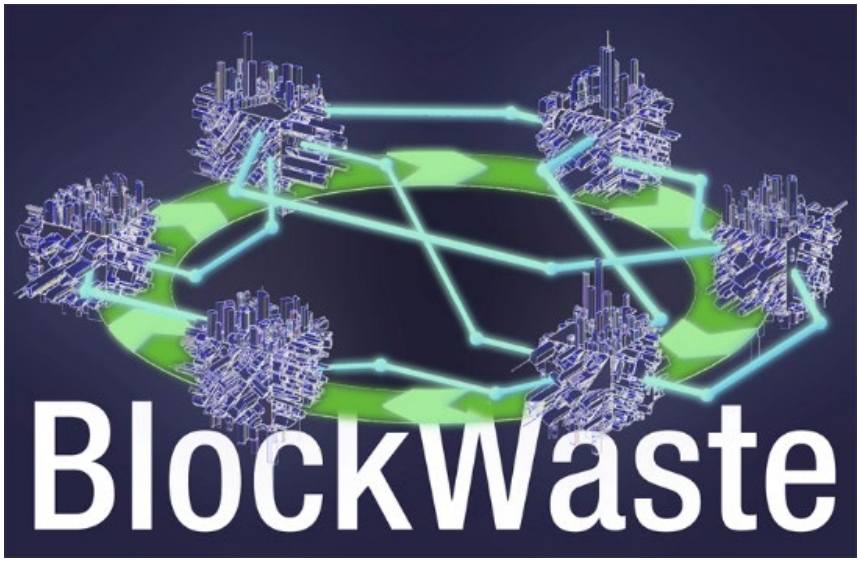
O3.A3 Interactive BlockWASTE Tool Manual



ΙΔΡΥΜΑ ΚΡΑΤΙΚΩΝ ΥΠΟΤΡΟΦΙΩΝ IKY

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Contents

Executive summary iv
1 Introduction 1
1.1. Description of the BlockWASTE project 1
1.2. Objectives and methodological approach 1
2 Blockchain module 3
2.1. The modified “Blockchain game!” 3
2.2. The Interactive Blockchain simulator 5
2.2.1. Creating a public and a private key 6
2.2.2. Playing the tool as a single player 8
2.2.3. Playing with multiple users 11
3 The BlockWASTE Tool 13
3.1. Introduction to the game 13
3.2. Detailed description of the calculations behind the game 13
3.2.1. Households 13
3.2.2. Mayor 15
3.2.3. Main assumptions 18
3.2.4. Outputs of the tool 20
3.3. Detailed description of the roles 28
3.3.1. Starting the game 28
3.3.2. Households 28
3.3.3. Mayor 31
3.4. Basic instructions on how to play 34
3.4.1. Playing the game 34
3.4.2. After playing the game 34
4 References 36

List of tables

Table 1. Relationship between time spent on waste segregation and percentage of waste separated in different bins 14
Table 2. Technical assumptions for the aerobic MBT 18
Table 3. Technical assumptions for the anaerobic MBT 19
Table 4. Technical assumptions for the aerobic BTF 19
Table 5. Technical assumptions for the anaerobic BTF 19
Table 6. Cost assumptions 20
Table 7. Revenues assumptions 20
Table 8. Waste composition and collection per household 22
Table 9. Input for the aerobic MBT facility 22
Table 10. Output from the aerobic MBT facility 23
Table 11. Input and output for the aerobic BTF 23
Table 12. Input and output for the Materials Recovery Facility 24
Table 13. Collection cost for mixed and separated waste (€/kg) 24
Table 14. Treatment cost for mixed and separated waste (€/kg) 25
Table 15. Landfill and total costs for mixed and separated waste (€/kg) 25
Table 16. Revenues from mixed waste (€/kg) 26
Table 17. Revenues from separated waste (€/kg) 26
Table 18. Net cost (€) per kg for mixed, separated and total waste 27
Table 19. Total revenues and net costs (€/kg) 27

List of figures

Figure 1: The Blockchain game Google Drive folder 3
Figure 2: View of the Blockchain problem used in BlockWASTE game 4
Figure 3: View of the solved problem 4
Figure 4: Result of a change in entry 3 4
Figure 5. Screenshot of the Bitcoin Blockchain Simulator 5
Figure 6. Creation of a new simulated wallet 6
Figure 7. Input for generating a new wallet 6
Figure 8. Generation of the new wallet 7
Figure 9. Generation of the public and private keys 7
Figure 10. Simulated blocks created on Blockchain 8
Figure 11. Block mining screen 9
Figure 12. Turning on the “Auto Mining” option 9
Figure 13. Message appearing when a block has successfully mine 10
Figure 14. Verifying the block reward 10
Figure 15. Balance of user’s wallet 11
Figure 16. Creating a new transaction 11
Figure 17. The “New Transaction” screen 11
Figure 18. Creating and signing a transaction 12
Figure 19. Sending the transaction 12
Figure 20: The game’s home screen 28
Figure 21. The “Add data” window 29
Figure 22: The simplified Blockchain problem 29
Figure 23: View of a solved Blockchain problem that allows for the submission of the data 30
Figure 24. The results window (only for player’s entries) 30
Figure 25. The results window (showing the results for all players) 31
Figure 26. The selection of MSW management plan window 31

Figure 27. The 'basic' information window where the used defines the municipal fees..... 32
Figure 28. The expanded financial information window..... 33
Figure 29. The detailed technical and financial window 34

List of abbreviations

Abbreviation	Definition
MSW	Municipal solid waste
MSWM	Municipal solid waste management
SMEs	Small and medium enterprises
IT	Information technology
GDP	Gross Domestic Product
OER	Open Educational Resource

Executive summary

In the context of the project, an interactive tool ("Interactive BlockWASTE Tool") has been developed, which is free of access and is implemented within the OER, developed in the "IO4: BlockWASTE Open Educational Resource".

The aim of the tool is to offer users several keys to achieve the integration of Blockchain-based MSW and help them understand the whole traceability and visibility of municipal solid waste from the beginning to the end of their management. With the "Interactive BlockWASTE Tool" (https://game.blockwasteproject.eu/), the user will be able to visualize how the encrypting of information of a Blockchain works is a role-playing environment, exploiting - whenever needed - the information collected within the waste database (i.e. "O3/A1. Production of the database for the E-Learning Tool") that has been created.

Although the Application Form initially foreseen one interactive tool (i.e. the "Interactive BlockWASTE Tool"), it was decided to develop two different modules in order to better serve the educational needs of the BlockWASTE project's identified target groups and final users. More specifically, the first module (Blockchain module) aimed to visualise how the encrypting of information of a Blockchain works and is addressed to users who are not familiar with Blockchain technology. The second module (initially called "MSW Management Tool") focused only on MSW management using an interactive role-playing game.

The aim of this manual is to explain what is the purpose of the games, what is the input needed by the users and how the games operate (i.e. details about the algorithms behind the results).

1 Introduction

1.1. Description of the BlockWASTE project

This comparative study is part of the BlockWASTE project, which is an EU-funded Erasmus Plus project. The project aims to address the interoperability between waste management and Blockchain technology and to promote its proper treatment through educational training, so that the data collected is shared within a safe environment, where there is no room for uncertainty and mistrust between all parties involved in waste chains or cycles.

For this purpose, the objectives of the BlockWASTE project are as follows:

- To conduct research on solid waste generated in cities and how it is managed, so that an information base of good practices can be created that helps reintroduce waste into the value chain, promoting the idea of Intelligent Circular Cities.
- To identify the benefits of the Blockchain Technology within the municipal waste management (MSW) process.
- To create a study plan that supports the training of teachers and professionals of organizations and companies of the sector, in the overlap of the fields of Waste Management, Circular Economy and Blockchain technology.
- To develop an interactive tool based on Blockchain technology, which will make it possible to put into practice the management of data obtained from urban waste, thus visualizing the way in which the data is implemented in the Blockchain and enabling users to evaluate different forms of management

Further information is available from the BlockWASTE project website https://blockwasteproject.eu.

1.2. Objectives and methodological approach

In the context of the project, an interactive tool ("Interactive BlockWASTE Tool") has been developed, which is free of access and is implemented within the OER, developed in the "IO4: BlockWASTE Open Educational Resource".

The aim of the E-learning tool is to offer users several keys to achieve the integration of Blockchain-based MSW and help them understand the whole traceability and visibility of municipal solid waste from the beginning to the end of their management. With the "Interactive BlockWASTE Tool", the user will be able to visualize how the encrypting of information of a Blockchain works is a role-playing environment, exploiting - whenever needed - the information collected within the waste database (i.e. "O3/A1. Production of the database for the E-Learning Tool") that has been created.

Although the Application Form initially foreseen one interactive tool (i.e. the "Interactive BlockWASTE Tool"), it was decided to develop two different modules in order to better serve the educational needs of the BlockWASTE project's identified target groups and final users. More specifically, the first module (Blockchain module) aimed to visualise how the encrypting of information of a Blockchain works and is addressed to users who are not familiar with Blockchain technology. The second module (initially called "MSW Management Tool") focused only on MSW management using an interactive role-playing game.

The first two pilot schools in Germany and Greece made use of these two modules. Although the overall opinion of the participants on the training tools was very positive, some comments mentioned that the role of Blockchain in the waste management system was not very clear. Taking into consideration the results of the pilot schools, a new version of the BlockWASTE tool was developed. It was decided to keep the "Blockchain module" separately and independent from the "MSW Management Tool", but the latter (i.e. the "MSW Management Tool") incorporated a short Blockchain game, as explained in more detail later on. The updated version of the "MSW Management Tool" is called "Interactive BlockWASTE tool". In the third pilot school (i.e. in Estonia), the new version of the "Interactive BlockWASTE tool" was tested.

In brief, in order to make it clearer for the users how Blockchain works, the "Blockchain module" includes a modified version of "The Blockchain Game!" (https://medium.com/predict/how-to-teach-blockchain-with-the-blockchain-game-44360c542c81) created by J. Scott Christianson, an Associate Teaching Professor at the University of Missouri. Further, an interactive Blockchain simulator is provided, where the users play and simulate all the steps behind a Blockchain (https://bitcoinsimulator.tk/).

The final version of the "Interactive BlockWASTE tool" focuses mainly on MSW management using an interactive role-playing game, which is based on two routes (roles), i.e. the Mayor (assumed to be in charge of the MSW management authority) and the households. During the game, the "households" group, using the information collected within the MSW database that has been created previously (O3/O1), provide input about the MSW quantity and composition per month (for one year) and the time devoted to separate MSW at the source (the latter is translated to a monetary value, as detailed in a later section) which determines the recycling rate. The "Mayor" must select a MSW treatment option (there are four different alternatives) and, each month, has to define the municipal fees charged to each household based on the total waste quantity, the separated and mixed waste quantities, the collection, treatment and disposal costs and the potential revenues from recyclable materials or electricity production from biogas. In order to demonstrate the interface of waste management and Blockchain, a simple Blockchain problem was been added. The user must solve the problem first (just like the problem is solved by bitcoin miners in real-life situations) in order to submit input data to the municipal authority. Further, all users are able to see anonymised information, which is recorded on a Blockchain, about waste generation, municipal charges, waste segregation habits, etc. The "Interactive tool BlockWASTE" is completely free of access and is implemented within the OER, developed in the "IO4: BlockWASTE Open Educational Resource".

The aim of this manual is to explain what is the purpose of the games, what is the input needed by the users and how the games operate (i.e. details about the algorithms behind the results).

2 Blockchain module

2.1. The modified "Blockchain game!"

To help the users understand the logic behind Blockchain, "The Blockchain Game!" (https://medium.com/predict/how-to-teach-blockchain-with-the-blockchain-game-44360c542c81) created by J. Scott Christianson, an Associate Teaching Professor at the University of Missouri, was selected after a thorough investigation of related tools.

"The Blockchain Game!" is hands-on exercise, which explains Blockchain's core principals using as an example a Blockchain for academic scores (Christianson, 2019). The game teaches Blockchain concepts like distributed ledger, transparent but anonymous ledger, immutable ledger, etc. One of the main advantages of this specific game is that the materials for The Blockchain Game are available under a Creative Commons Attribution-Non Commercial-Share Alike International License, making it free for anyone to use and alter for their own purposes (Christianson, 2019). Further, the creator provides guidelines on how to teach Blockchain with "The Blockchain Game!" (Christianson, 2022) and all necessary files (including the game in Excel format, presentations of the game, students handouts, etc.) are available via Google Drive (https://drive.google.com/drive/folders/1c7_zfwzZ_acsVN4n7tS_ItRUOpLN0vPd), as shown in Figure 1.

