.

To combat these problems and help achieve the environmental goals set by the UE, we present Waste2Block, a modular distributed ledger technology based in a Hyperledger Blockchain solution to enable the tracking of waste from waste producers to waste buyers.

This will allow waste producers to understand the full journey of the waste they produce while implementing reward schemes and price discovery for those who recycle the most, contributing to higher recycling rates and a more sustainable world.

Introduction

This project Waste2Block aims to present the results of the research made in Crypto Summer by Bee2WasteCrypto, a summer school within the Bee2WasteCrypto project, one of the 10 projects selected by the Carnegie Mellon Portugal Program (CMU Portugal).

This research was leaded by Compta in the context of technical collaboration between NOVA Information Management School, Instituto Superior Técnico, Carnegie Mellon University, NovaCryptoClub and 3drivers, and it aims to create an innovative platform, using blockchain and cryptocurrency technology for municipal solid waste (MSW) management.

In the last years, Blockchain Technology has received a lot of interest by academia and industrial companies in the most different sectors because it helps organizations optimizing processes and reducing costs with intrinsic transparency. The waste

management industry is no exception. A common EU target for recycling is 65% of municipal waste by 2030 [11] [6] where Portugal stands at 28.9% in 2018 [15]. The only way we could achieve that target is through innovation. To tackle this issue, Waste2Block aims to explore blockchain and gamification solutions in order to increase transparency in the sector, reward citizens individually for good recycling behavior, reduce fees paid by the municipalities and increase the quality of waste of screening companies.

What do we intend to solve?

Developed from August 2020 to October 2020, field data related to Waste2Block's impact on increasing the recycling rate were not collected yet, although a complete investigation was deployed through relevant recorded data of the community and the municipality, group discussions and interviews with key specialists for each topic.

Besides that, in order to understand the main challenges to face in the waste management sector, it was assembled a survey filled out by more than 350 citizens where it was intended to realize the main reasons why Portugal municipal recycling rate is so low when compared with the rest of european countries. Almost 98% of participants recognize that recycling is important although 35% of them state that they don't know if their efforts make any difference, ence the trust problem. It is also important to state that only half the responses are positive when asked if they do the correct separation on a regular basis. The main reason registered is the lack of incentives to recycle since the citizen is not rewarded for it and also pays taxes included on the water bill, regardless of whether they recycle or not. Almost the totality of the participants wish to know what happens to their waste and if it is actually recycled or not.

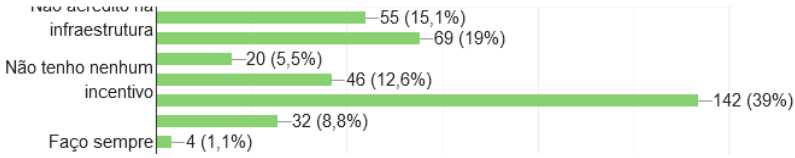
Therefore it was concluded that a trustable report of the all process of the waste complemented with a reward scheme and with additional educational purposes would increase not only recycling rate but also recycling quality.

Waste2Block - The Solution

The solid waste management sector is under a significant transition, already with several initiatives [3] [17], with different levels of success, that promote better waste management and stimulate recycling habits.

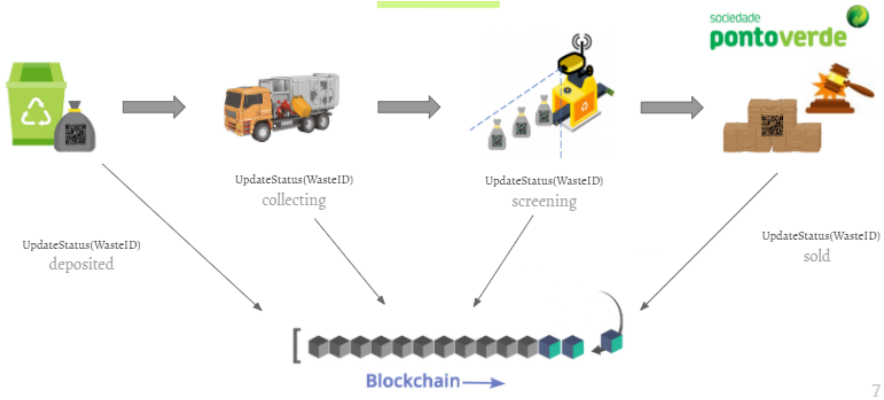
Hence the project Waste2Block was refined on the same scope to tackle the main problems that involve the Regional Waste Management Utilities in general: Recycling Rate – in Portugal the Municipal Recycling Rate is around 28.9%;[15] Recycling Contamination – almost half of the Europeans admit not knowing how to recycle properly;[6] Discrimination of price – in Portugal there is a waste tax paid through the water bill, based on assumptions that these two are correlated regardless of whether the citizens recycle or not.[2] Trust Problem - In Portugal people