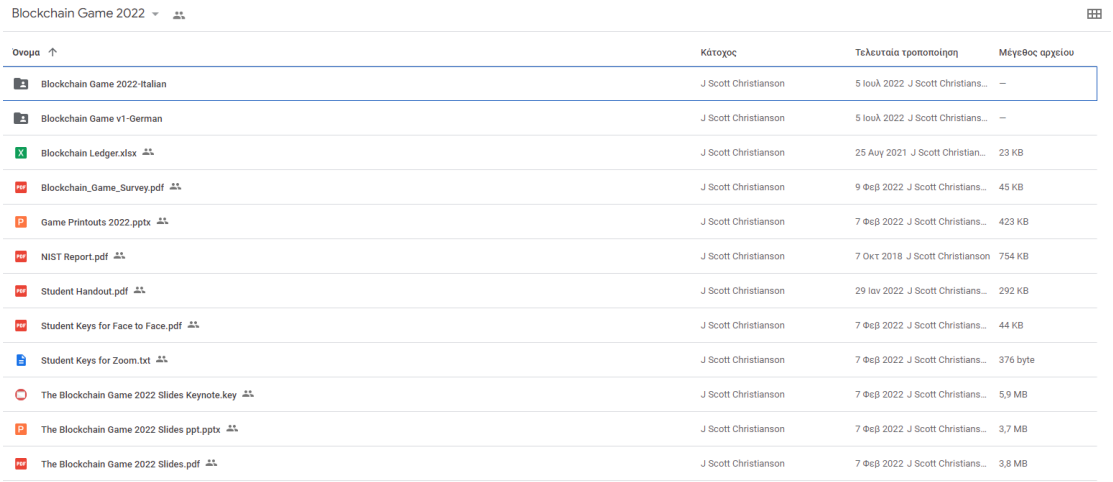


Figure 1: The Blockchain game Google Drive folder

For the purposes of BlockWASTE, the original Excel file was altered and the example used is relating to MSW management. Specifically, the problem involves households living in different areas of a city (e.g., Red, Blue, Green, etc.), have a public identification key (similar to the public key of Bitcoin) and produce different quantities of waste (Figure 2).

Following the initial idea of the game, the user must solve a hash, i.e. the function that meets the encrypted demands needed to solve for a Blockchain computation, as follows:

Hash = Nonce + a + b + c – Value of Last 2 digits of Previous Hash

where: a = Value of the first letter of the area

b = Value of the first letter of the Household Public Key

c = Value of the Total Waste

Nonce = value between 1 and 3 that must be adjusted to calculate a hash that can be equally divisible by 3

Block	Area	Householder	Total waste	Nonce (1-3	a	b	c	Last two digits from prev. Hash	Hash	Divid 3
									212	
1	Red	ad59dn	25	2	82	65	25	12	162	
2	Blue	Bd9efe	30	2	66	66	30	62	102	
3	Green	da603d	90							
4	Red	ad59dn	18							
5	Blue	Bd9efe	16							
6	Green	da603d	30							

Figure 2: View of the Blockchain problem used in BlockWASTE game

The values of a, b and c parameters are retrieved from a lookup table, which is included in the Excel file. If the hash is solved correctly, the last column becomes green (Figure 3). Moreover, if the ledger is attacked (i.e. someone changes a previous entry), then the last column becomes red from the point of change and onwards (Figure 4).

Block	Area	Householder	Total waste	Nonce (1-3)	a	b	c	Last two digits from prev. Hash	Hash	Divid 3
									212	
1	Red	ad59dn	25	2	82	65	25	12	162	
2	Blue	Bd9efe	30	2	66	66	30	62	102	
3	Green	da603d	90	1	71	68	90	2	228	
4	Red	ad59dn	18	1	82	65	18	28	138	
5	Blue	Bd9efe	16	1	66	66	16	38	111	
6	Green	da603d	30	1	71	68	30	11	159	
7	Red	ad59dn	44	3	82	65	44	59	135	
8	Blue	Bd9efe	21	2	66	66	21	35	120	
9	Green	da603d	10	3	71	68	10	20	132	
10	Red	ad59dn	51	2	82	65	51	32	168	
11	Blue	Bd9efe	66	2	66	66	66	68	132	
12	Green	da603d	19	3	71	68	19	32	129	

Figure 3: View of the solved problem

Block	Area	Householder	Total waste	Nonce (1-3)	a	b	c	Last two digits from prev. Hash	Hash	Divid 3
									212	
1	Red	ad59dn	25	2	82	65	25	12	162	
2	Blue	Bd9efe	30	2	66	66	30	62	102	
3	Green	da603d	90	1	73	68	90	2	230	
4	Red	ad59dn	18	1	82	65	18	30	136	
5	Blue	Bd9efe	16	1	66	66	16	36	113	
6	Green	da603d	30	1	71	68	30	13	157	
7	Red	ad59dn	44	3	82	65	44	57	137	
8	Blue	Bd9efe	21	2	66	66	21	37	118	
9	Green	da603d	10	3	71	68	10	18	134	
10	Red	ad59dn	51	2	82	65	51	34	166	
11	Blue	Bd9efe	66	2	66	66	66	66	134	
12	Green	da603d	19	3	71	68	19	34	127	

Figure 4: Result of a change in entry 3

2.2. The Interactive Blockchain simulator

As written in the introduction, in addition to "The Blockchain Game!" an interactive Bitcoin Blockchain simulator is used, which provides the user with the experience of how Blockchain practical works on the background. The Interactive Blockchain simulator can be found on the following website: https://www.bitcoinsimulator.tk/blockchain?chain=BlockWaste (Figure 5).

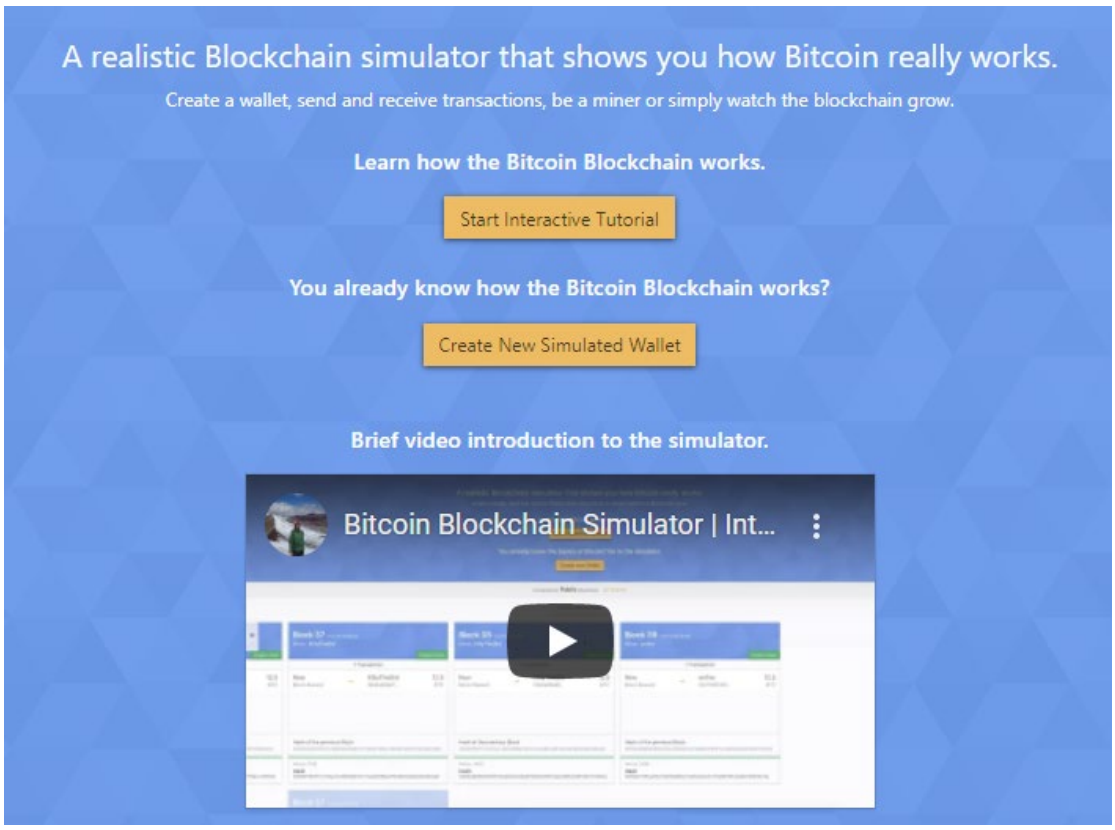


Figure 5. Screenshot of the Bitcoin Blockchain Simulator

Users who are not familiar with Blockchain, are strongly advised to start with the Interactive Tutorial on this website. When the user has understood the theoretical part can continue to the part where she/he learns how a Blockchain practical works on the background. The user can watch the video on the webpage and/or follow the steps described below to gain better understanding of what happens.

What the user will learn through this game is:

- What public and private keys are and how an identity is created.
- How a user can use those keys to create a transaction.
- How a transaction is processed on the Blockchain, how the validation process is going and how the mining process works.
- How a transaction is processed on the Blockchain.

2.2.1. Creating a public and a private key

To start playing with the Interactive Blockchain simulator you have to create public and a private key. You can do this by clicking on Create New Simulated Wallet (Figure 6):

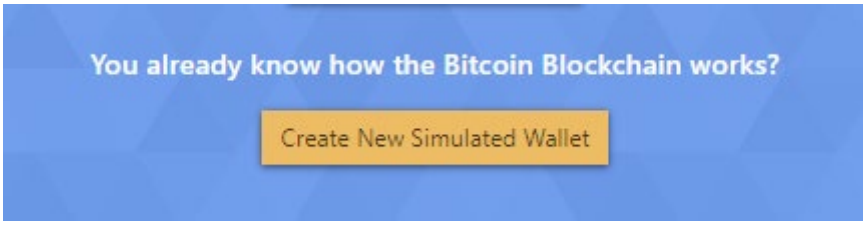


Figure 6. Creation of a new simulated wallet

After clicking on the button Generate a new Wallet, this screen will appear (Figure 7):

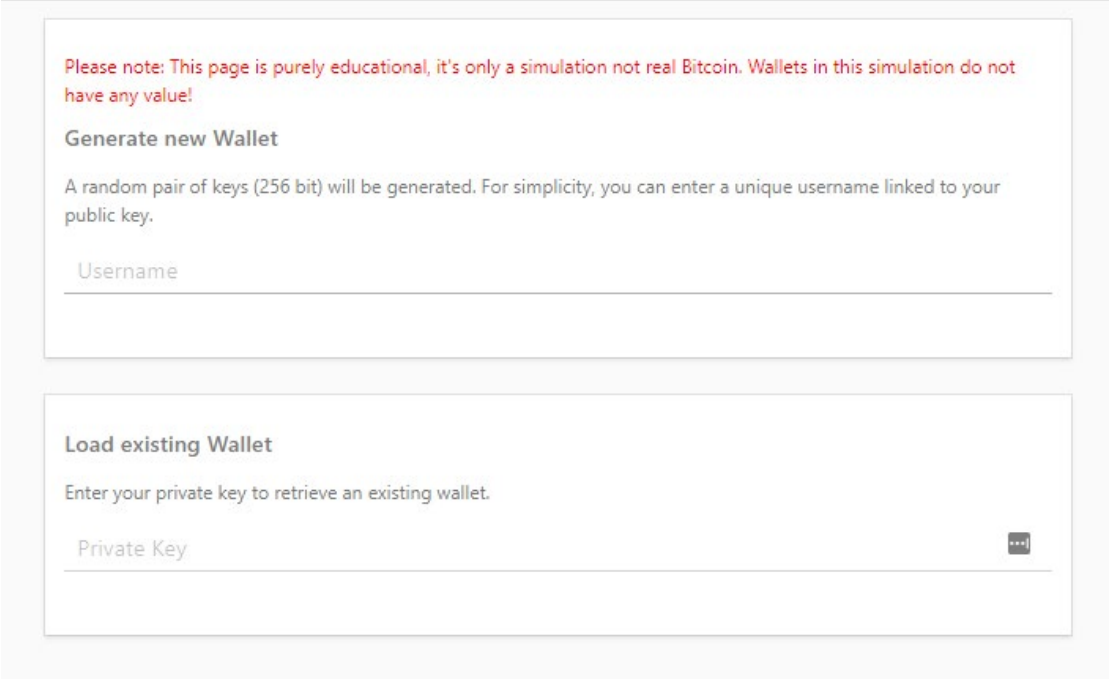


Figure 7. Input for generating a new wallet

When filling a username, a blue button “Generate new Wallet” will appear (Figure 8):

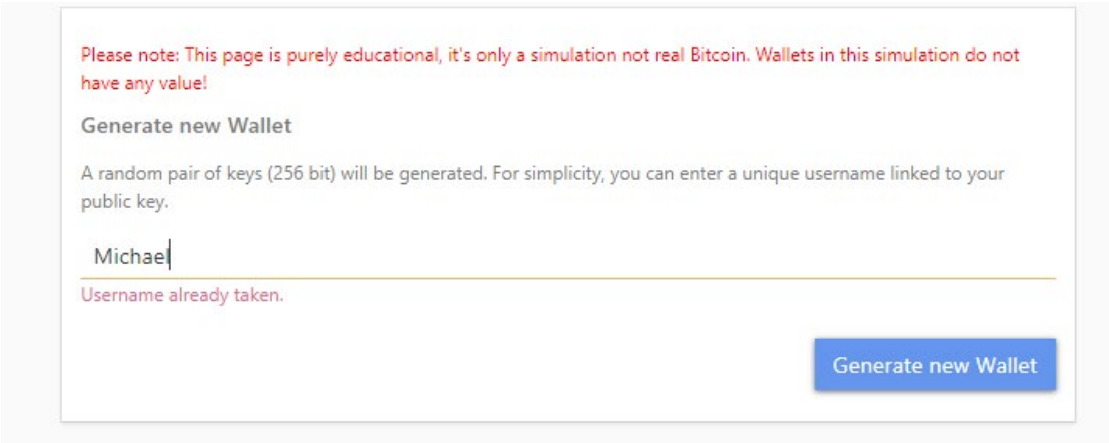


Figure 8. Generation of the new wallet

Finally, by clicking the "Generate new Wallet" button, one Public and one Private keys will be created (Figure 9).

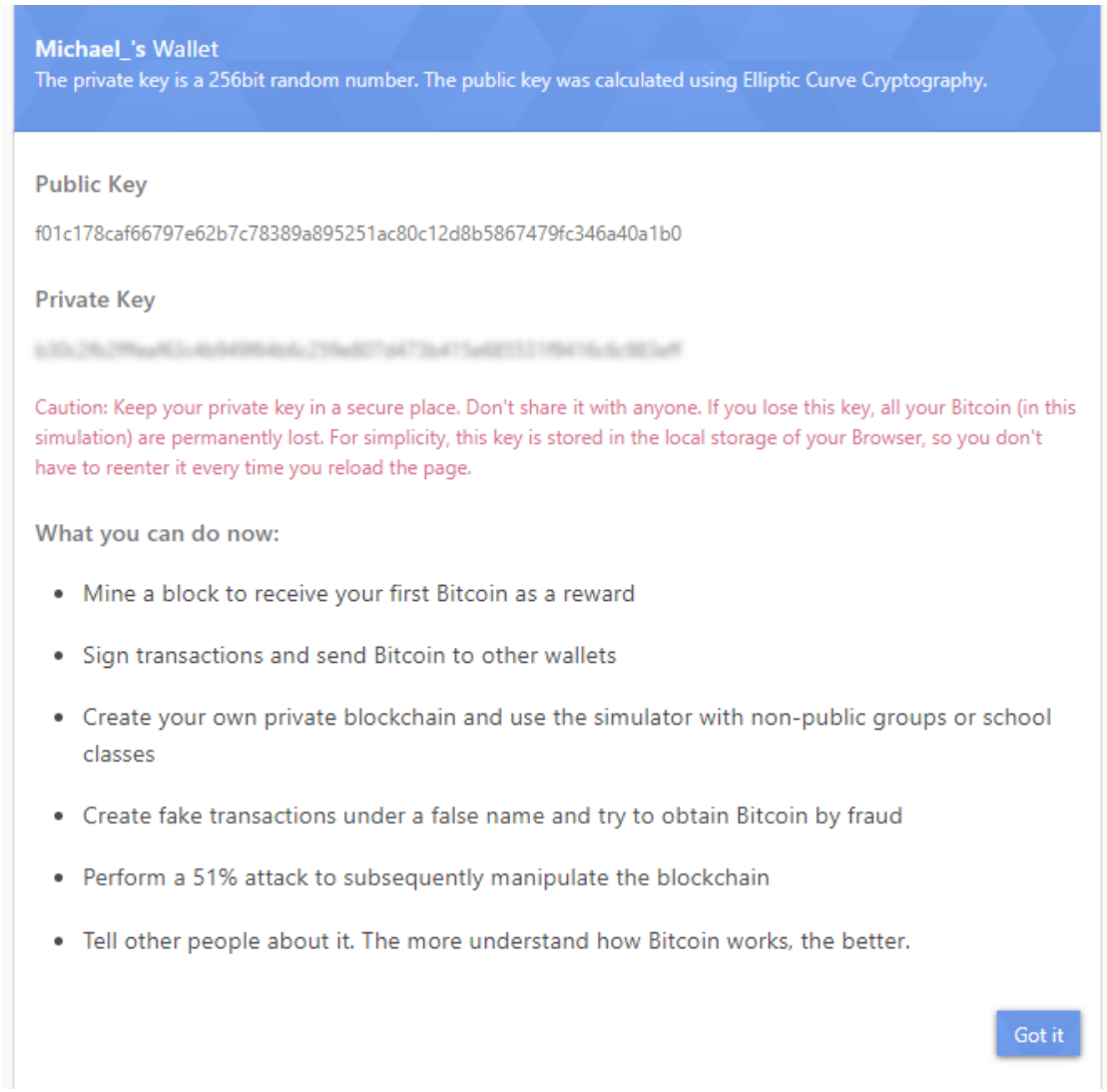


Figure 9. Generation of the public and private keys

The private key is blurred but when you put your mouse over key you can see the private keys. It's handy to copy and paste your public and private key in a temporarily file.

> *A little note about creating public and private keys:*
>
> *Normally if you have a bitcoin wallet you don't create your keys by adding a username; the wallet will generate a random key automatically for you. Additionally, it will give you 12 to 24 so-called seed words, which can be used to restore your keys if you want to reinstall your wallet. If you lose the seed words, you will never be able to restore your wallet, so important enough to always write them down and keep them safe.*

After the public and private keys have been created, the user will be able to test all the other Blockchain features. The user can play with the tool as a single player and with multiple users, as described in the following sections.

2.2.2. Playing the tool as a single player

The user can copy and paste her/his keys and read the steps on the window. Then the user can click on the button "Got it", right under the corner. The following screen comes up (Figure 10), which simulate some blocks already created on a Blockchain. In this case, we are looking to a public Blockchain in a test mode. The transactions have no real value.

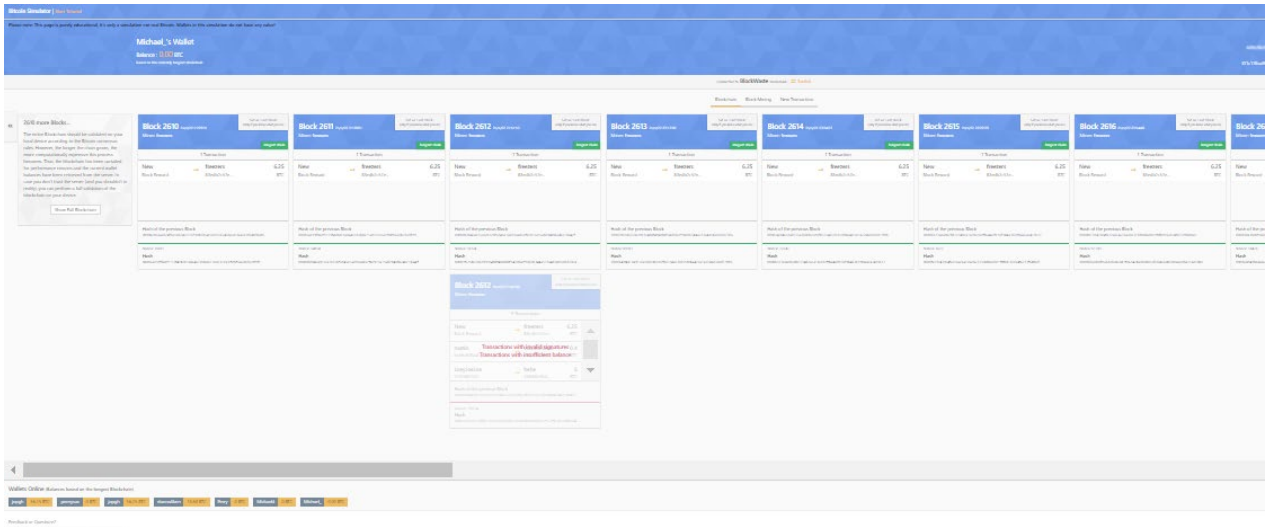


Figure 10. Simulated blocks created on Blockchain

At the bottom of the screen, the usernames of the user and of other wallets, which are active on the Blockchain, appear. Let's get some coins first.

When the user starts the simulator for the first time, the balance of her/his wallet is zero. To earn bitcoins the user can do two things:

1. Ask another user to send bitcoins.
2. Play the role of a miner and get some rewards for the mining.

Let's have a look at the second path and get some coins by mining.

By clicking the tab "Block mining" in the middle of the page, the following screen comes up (Figure 11):

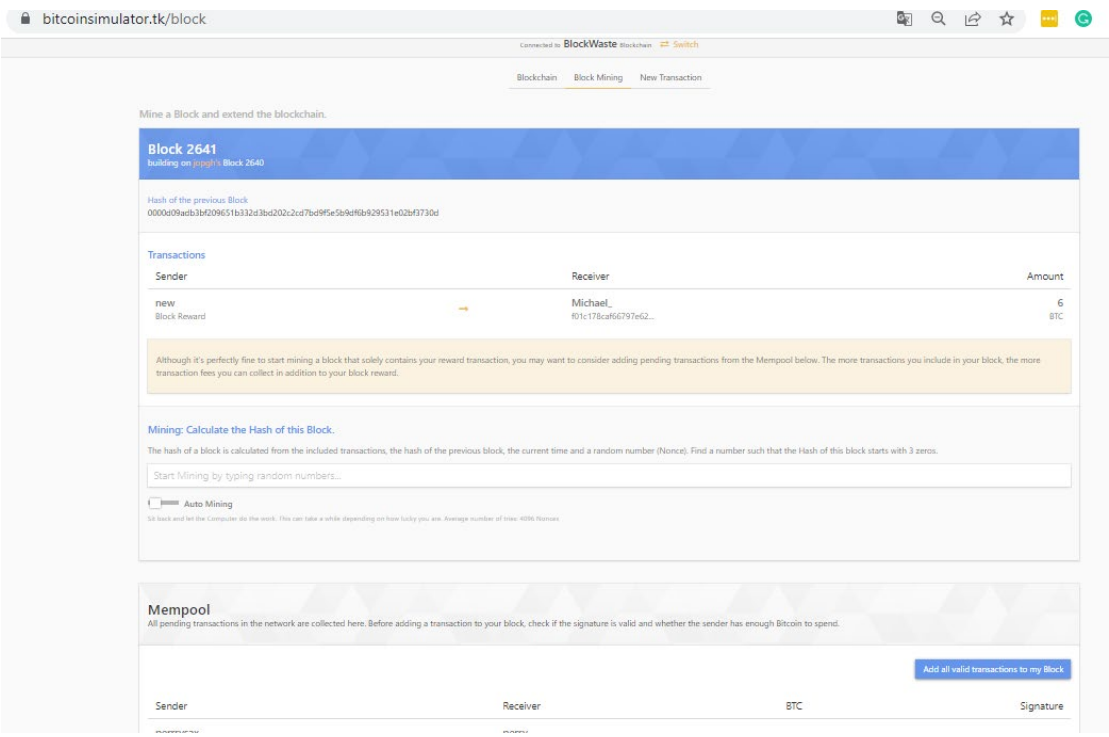


Figure 11. Block mining screen

In order to calculate the hash of a block, the user will turn on the "Auto Mining" option and wait for a couple of minutes (Figure 12).