don't trust the waste management system (See chart below from our questionaire).



With this in mind, *Waste2Block* aims to stimulate the proper separation of the waste providing the right incentives for it, increasing the profit for the companies involved in the process.

This way, the solution can be defined as a scalable WAYT Reward system with a blockchain based solution that, using waste bags with RFID, will allow all the involved entities to trackable each waste bag during the all process. Also, through the blockchain network, rewards will be distributed among the users depending on contamination of the waste, as well as, on the companies' side, a more effective and regulated management of all waste processes will be expected.



Considerable improvements are expected including:

- Increased recycling rate – with an increased in the quantity and quality of recyclable materials;
- Less contamination – We estimate to reach 15%-20% less waste on undifferentiated;
- Millions saved – from municipalities to the cost of waste treatment systems on the screening process.
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Waste producer's perspective

One of the project's ultimate goals passes by strengthening the relation community-waste management sector by introducing the concepts of process-transparency, reward scheme and gamification that, by means of a mobile application, will allow waste producers to:

- Receive waste bags at home;
- Learn how to do the proper separation of the waste;
- Track their waste bags through all process;
- Be rewarded for recycling.

Partner's perspective

On the partners' side, which will include the City Councils and the Screening Companies, Waste2Block will assure a considerable improvement on the supervision of all process but also will mean a substantial increase on the revenue, by allowing a more expensive sell of the waste and also a reduction on the treatment process's costs.

The Technology

Trust Problem

As we found in our survey, we also found many other studies that proved the existence of a trust problem in waste management, people do not separate their waste, as they believe it will eventually end up in a landfill and therefore think that they have no impact in the waste management cycle. Costs are important, but equally important is the trust in the waste management system [8][22]. Many simply don't trust the government with the recycling process. "We don't know anything about what happens with the separated waste. I think that after the work, the company just takes the separated garbage and mixes it with the other waste and leaves it in the landfill." [5]

Blockchain

In a very short way, Blockchain is a new kind of decentralized database, resistant to modification of the data by using an distributed ledger that can record transactions between two parties or more parties efficiently. A distributed ledger is a consensus of replicated, shared, and synchronized digital data geographically spread across multiple sites.

The most cited fundamental feature of blockchain technology is the fact that it makes the need for trust during transactions unnecessary.

There are three types of blockchain networks: Public, Private and Permissioned. On this project we chose to utilize a Distributed Ledger Technology (DLT), a permissioned ledger, using Hyperledger Fabric technology. Hyperledger Fabric is an

open source community focused on developing a suite of stable frameworks, tools and libraries for enterprise-grade blockchain deployments.

From a technological perspective, most waste management businesses consist of logistics supply-chain management. Papers like ''Distributed ledger technology in supply chains: a transaction cost perspective" by Dominik Roeck, Henrik Sternberg and Erik Hofmann (2019) wrote that ''DLT solutions that have a cost-reducing or cost avoidance impact on supply chain transactions" and ''Distributed Ledger Technology in the supply chain" lead by Nikhil Vadgama with UCL Centre for Blockchain Technologies and support of Retail Blockchain Consortium states that ''DLT can improve consumer trust in relation to labels such as "organic", "local" or "responsibly sourced" by ''recognising that improved proof of provenance can add value to their brand in markets which increasingly value authenticity with consumers who want to know the full product journey. [16][19].