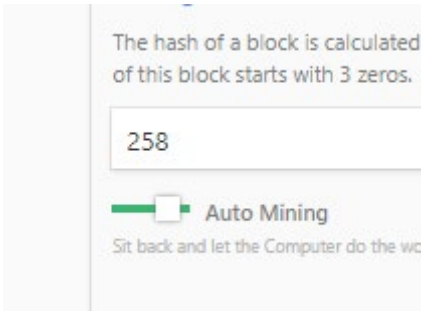


Figure 12. Turning on the "Auto Mining" option

The mining will start trying to solve a puzzle (in this case, the miner has to find a number that will create a hash starting with 3 zero's). When the problem is solved, the following message will pop-up (Figure 13):

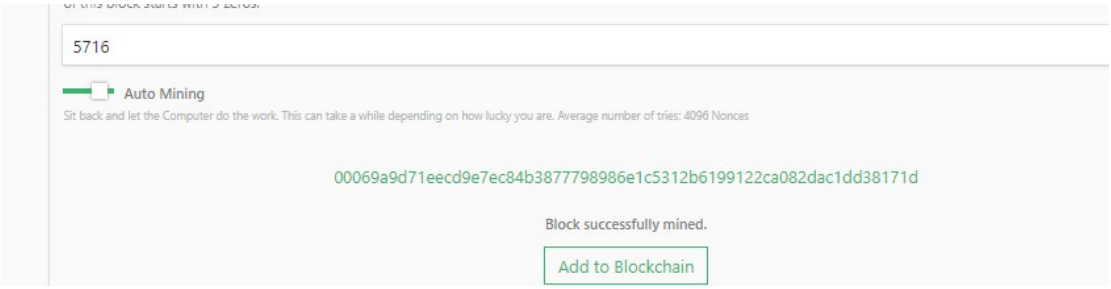


Figure 13. Message appearing when a block has been successfully mined

By clicking the button "Add to Blockchain", a new window will be displayed (Figure 14) to the user verifying the block and offering the option to add the reward to her/his wallet.

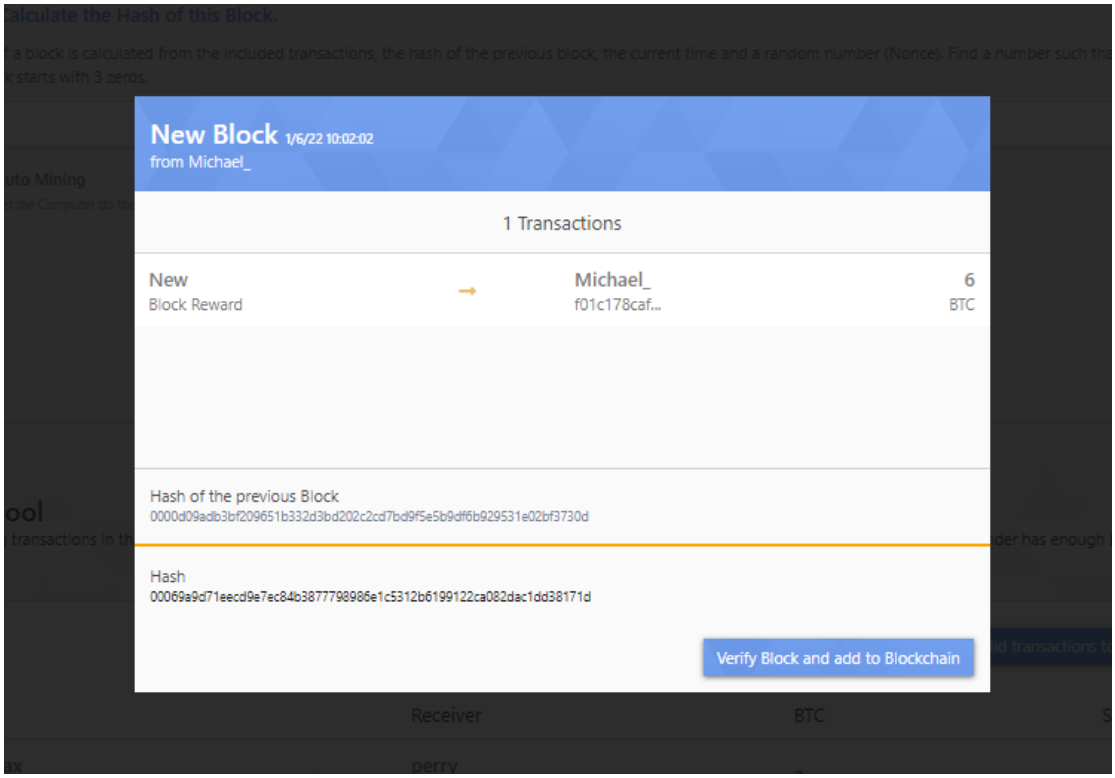


Figure 14. Verifying the block reward

As shown in Figure 15, the new balance of user's wallet is now 6.25 BTC.

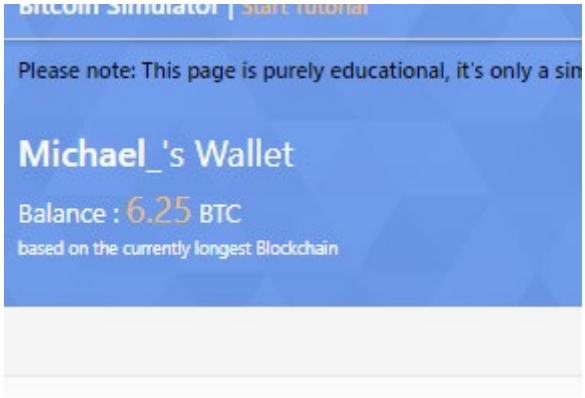


Figure 15. Balance of user's wallet

Now that the user owns some bitcoins, she/he can send some coins to a friend.

2.2.3. Playing with multiple users

In order to play the game with multiple users, each of the users has to create a unique account following the above-mentioned process. When the account has been created, the user can click on New Transaction (Figure 16):

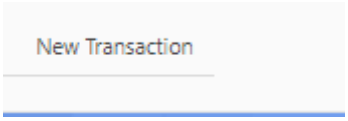


Figure 16. Creating a new transaction

In this case, the following screen comes up (Figure 17):

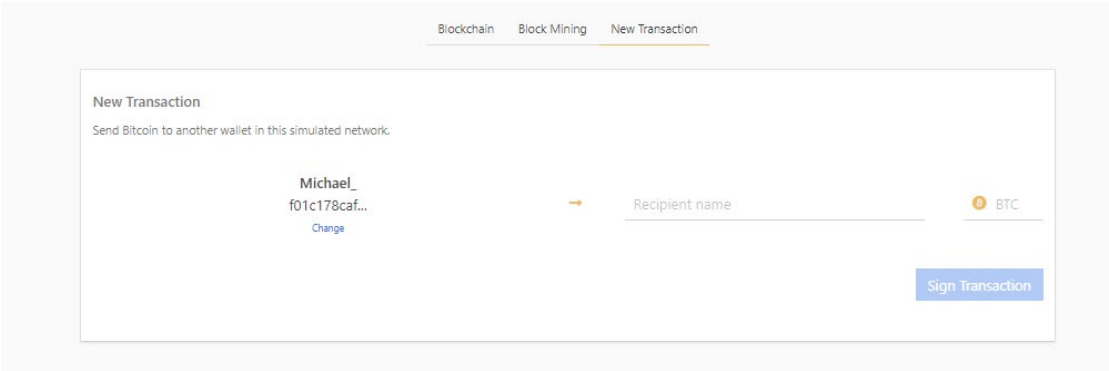


Figure 17. The "New Transaction" screen

The user must fill in the username of the recipient and the amount of bitcoins to be sent and then click on the "Sign transaction" (Figure 18).

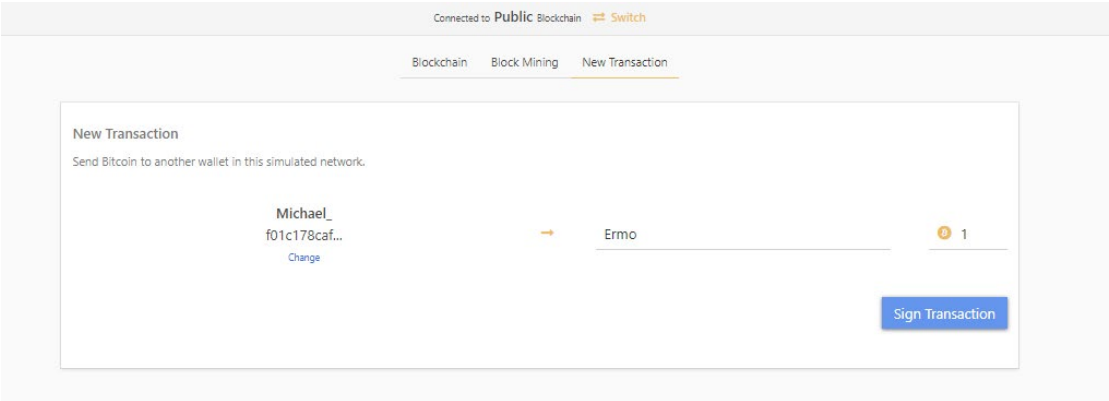


Figure 18. Creating and signing a transaction

After signing transaction, the following screen comes up (Figure 19), and the user can now send the transaction to the Blockchain.

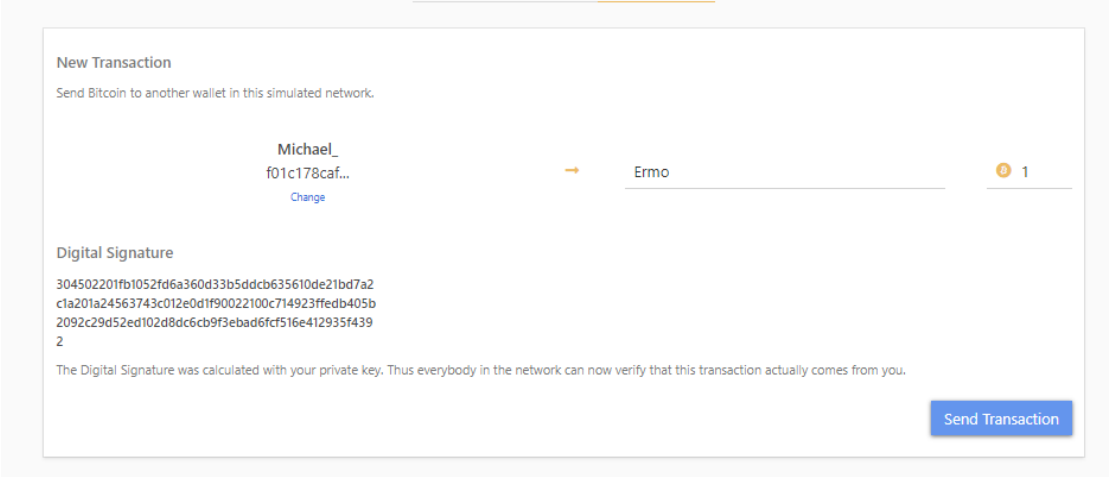


Figure 19. Sending the transaction

Now, the users can go the “Block Mining” tab and validate the transaction by using the “Auto Mining” again. When the block is solved, the recipient will receive the bitcoins sent.

3 The BlockWASTE Tool

3.1. Introduction to the game

As already mentioned, the "Interactive BlockWASTE Tool" (https://game.blockwasteproject.eu/) is an interactive role-playing game focused on MSW management with the integration of a simple Blockchain problem. The game allows the interaction of a class group through the use of computers (but also tablets or even smartphones), and it shows in real-time the progress to the whole class.

The game involves two different roles, i.e. the Mayor (assumed to be in charge of the MSW management authority) and the households. The class group is divided at the beginning of the game into these two groups, but the role of the Mayor is assigned only to one person. During the game, the "households", using the information collected within the MSW database that has been created (O3/O1), provide input about the MSW quantity and composition per month (for one year) and the time devoted to separate MSW at the source (the latter is translated to a monetary value), which determines the recycling rate. The "Mayor" selects a MSW treatment option (there are four different alternatives) and, each month, defines the municipal fees charged to each household based on the total waste quantity, the separated and mixed waste quantities, the collection, treatment and disposal costs and the potential revenues from recyclable materials or electricity production from biogas.

Role-playing helps students to reach their goals (e.g. the Mayor may wish to minimise disposal of waste to landfills or the households may wish to minimise the cost of MSW management). The game allows the interaction of a class group through the use of computers (but also tablets or even smartphones), and it shows in real-time the progress to the whole class. The effective output of the tool is guaranteed by the presence of paths with different MSW treatment systems and different aspirations and objectives between households and the municipality or between households themselves. In this way, the tool has a direct impact on MSW management and on the bad practices that currently exist with regard to the accuracy of information on types, quantities and final destinations of MSW waste.

At the end of the game, that is after running the game for 12 periods (i.e. months), a report can be created detailing the paths followed by the players (i.e. the Mayor and the households), including information about the types, quantities and final destinations of MSW waste, the MSW collection, treatment and disposal costs, the revenues from recycling and utilising specific waste, etc. In this way, the class group and the instructor can discuss the strategic goals and objectives of the players and the impact that these strategies may have on MSW management practices.

3.2. Detailed description of the calculations behind the game

Prior to discussing the roles and the input needed for the game, it is necessary to demonstrate in detail the basic assumptions and calculations behind the results. To facilitate the instructors and the players of the game, the details are given below separately for the two roles.

3.2.1. Households

As far as the households are concerned, the game takes into consideration the following variables:

- HH members
- MSW generation pc/year
- HH MSW generation/month
- Composition of MSW:
    - Organics
    - Paper
    - Plastics
    - Metal
    - Glass
    - Other
- Time spent on sorting waste (between 0-45 minutes per week)
- Value of time (€/hour.month)
- Percentage of waste separated in different bins
- Percentage of mixed MSW (mixed waste, organic and other)
- Municipal fees (€/month)
- Total cost (€/month)

The variables HH members, MSW generation pc/year, Composition of MSW and Time spent on sorting waste are defined by the user. Specifically, MSW generation pc/year and Composition of MSW can be retrieved by the MSW database that has been created in O3/O1. The database includes data on MSW generation and management in European countries, socioeconomic data, composition of MSW, prices for recycled plastics, glass and paper, etc.

The Time spent on sorting waste was based on the assumption that a household spends between 15 and 45 min per week for recycling (Nainggolan et al., 2019) and those who sort their household waste they use on average 30 min a week doing this (Bruvoll et al., 2002). Based on these findings, it was assumed that there exists a relationship between time spent on waste segregation at source level and the Percentage of waste separated in different bins, which is shown in Table 1.

Table 1. Relationship between time spent on waste segregation and percentage of waste separated in different bins

Time spent on waste segregation (minutes per week)	Percentage of waste separated in different bins
0-2	0%
3-10	10%
11-15	25%
16-20	50%
21-30	75%
31-45	100%

The Percentage of mixed MSW is estimated by the Percentage of waste separated in different bins, as follows:

Percentage of mixed MSW = 1 - Percentage of waste separated in different bins

The value of time spent on sorting the waste was based on previous surveys (Bartelings & Sterner, 1999; Bruvoll et al., 2000; Huhtala, 2010; Lee et al., 2017; Nainggolan et al., 2019).

The value of time ranges significantly between 0.3 € per hour (Bruvoll et al., 2000) up to 283.9 € per hour based on the average number of hours spent on sorting and the average income per hour after tax (Bartelings & Sterner, 1999). For the purposes of the game, a value of time equal to 15 € per hour has been adopted.

The Municipal fees are determined by the Mayor, as explained later on in this manual, and the Total cost for the household is estimated, as follows:

Total cost = Value of time + Municipal fees

3.2.2. Mayor

There are four alternative waste management schemes as options for the municipal authorities:

- S1. Aerobic MBT – Compost
- S2. Anaerobic MBT – Compost
- S3. Anaerobic MBT – Anaerobic
- S4. Biodrying MBT - Anaerobic

These alternatives are discussed in more detail below.

S1. Aerobic MBT – Compost

According to S1, mixed waste (i.e. Organics, Paper, Plastics, Metal, Glass and Other) are directed to a Mechanical Biological Treatment (MBT) Facility with aerobic digestion. The facility produces as output:

- Paper
- Plastics
- Metal
- Glass
- Other
- RDF
- Compost Like Output (CLO)

There are also Losses (moisture) and Residues that are disposed of to a landfill.

The Organics from the separated waste are directed to an aerobic Biowaste Treatment Facility, which produces Compost. There are again Losses from moisture. Paper, Plastics, Metal, Glass and Other waste are transferred to a Materials Recovery Facility (MRF), which produces clean recyclables.

S2. Anaerobic MBT – Compost

According to S2, mixed waste (i.e. Organics, Paper, Plastics, Metal, Glass and Other) are directed to a Mechanical Biological Treatment (MBT) Facility with anaerobic digestion. The facility produces as output:

- Paper
- Plastics
- Metal

- Glass
- Other
- RDF
- Compost Like Output (CLO)
- Electricity from biogas

There are also Losses (moisture) and Residues that are disposed of to a landfill.

The Organics from the separated waste are directed to an aerobic Biowaste Treatment Facility, which produces Compost. There are again Losses from moisture. Paper, Plastics, Metal, Glass and Other waste are transferred to a Materials Recovery Facility (MRF), which produces clean recyclables.

S3. Anaerobic MBT – Anaerobic

According to S3, mixed waste (i.e. Organics, Paper, Plastics, Metal, Glass and Other) are directed to a Mechanical Biological Treatment (MBT) Facility with anaerobic digestion. The facility produces as output:

- Paper
- Plastics
- Metal
- Glass
- Other
- RDF
- Compost Like Output (CLO)
- Electricity from biogas

There are also Losses (moisture) and Residues that are disposed of to a landfill.

The Organics from the separated waste are directed to an anaerobic Biowaste Treatment Facility, which produces Electricity from biogas and Compost. There are again Losses from moisture. Paper, Plastics, Metal, Glass and Other waste are transferred to a Materials Recovery Facility (MRF), which produces clean recyclables.

S4. Biodrying MBT - Anaerobic

According to S4, mixed waste (i.e. Organics, Paper, Plastics, Metal, Glass and Other) are directed to a Biodrying Mechanical Biological Treatment (MBT) Facility. The facility produces as output:

- SRF
- Metal
- Glass

There are also Losses (moisture) and Residues that are disposed of to a landfill.

The Organics from the separated waste are directed to an anaerobic Biowaste Treatment Facility (BTF), which produces Electricity from biogas and Compost. There are again Losses from moisture. Paper, Plastics, Metal, Glass and Other waste are transferred to a Materials Recovery Facility (MRF), which produces clean recyclables.

Based on the input and output of each alternative MSW management scenario, the Mayor receives information about:

- the total quantity of MSW generated by each household, the quantity of MSW that was separated by each household and the quantity of MSW that was disposed of as mixed waste
- the total MSW collection cost (for separated, mixed and total waste)
- the total MSW treatment cost (for separated, mixed and total waste)
- the total revenues from selling compost, recycled materials, electricity, etc. (for separated, mixed and total waste)
- the total net cost (for separated, mixed and total waste)
- the net cost per kg (for separated, mixed and total waste)
- the net cost per household

The total quantity of MSW as well as the quantities of separated and mixed MSW generated by each household are assumed to be known (e.g. by introducing customised trash bags, using collection trucks with equipment to weigh the garbage, place smart garbage bins with scales to measure the weight and radio-frequency identification (RFID) tags to identify households, etc.).

The collection costs are estimated, as follows:

*Collection cost for mixed waste (€) = Collection cost (€/ton) * Mixed MSW quantity (ton)*

*Collection cost for separated waste (€) = Collection cost (€/ton) * Separated MSW quantity (ton)*

*Collection cost for total waste (€) = Collection cost (€/ton) * Total MSW quantity (ton)*

Similarly, treatment costs are estimated, according to the treatment facility, as follows:

*Treatment cost for mixed waste (MBT aerobic) (€) = Treatment cost (€/ton) * Mixed MSW quantity (ton)*

*Treatment cost for mixed waste (MBT anaerobic) (€) = Treatment cost (€/ton) * Mixed MSW quantity (ton)*

*Treatment cost for separated organic waste (BTF aerobic) (€) = Treatment cost (€/ton) * Separated organic waste (ton)*

*Treatment cost for separated organic waste (BTF anaerobic) = Treatment cost (€/ton) * Separated organic waste (ton)*

*Treatment cost for separated materials, e.g. plastics, glass, etc. (MRF) (€) = Treatment cost (€/ton) * Separated materials (ton)*

The revenues are estimated by multiplying the waste 'products' (e.g. electricity, recyclables, etc.) by the respective price.

The net costs are calculated by subtracting the revenues from the costs, i.e.:

Net cost for mixed waste (€) = Total cost for mixed waste (€) – Revenues for mixed waste (€)

Net cost for separated waste (€) = Total cost for separated waste (€) – Revenues for separated waste (€)

Net cost for total waste (€) = Total cost for total waste (€) – Revenues for total waste (€)

The net cost per kg of waste is given by:

Net cost for mixed waste per kg (€/kg) = Net cost for mixed waste (€) / Mixed MSW quantity (kg)

Net cost for separated waste per kg (€/kg) = Net cost for separated waste (€) / Separated MSW quantity (kg)

Net cost for total waste per kg (€/kg) = Net cost for total waste (€) / Total MSW quantity (kg)

Finally, the net cost per household is calculated according to the following equation:

*Net cost per household (€) = Net cost for mixed waste per kg (€/kg) * Mixed MSW quantity per household (kg) + Net cost for separated waste per kg (€/kg) * Separated MSW quantity per household (kg)*

Based on the results for the net cost per household, the Mayor must define the Municipal fees to be charged to each household. The Mayor's fees policy has great degrees of freedom, as long as the total fees cover the total net cost of MSW management (an example is given in a following section).

3.2.3. Main assumptions

In order to conduct the calculations, the following technical and financial assumptions were taken into consideration. The assumptions were based on data retrieved by scientific and gray literature (e.g. (Arcadis & Eunomia, 2010; Hogg, n.d.; Lasaridi et al., 2006; Seruga et al., 2020; Velis et al., 2010), as well as the waste management experts that participate in the BlockWaste project.

A. Technical assumptions

The technical assumptions are related to the recovery of materials from the MBT facility, the conversion factors for the production of biogas and electricity from the anaerobic treatment of organics in MBT and BTF and the recovery of materials from the MRF plan.

The technical assumptions are presented in the following tables.

Table 2. Technical assumptions for the aerobic MBT

Products from MBT (aerobic)	Recovery factors
Recyclables	
- Paper (kg)	56%
- Plastics (kg)	59%
- Metal (kg)	95%
- Glass (kg)	90%
- Other (kg)	50%
CLO (kg) for landfill cover or soil restoration	52%
RDF (kg) for energy production	15%
Losses	20%

Table 3. Technical assumptions for the anaerobic MBT

Products from MBT	Recovery factors
Recyclables	
- Paper (kg)	56%
- Plastics (kg)	59%
- Metal (kg)	95%
- Glass (kg)	90%
- Other (kg)	50%
Biogas (m^3)	105 m^3/ton
Electricity (kWh)	150.4 kWh/ton
CLO (kg) for landfill cover or soil restoration	31%
RDF (kg) for energy production	15%
Losses (kg)	25%

Table 4. Technical assumptions for the aerobic BTF

Organics from separated waste	Recovery factors
Compost	55%
Losses	45%

Table 5. Technical assumptions for the anaerobic BTF

Organics from separated waste	Recovery factors
Biogas (m^3)	110 m^3/ton
Electricity (kWh)	240 kWh/ton
Compost	16%

As far as the Materials Recovery Facility (MRF) is concerned, a recovery factor of 100% is assumed provided that the materials are collected from different bins.

B. Financial assumptions

The financial assumptions refer to MSW costs for collection, treatment and landfilling and revenues from selling electricity, recycled materials, compost, SRF and CLO. The produced RDF is assumed to be used for energy production, but its price is practically zero.

The following tables (Table 6 and Table 7) present the financial assumptions used for the calculations of the MSW Management Tool.

Table 6. Cost assumptions

Cost category	Cost (€/ton)
Collection cost - mixed waste	60
Collection cost - mixed recyclables	140
Collection cost - organics	80
Collection cost - paper	60
Collection cost - plastics	350
Collection cost - metals	150
Collection cost - glass	60
Collection cost - other recyclables	100
Landfilling cost	100
Composting	65
Anaerobic MBT	90
Aerobic MBT	70
Biodrying MBT	80
Anaerobic digestion	60
Sorting for mixed recyclables	180
Processing of separated waste	50

Table 7. Revenues assumptions

Revenues category	Revenues (€/ton and €/MWh for electricity)
Electricity (€/MWh)	129
Paper	100
Plastics	250
Metal	212.5
Glass	40
Other	20
Compost	20
SRF	25
CLO	1
RDF	0

Note: RDF is used for energy production but its price is 0

3.2.4. Outputs of the tool

The MSW Management Tool provides a wide range of technical and financial results. More specifically, the tool analyses the input and output of all treatment facilities, the collection, treatment and landfilling costs (for mixed, separated and total MSW), the revenues from different waste streams and products and the net costs (for mixed, separated and total MSW) for the total quantities, per kg of waste (for mixed, separated and total MSW) and per household. It should be noted that, for calculation purposes, the analysis is conducted by household. Nevertheless, the online MSW Management Tool presents only those results that would be available in a real case (e.g. total quantities of materials, total costs, cost per kg based on the total costs and total MSW quantities, etc.). For educational purposes, however,

an Excel file is provided as supporting material, which details all the calculations and offers the instructor and the class group the opportunity to experiment with various input data, as well as to formulate their own scenarios.