The same principles could be transposed to the waste management business. By using a DLT, the cost of running the nodes are much cheaper than the interactions on a public blockchain where for every transaction you need to pay fees to interact with (for example Ethereum). In addition to the monetary aspect, it is possible to have control over the parties who can intervene on the network while, simultaneously, have publicly available and transparent information for all participants in a certain channel (in our case: The Screening Companies, Municipalities, Collectors, and Regulators).[13]

In terms of privacity, even though we want to allow all channel participants to see when it is generated a transaction - when a new bag is deposited, collected, passes through the screening process and it is sold - it is important at the same time to keep a portion of the data private (e.g. employees personal data, monetary transactions between a group of organizations). Hyperledger Fabric offers the ability to create private data collections, and the possibility to query, endorse, and write data from those collections is determined by roles and permissions defined by the network administrators.[13]

Therefore, we pretend to use the Blockchain technology to:

- Keep a trustworthy record of the entire waste management process.
- Know the current location and status of the waste.
- Share easy and transparent information between allowed parties.
- Reward the households that recycle better.

The Network

To build our network we will use Hyperledger Fabric, a DLT solution that allows for development of applications with modular architecture. Our network will have multiple nodes, each organization will have its own node. Each node may contain one or more peers (the more peers the better for fault tolerance purposes, but that is completely up to each organization).

All operations that are allowed in the network are defined under the form of Smart Contracts - *A smart contract is a computer script used for automatic verification of a*

certain protocol, that ensures that negotiations and operations are done according to a contract.

For example, when a bag is registered into the system, a certain portion of the smart contract will be activated, all of the nodes will run their version of the contract, and if the a majority of the nodes run it "successfully" the operation will be validated and the bag will be registered on to blockchain. This is necessary because no parties trust each other, and therefore, having an automatic and transparent intermediate (that can be consulted by everyone participating on the channel) ensures that everybody will use the same protocol and protects the network against someone "changing" the contract to their advantage.

Hyperledger Fabric uses the RAFT consensus protocol (starting at version *1.4.1*), a protocol in which guarantees consensus in a distributed system and it's scalable. We will leave the details of RAFT to the curiosity of the reader, since it goes outside of the scope of this paper.

Hyperledger allows for channels which can be viewed as private subnets of communication between two or more specific network participants [12], this will allow separate flows and the information that is shared between the participants, different flows and operations usually require different participants and with channels we can make this organization according to our necessities. Each channel will have its own smart contract(s) deployed.[12]

This is crucial to our architecture, since it will allow for versatility of the system and its architecture. Using this we can make many different channels (organic, urban, green. . .) or, for example, separate the channels by municipality. This will have a positive impact on the trust the participants have in the network, as well as it will improve scalability of the system (since after a certain point, having a lot of participants in the channel will deteriorate performance significantly).

Another powerful feature of Hyperledger is the capability to define who can activate certain entry points on the smart contract using the roles defined within a channel. This ensures that while all participants of the channel must agree upon a transaction, only some of the participants can make certain calls (for example only an administrator can add a screening company). This is important due to the natural flow of the business as well as giving some interesting security properties like authenticity of the operations and making it harder for malicious parties to "spam" the system with calls and/or information.[12]

In the first instance of our project, a test network was developed only for urban solid waste, which means, a network with only one channel for transaction of information between 3 organizations: **waste collectors, screening companies and municipalities**.

The API

To communicate with our blockchain we constructed a *REST* API using *Express*[7] which is a web application framework for *Node JS*[14].

Clients of the system (like users of the mobile app and phone app) will be to fetch and insert information into the blockchain by calling the appropriate entry points of the API.

Client Applications

In order to have users (being the employees of the participants of the system or the regular citizens) participants in our ecosystem, we will have a mobile app for citizens and desktop apps for the companies.

The desktop app will have different features depending on the type of organization or if it is to be used by an admin of the network, but in all of those cases the desktop application will allow for a general overview of the bags deposited as well as the information about them.