The following tables present, as an example, the output of S1. Aerobic MBT – Compost.

Table 8. Waste composition and collection per household

	Waste composition						Waste collection		
Households	**Organics (kg)**	**Paper (kg)**	**Plastics (kg)**	**Metal (kg)**	**Glass (kg)**	**Other (kg)**	**Mixed collected waste (kg)**	**Separated collected waste (kg)**	**Total waste collected (Kg)**
HH1	36.6	18.7	15.3	2.6	0.0	11.9	0.0	85.0	85.0
HH2	42.0	21.0	12.6	1.1	3.2	25.2	26.3	78.8	105.0
HH3	64.8	27.8	21.6	3.1	3.1	33.9	138.8	15.4	154.2
Totals	**143.3**	**67.5**	**49.5**	**6.7**	**6.2**	**71.0**	**165.0**	**179.2**	**344.2**

Table 9. Input for the aerobic MBT facility

	MBT (AEROBIC DIGESTION) - INPUT						
	From mixed waste						
Households	**Total waste (Kg)**	**Organics (kg)**	**Paper (kg)**	**Plastics (kg)**	**Metal (kg)**	**Glass (kg)**	**Other (kg)**
HH1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HH2	26.3	10.5	5.3	3.2	0.3	0.8	6.3
HH3	138.8	58.3	25.0	19.4	2.8	2.8	30.5
Totals	**165.0**	**68.8**	**30.2**	**22.6**	**3.0**	**3.6**	**36.8**

Table 10. Output from the aerobic MBT facility

	MBT (AEROBIC DIGESTION) - OUTPUT								
	From mixed waste								
Households	**Paper (kg)**	**Plastics (kg)**	**Metal (kg)**	**Glass (kg)**	**Other (kg)**	**CLO (kg)**	**RDF (kg)**	**Losses (kg)**	**Residues (kg)**
HH1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HH2	2.9	1.9	0.2	0.7	3.2	5.5	2.4	2.1	7.4
HH3	14.0	11.5	2.6	2.5	15.3	30.3	12.1	11.7	38.9
Totals	**16.9**	**13.3**	**2.9**	**3.2**	**18.4**	**35.8**	**14.4**	**13.8**	**46.3**

Table 11. Input and output for the aerobic BTF

	BIOWASTE TREATMENT FACILITY (AEROBIC) - INPUT	BIOWASTE TREATMENT FACILITY (AEROBIC) - OUTPUT	
	From separated organics		
Households	**Organics (kg)**	**Compost (kg)**	**Losses (kg)**
HH1	36.6	20.1	16.4
HH2	31.5	17.3	14.2
HH3	6.5	3.6	2.9
Totals	**74.5**	**41.0**	**33.5**

Table 12. Input and output for the Materials Recovery Facility

	MRF (MATERIALS RECOVERY FACILITY) / INPUT=OUTPUT				
	From separated waste				
Households	**Paper (kg)**	**Plastics (kg)**	**Metal (kg)**	**Glass (kg)**	**Other (kg)**
HH1	18.7	15.3	2.6	0.0	11.9
HH2	15.8	9.5	0.8	2.4	18.9
HH3	2.8	2.2	0.3	0.3	3.4
Totals	**37.2**	**26.9**	**3.6**	**2.7**	**34.2**

Table 13. Collection cost for mixed and separated waste (€/kg)

	Collection cost						
		Separated waste					
Households	**Mixed waste**	**Organics**	**Paper**	**Plastics**	**Metal**	**Glass**	**Other**
HH1	0.0	2.9	1.1	5.4	0.4	0.0	1.2
HH2	1.6	2.5	0.9	3.3	0.1	0.1	1.9
HH3	8.3	0.5	0.2	0.8	0.0	0.0	0.3
Totals	**9.9**	**6.0**	**2.2**	**9.4**	**0.5**	**0.2**	**3.4**

Table 14. Treatment cost for mixed and separated waste (€/kg)

	Treatment cost						
		Separated waste					
Households	**Mixed waste**	**Organics**	**Paper**	**Plastics**	**Metal**	**Glass**	**Other**
HH1	0.0	2.4	0.9	0.8	0.1	0.0	0.6
HH2	1.8	2.0	0.8	0.5	0.0	0.1	0.9
HH3	9.7	0.4	0.1	0.1	0.0	0.0	0.2
Totals	**11.6**	**4.8**	**1.9**	**1.3**	**0.2**	**0.1**	**1.7**

Table 15. Landfill and total costs for mixed and separated waste (€/kg)

	Landfill cost	**Total cost**	**Total cost**	**Total cost**
		Mixed waste	**Separated waste**	**Total waste**
Households				
HH1	0.0	0.0	15.8	15.8
HH2	0.7	4.2	13.3	17.5
HH3	3.9	21.9	2.7	24.6
Totals	**4.6**	**26.1**	**31.8**	**57.9**

Table 16. Revenues from mixed waste (€/kg)

	Revenues from Mixed waste						
Households	**Paper**	**Plastics**	**Metal**	**Glass**	**Other**	**CLO**	**RDF**
HH1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HH2	0.3	0.5	0.1	0.0	0.1	0.0	0.0
HH3	1.4	2.9	0.6	0.1	0.3	0.0	0.0
Totals	**1.7**	**3.3**	**0.6**	**0.1**	**0.4**	**0.0**	**0.0**
						Total revenues from mixed waste	**6.2**

Table 17. Revenues from separated waste (€/kg)

	Revenues from Separated waste					
Households	**Compost**	**Paper**	**Plastics**	**Metal**	**Glass**	**Other**
HH1	0.4	1.9	3.8	0.5	0.0	0.2
HH2	0.3	1.6	2.4	0.2	0.1	0.4
HH3	0.1	0.3	0.5	0.1	0.0	0.1
Totals	**0.8**	**3.7**	**6.7**	**0.8**	**0.1**	**0.7**
					Total revenues from separated waste	**12.8**

Table 18. Net cost (€) per kg for mixed, separated and total waste

Net cost of mixed waste per kg	Net cost of separated waste per kg	Net cost of total waste per kg
0.121	0.106	0.113

Table 19. Total revenues and net costs (€/kg)

	Total revenues	Net cost	Net cost	Net cost	Net cost for municipality
		Mixed waste	Separated waste	Total waste	per household
Households					
HH1	6.9	0.0	8.9	8.9	9.0
HH2	5.8	3.2	8.4	11.7	11.5
HH3	6.3	16.7	1.7	18.3	18.4
Totals	**19.0**	**19.9**	**19.0**	**38.9**	**38.9**

3.3. Detailed description of the roles

3.3.1. Starting the game

The game is available at https://game.blockwasteproject.eu/. To provide more flexibility, the game includes five different slots, which allow five different teams to play simultaneously. In order to start a game, the player who is assigned with the role of the Mayor needs to enter first in s free slot (Figure 20). After that, the rest players must enter the same slot. The total number of players who can act as 'households' is 30. Therefore, prior to starting the game each player needs to be assigned to a unique number between 1 and 30.

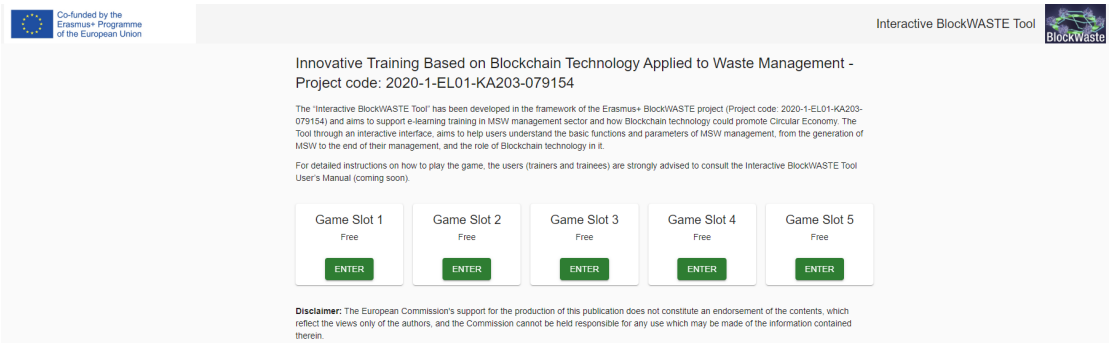


Figure 20: The game's home screen

3.3.2. Households

Once the 'household' players enter the slot,

After login, the user clicks on the "Add data" button and the window expands (Figure 21), allowing the player to specify the following information:

- Household members
- MSW generation per capita and year
- Composition of household's MSW
- Time spent on sorting waste (in minutes per week)
- Month of the year

After entering the data, the user must click the "Submit" button to submit it. The game always starts with the first month of the year (i.e. January) unlocked. The next month is automatically unlocked when the player receives the previous month's municipal fees from the Mayor.

Figure 21. The "Add data" window

However, to submit the data the user has to solve a short - and simplified – Blockchain problem, i.e. to find a suitable nonce that will calculate a hash which can be equally divisible by 3 (Figure 22).

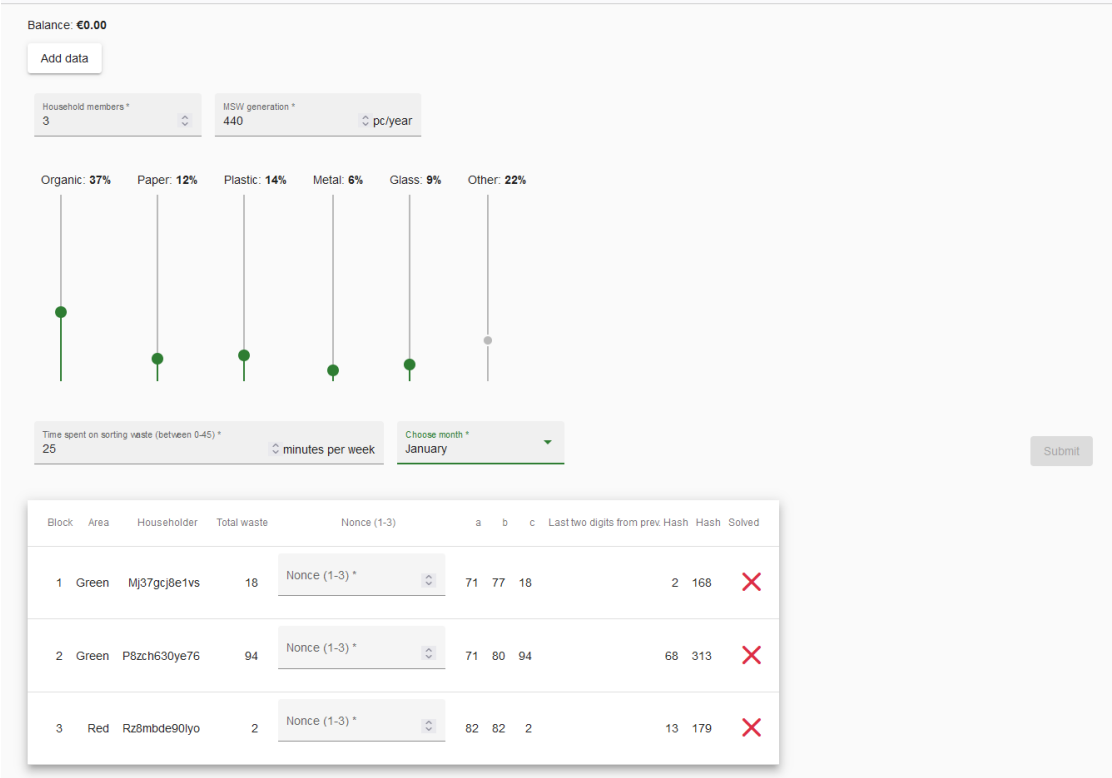


Figure 22: The simplified Blockchain problem

When the problem is successfully solve, the "Submit" button becomes green and the user is ready to submit the data to the 'Mayor' ().

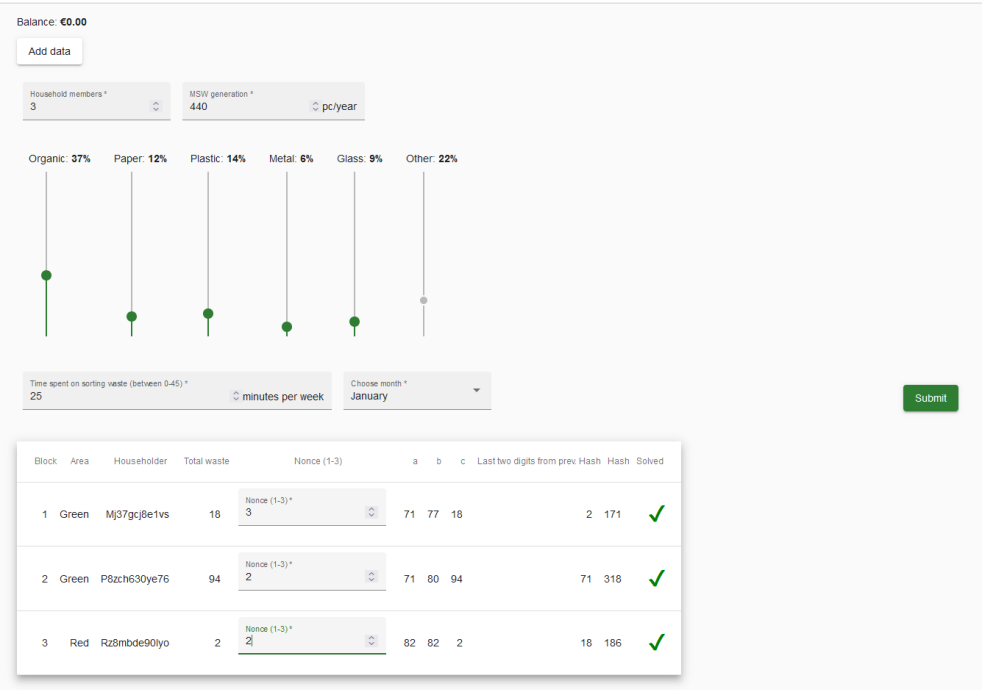
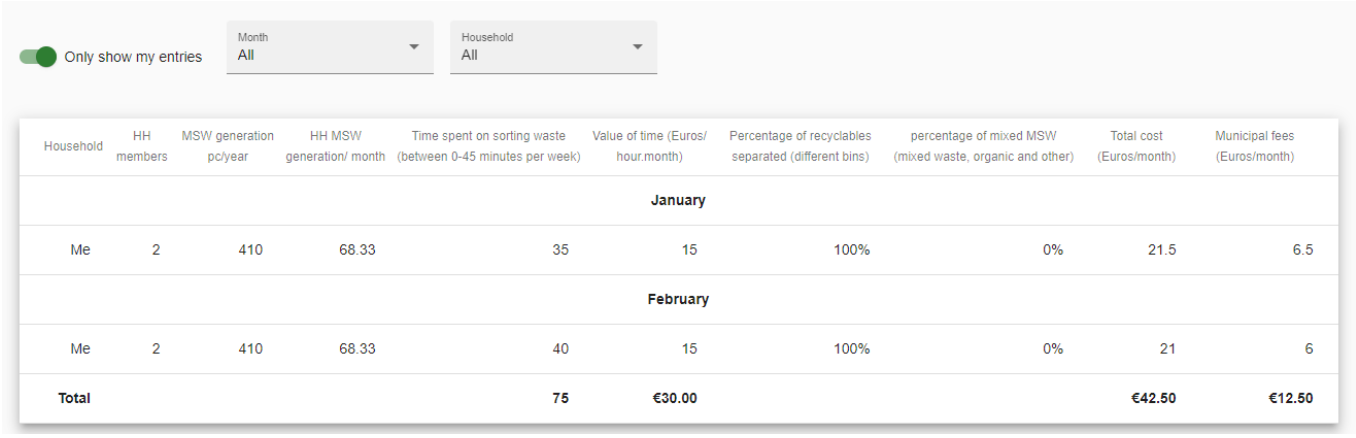


Figure 23: View of a solved Blockchain problem that allows for the submission of the data

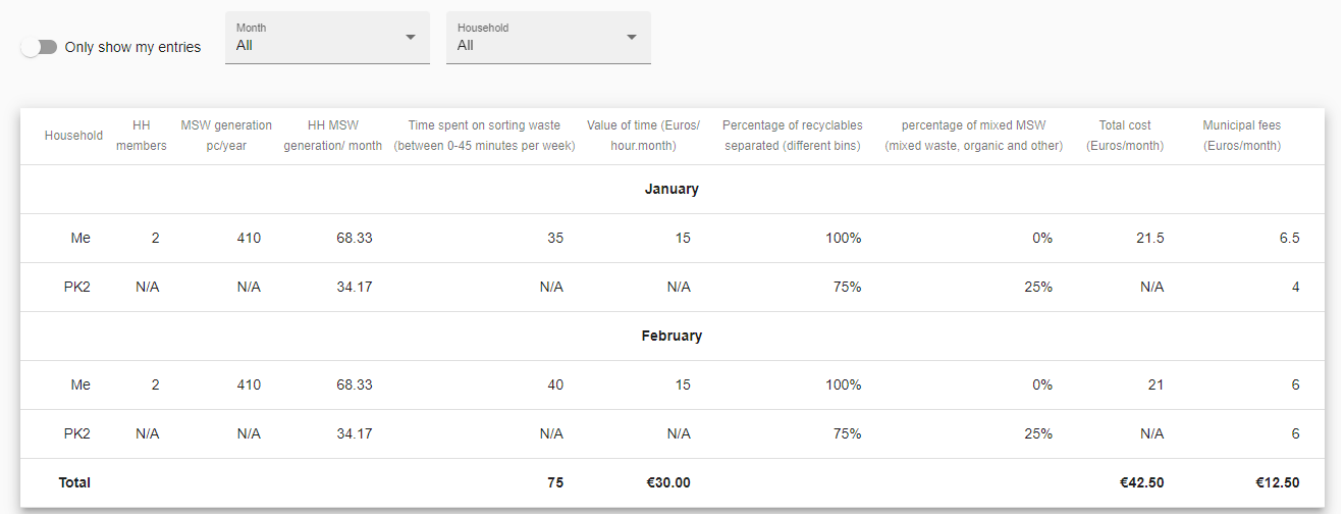
After submitting the data, the user will receive the municipal fees (as defined by the Mayor) and will be presented with her/his total cost (i.e. the value of time spent on sorting the waste plus the municipal fees).

As the game progresses, the user has the ability to monitor the results of the previous months for her/his household (Figure 24) or for all the households participating in the game (Figure 25) (without knowing however the true identity of the other players or other 'sensitive' data, e.g. the number of household members, the MSW generation per capita, etc.).



Household	HH members	MSW generation pc/year	HH MSW generation/ month	Time spent on sorting waste (between 0-45 minutes per week)	Value of time (Euros/ hour.month)	Percentage of recyclables separated (different bins)	percentage of mixed MSW (mixed waste, organic and other)	Total cost (Euros/month)	Municipal fees (Euros/month)
				January					
Me	2	410	68.33	35	15	100%	0%	21.5	6.5
				February					
Me	2	410	68.33	40	15	100%	0%	21	6
Total				**75**	**€30.00**			**€42.50**	**€12.50**

Figure 24. The results window (only for player's entries)



Household	HH members	MSW generation pc/year	HH MSW generation/ month	Time spent on sorting waste (between 0-45 minutes per week)	Value of time (Euros/ hour.month)	Percentage of recyclables separated (different bins)	percentage of mixed MSW (mixed waste, organic and other)	Total cost (Euros/month)	Municipal fees (Euros/month)
				January					
Me	2	410	68.33	35	15	100%	0%	21.5	6.5
PK2	N/A	N/A	34.17	N/A	N/A	75%	25%	N/A	4
				February					
Me	2	410	68.33	40	15	100%	0%	21	6
PK2	N/A	N/A	34.17	N/A	N/A	75%	25%	N/A	6
Total				**75**	**€30.00**			**€42.50**	**€12.50**

Figure 25. The results window (showing the results for all players)

The game ends when receiving the municipal fees for the last month of the year (i.e. December).

3.3.3. Mayor

After entering the slot, the user who's assigned with the role of the 'Mayor' has to choose one out of the four alternative MSW management scenarios and then click "Proceed" (Figure 26).

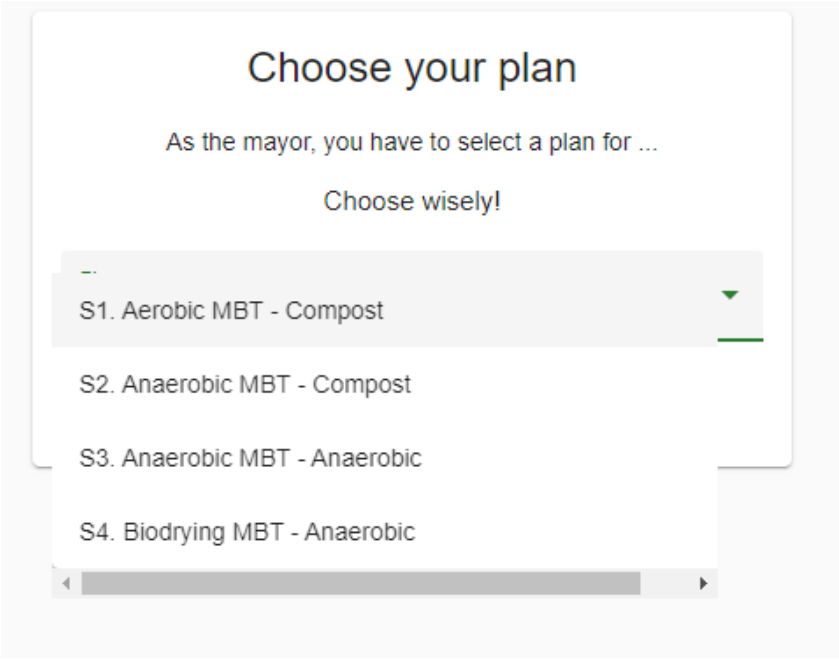


Figure 26. The selection of MSW management plan window

Then the user is directed to a new window showing the entries of the participating households (Figure 27). The information provided is, as follows:

- Mixed, separated and total waste collected (i.e. generated) by each household and
- Net cost for the Municipality per household

It should be highlighted that the 'Mayor' before proceeding with the calculation of the fees must wait for all households to respond.