Mobile Application

In order to connect all the waste producers to the blockchain network, an intuitive, secure and easy to use mobile application will enable waste producers to register their bags and visualise the full journey of the waste they produced followed by individual and municipal statistics. This application will also follow the rewards of each waste producer, according to their performance on the separation of the waste, and to redeem those rewards for goods and services.

The mobile app will have the following features:

- Registration of users.
- Registration of bags.
- Educational information.
- A way to track the current state of the bags registered by a user.
- Gamification devices, like leaderboards (more information later in the document).
- Overview of the user wallet (the points and number of bags deposited)
- General and personal statistics.
- Redemption of rewards using the points

Also, according to REA (State of Environment Portal Portugal) although people are more aware of climate challenges, portuguese citizens don't know how to properly separate their waste, and the difference of biodegradable and recyclable. This way, it will be included on the Waste2Block's mobile application an educational page where the user can learn about how to recycle properly.

The desktop app will have different features depending on the type of organization or if it is to be used by an admin of the network, but in all of those cases the desktop application will allow for a general overview of the bags deposited as well as the information about them.

RFID Bags and Stickers

The most common code identifiers when addressing supply chains are barcodes and QR codes. Due to the requirement of a direct line of sight and commonly the need of manual work we chose to explore RFID technology that is currently available in the market.

As it was stated in [20], radio frequency identification technology (RFID) enables identification from a distance, and unlike earlier bar-code technology, it does so without requiring a line of sight. This technology can be split into two different types: active and passive. Active RFID needs a power source and therefore the tags lifetime is limited due to battery lifetime. Considering the high cost of active RFID tags we have chosen to use passive that have a higher lifetime and a lower cost. Citing the previous paper "Passive RFID is of interest because the tags don't require batteries or maintenance. The tags also have an indefinite operational life and are small enough to fit into a practical adhesive label. A passive tag consists of three parts: an antenna, a semiconductor chip attached to the antenna, and some form of encapsulation." [20] In pursuance of a full waste journey that is public and transparent for the waste producers we need to create a way to make trackable waste. In this project we explored two ways to create traceable waste: RFID Bags and RFID Stickers.

RFID Bags are waste bags with RFID stickers built in that could be associated individually or in bulk with a QR Code technology to each individual user account. Our purpose is to associate a user account to any household so that we are able to reward according to waste separation performance. This will be made using the Waste2Block Mobile App. This solution is not only cheap but it also aims to avoid disturbing the current process of waste sorting without requiring major alterations in the standard procedures. Its scalability facilitates the reading of the trash content at the screening process.

RFID Stickers would be a more versatile solution since this is a technology that enables every bag to become traceable [20] and therefore be part of this solution. This will be easy to distribute throughout the general population in fixed distribution points (like train stations or supermarkets) or even by mail.

The bulk cost of this project is associated with logistics distribution of the identifiers, there are several solutions that can address this challenge.Both can be freely distributed at supermarkets or at city councils or sold with a tare that will be cashed-back when users deposit their waste.

Reward System

A research conducted by Greenredeem [10], a reward recycling company, found out that the 'carrot' approach (rewarding good behaviors) was twice as effective as the 'stick' approach (punishing bad behaviors) to improving dry recycling rates, which includes glass, plastic and carton materials. The study, which covers the period 2009/10 to 2013/14, shows how local authorities in England, which introduced

recycling reward schemes, had dry recycling rates of almost 27%, while those with compulsory recycling strategies had a rate of just 15%.

With this conclusion we see the importance of introducing a strong reward system to reward waste producers by their behavior. With these in mind, these will be the types of rewards we will implement

Monetary Incentives

When we investigated how we could reward the trash producers, we found out that the user currently is not rewarded directly, but punished in the water bill (20% of its value is taxed as a “waste management tax”).[18]

When we investigated how we could reward the trash producers, we found out that the user having to pay fees, even if an extrinsic reward is given, the users are not prone to improve the recycling rate, which also comproves that even if we try to mix the “stick and carrot approach” we are better off only using the reward without the punishment. [10][18][9] [21]

These findings are consistent with studies [21] showing that the influence of an economic reward depends on how the selected individuals view it, in addition to the price-effect. There is a significant body of scientific data to support the hypothesis that internalized desire to pursue a positive action can be compromised if an external reward is presented, However, in the case of trash management the economic incentive seems to enhance, rather than undermine, internalized motivation.

Therefore the conclusion in this study that the economic reward has a beneficial impact on behavior, influenced by presumed self-efficacy, fits well with this information base and project.

We will manage to reward the users a percentage of the total price of their waste, this reward is based on the price of the trash sold. This could be a discount on the water bill, points or even real money.

(If we improve the numbers of trash qualified for recycling more than the % we are going to give back to the people, screening companies would greatly approve this. Municipalities would also approve because it would help make the city "greener").

Incentive systems are usually believed to affect presumed quality through the feedback they provide regarding success, and in real-life environments the majority inevitably gets the (negative) feedback that they do less than excellent, which could demotivate users if not explained properly.[18]

However this also means that the user would greatly benefit if we can provide good and practical feedback to improve its efficiency, as well as include gamification, which will make him win more rewards.

Gamification

The key goal of gamification is the application of game design elements for non-gaming purposes in real-world environments, is to promote human motivation and success in respect of a given task.

To summarize, gamification is defined as "the use of design (rather than game-based technology or other game-related practices) elements (rather than fully developed games) characteristic for games (rather than play or playfulness) in non-game contexts (regardless of specific usage intentions, contexts, or implementation media)" [4]. Among these typical game design elements, which we will discuss in more detail below, are (1) points, (2) badges, (3) leaderboards, (4) performance graphs, (5) meaningful stories, (6) avatars and (7) teammates.

1. Points are essential elements of a number of games and gamified applications. Usually, they are rewarded for good performance of particular tasks within the game environment and serve to reflect numerically the progress of a player. We will use points to empower players to quantify their in-game actions and act as continuous and immediate feedback and reward.
2. Badges are characterized as visual representations of accomplishments and can be obtained and collected in gamification. We will use badges to affirm the accomplishments of the players, symbolize their qualities and display clearly the accomplishment of their levels or goals. The user could then show off their badges in their profile. Additionally, as badges symbolize one's membership in a group of those who own this particular badge, they also can exert social influences on players and co-players [1], particularly if they are rare or hard to earn.
3. Leaderboards rate players by their relative success, evaluating them against a specific criteria for achievement. As such, leaderboards can help decide who does well in any game, and are therefore competitive success metrics compared to the performance of others through the player's own results.We will use public leaderboards and private leaderboards to incentivize healthy competition.
4. Performance Graphs, unlike leaderboards, performance graphs do not compare the performance of the player to other players, but measure the player's own success over time. Unlike the leaderboard social comparison model, results graphs are based on their own user recycling rate over time.
5. Meaningful stories are game design elements that do not relate to the player's performance. Instead they will relate to what happens to the trash and to what it will be transformed, informing and delight the user.
6. Avatars are visual representations of players within the game or gamification environment, this will be used within our app to give the user some aspect of personalization and individuality.
7. Teammates, by creating defined groups of players that work together towards a shared objective, in this case the objective would be achieving a good recycling score.

Conclusion

Sustainable development has long been at the heart of the European Union and its economic , social and environmental aspects have been acknowledged by the EU Treaties. Without undermining the capacity of future generations to meet their own needs, growth must fulfill the needs of the present.
The 2030 agenda is completely in line with the vision of Europe which has now become the political blueprint for sustainable global growth.
We firmly believe that it should be a main goal of all countries to meet these requirements, and as such it will be needed a disruptive and inovative project like ours to transform the urban waste sector.
To meet the goal of making the world a better place we need to have the right project, the right tools, the right team and the right partners. In fact, we have all of those! We did the research and we are on the right track to implement our project with real and practical results.
This goal may not be a easy one to achieve, but things that are worth doing are often not easy.

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