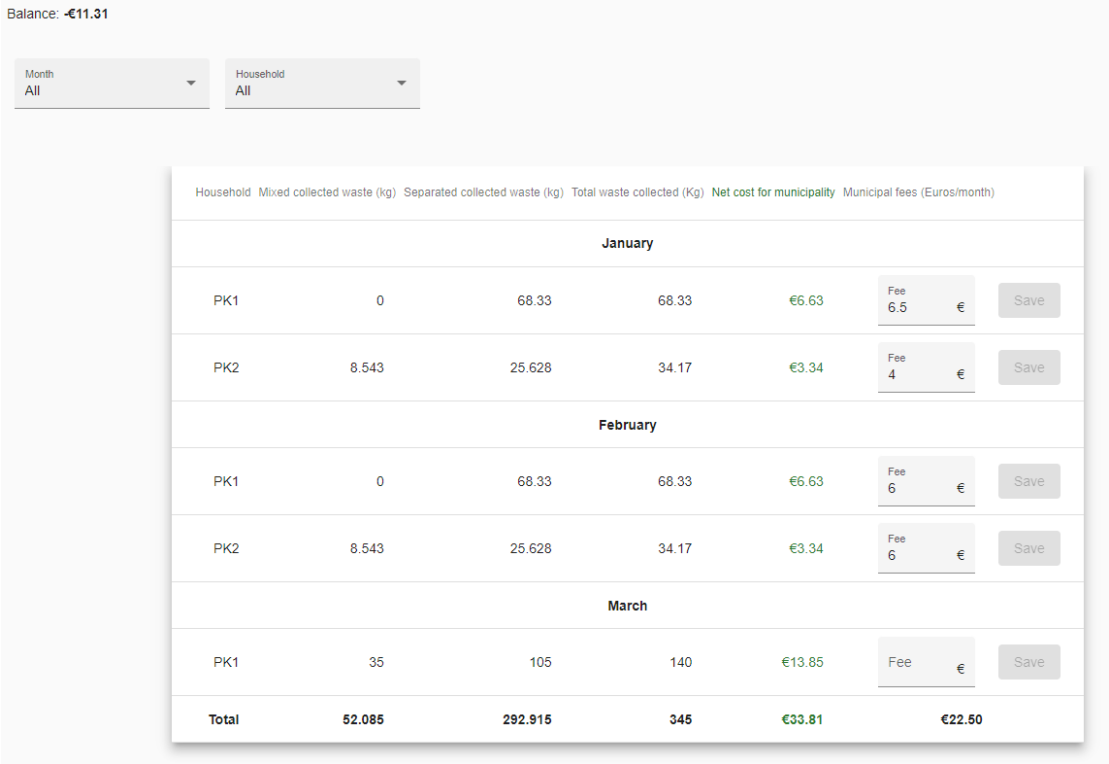


Figure 27. The 'basic' information window where the used defines the municipal fees

Based on the net cost for the municipality per household, the 'Mayor' will select an appropriate municipal fee. The only rule that should be followed is that the "Balance" for the Municipality cannot be negative (i.e. the user cannot create a financial deficit). Apart from that, the user is totally free to select her/his own strategy. For example, suppose that the 'Mayor' wishes to offer a discount of 10% to the households that recycle at a rate of 100%. The net cost for total waste per kg is calculated according to the following equation:

Net cost for total waste per kg (€/kg) =

Net cost for total waste (€) / Total MSW quantity (kg) =

*[Net cost for mixed waste per kg (€/kg) * Total mixed MSW (kg) + Net cost for separated waste per kg (€/kg) * Total separated MSW] / Total MSW (kg)*

The 'Mayor' knows the total Net cost for mixed waste per kg (€/kg), the total Net cost for separated waste per kg (€/kg) and the total Net cost for mixed waste per kg (€/kg) as well as the total mixed and separated quantities of waste.

Let's assume that the above figures are, as follows

- Net cost for mixed waste per kg (€/kg): 0.121
- Net cost for separated waste per kg (€/kg): 0.106
- Net cost for total waste per kg (€/kg): 0.113
- Total mixed MSW (kg): 165
- Total separated MSW (kg): 179.2
- Total MSW (kg): 344.2

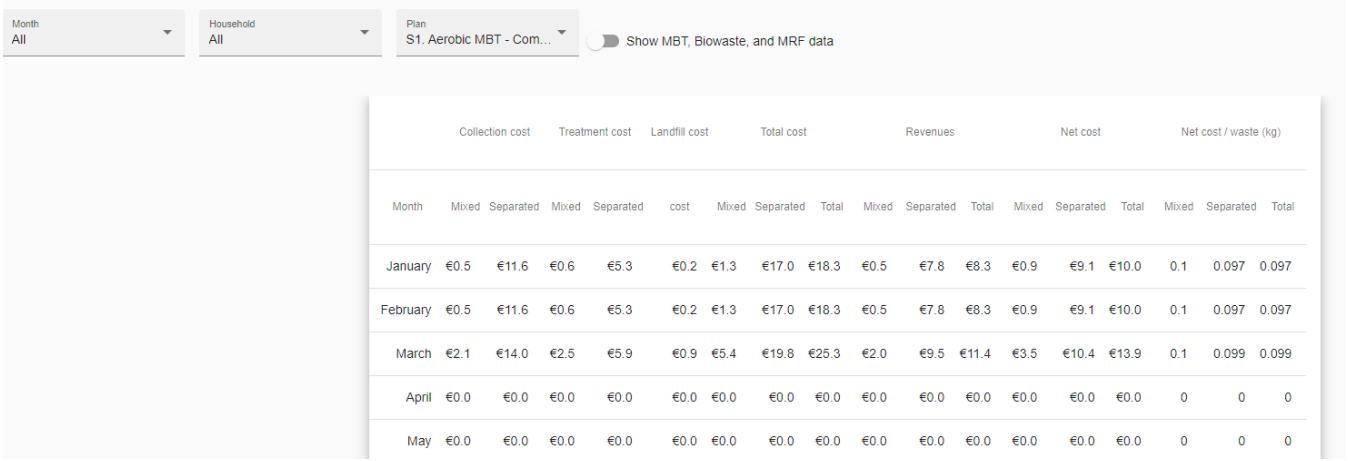
The discount of 10% will result in a municipal fee of for separated waste per kg (€/kg) equal to 0.095 (i.e. 90% * 0.106). In order to avoid the financial deficit, the 'Mayor' must increase the municipal fee for the mixed waste per kg to keep the Net cost for total waste per kg constant (i.e. 0.113 €/kg). The municipal fee for the mixed waste per kg can be calculated, as follows:

Net cost for mixed waste per kg (€/kg) =

*[Net cost for total waste per kg (€/kg) * Total MSW (kg) - Net cost for separated waste per kg (€/kg) * Total separated MSW] / Total mixed MSW (kg)*

Replacing the number of the example results in a Net cost for mixed waste per kg (€/kg) equal to 0.132 €/kg (i.e. there is an increase of 9.1%).

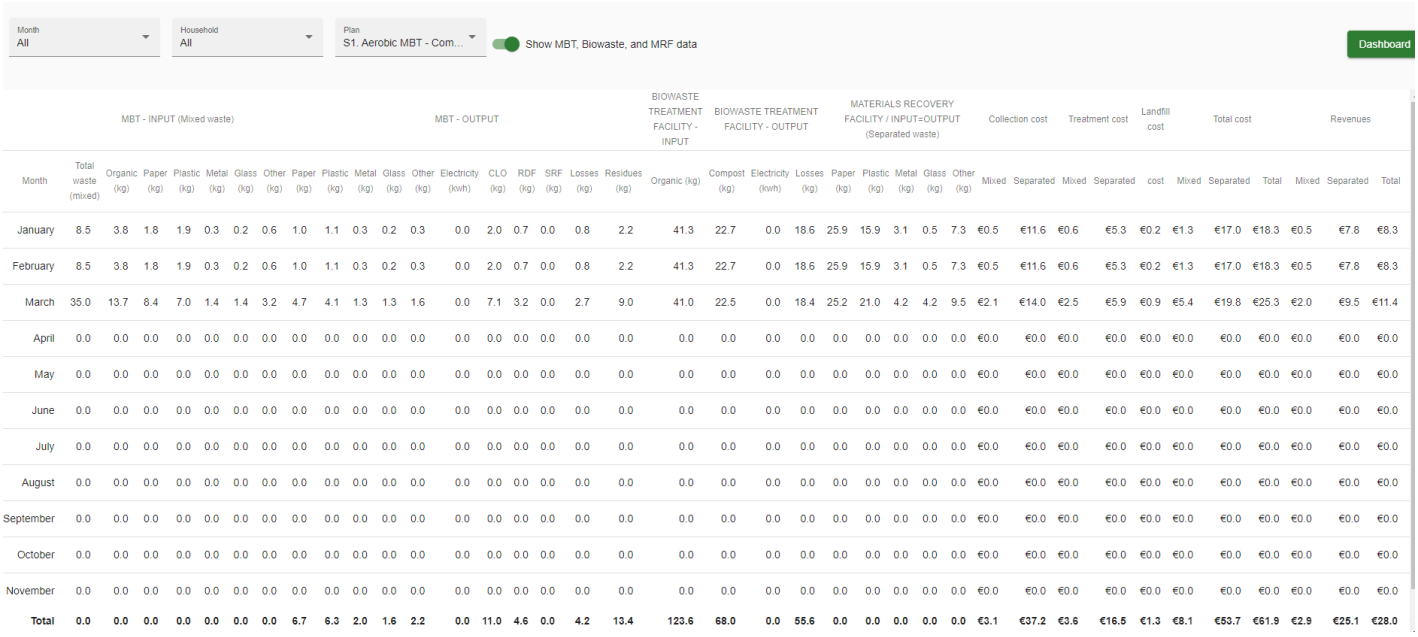
By pressing the "Report" button, the 'Mayor' is presented with further financial details (Figure 28).



	Collection cost		Treatment cost		Landfill cost	Total cost			Revenues			Net cost			Net cost / waste (kg)		
Month	Mixed	Separated	Mixed	Separated	cost	Mixed	Separated	Total	Mixed	Separated	Total	Mixed	Separated	Total	Mixed	Separated	Total
January	€0.5	€11.6	€0.6	€5.3	€0.2	€1.3	€17.0	€18.3	€0.5	€7.8	€8.3	€0.9	€9.1	€10.0	0.1	0.097	0.097
February	€0.5	€11.6	€0.6	€5.3	€0.2	€1.3	€17.0	€18.3	€0.5	€7.8	€8.3	€0.9	€9.1	€10.0	0.1	0.097	0.097
March	€2.1	€14.0	€2.5	€5.9	€0.9	€5.4	€19.8	€25.3	€2.0	€9.5	€11.4	€3.5	€10.4	€13.9	0.1	0.099	0.099
April	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	0	0	0
May	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	0	0	0

Figure 28. The expanded financial information window

Also, by activating the option "Show MBT, Biowaste and MRF data", the 'Mayor' will receive additional data regarding the material flows (input and output) in the different treatment facilities (Figure 9). Also, the tool provides the opportunity to export the detailed results to a csv file for further processing.



	MBT - INPUT (Mixed waste)								MBT - OUTPUT									BIOWASTE TREATMENT FACILITY - INPUT	BIOWASTE TREATMENT FACILITY - OUTPUT			MATERIALS RECOVERY FACILITY / INPUT=OUTPUT (Separated waste)					Collection cost		Treatment cost		Landfill cost	Total cost			Revenues		
Month	Total waste (mixed)	Organic (kg)	Paper (kg)	Plastic (kg)	Metal (kg)	Glass (kg)	Other (kg)	Paper (kg)	Plastic (kg)	Metal (kg)	Glass (kg)	Other (kg)	Electricity (kwh)	CLO (kg)	RDF (kg)	SRF (kg)	Losses (kg)	Residues (kg)	Organic (kg)	Compost (kg)	Electricity (kwh)	Losses (kg)	Paper (kg)	Plastic (kg)	Metal (kg)	Glass (kg)	Other (kg)	Mixed	Separated	Mixed	Separated	cost	Mixed	Separated	Total	Mixed	Separated	Total
January	8.5	3.8	1.8	1.9	0.3	0.2	0.6	1.0	1.1	0.3	0.2	0.3	0.0	2.0	0.7	0.0	0.8	2.2	41.3	22.7	0.0	18.6	25.9	15.9	3.1	0.5	7.3	€0.5	€11.6	€0.6	€5.3	€0.2	€1.3	€17.0	€18.3	€0.5	€7.8	€8.3
February	8.5	3.8	1.8	1.9	0.3	0.2	0.6	1.0	1.1	0.3	0.2	0.3	0.0	2.0	0.7	0.0	0.8	2.2	41.3	22.7	0.0	18.6	25.9	15.9	3.1	0.5	7.3	€0.5	€11.6	€0.6	€5.3	€0.2	€1.3	€17.0	€18.3	€0.5	€7.8	€8.3
March	35.0	13.7	8.4	7.0	1.4	1.4	3.2	4.7	4.1	1.3	1.3	1.6	0.0	7.1	3.2	0.0	2.7	9.0	41.0	22.5	0.0	18.4	25.2	21.0	4.2	4.2	9.5	€2.1	€14.0	€2.5	€5.9	€0.9	€5.4	€19.8	€25.3	€2.0	€9.5	€11.4
April	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0
May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0
June	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0
July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0
August	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0
September	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0
October	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0
November	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0	€0.0
Total	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**6.7**	**6.3**	**2.0**	**1.6**	**2.2**	**0.0**	**11.0**	**4.6**	**0.0**	**4.2**	**13.4**	**123.6**	**68.0**	**0.0**	**55.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**€3.1**	**€37.2**	**€3.6**	**€16.5**	**€1.3**	**€8.1**	**€53.7**	**€61.9**	**€2.9**	**€25.1**	**€28.0**

Figure 29. The detailed technical and financial window

3.4. Basic instructions on how to play

3.4.1. Playing the game

The instructor needs first to provide a short description of the scenario and then assign the roles to the players (one Mayor and the households). They players may be given specific instructions on how to act, or may be asked to act in their own self-interest. It is important to make it clear that everyone's contribution is valuable in the game and that there is no judging. Also, it's important to define a time limit (the game can last from 15 minutes to 30 minutes, depending on the skills being practiced) and the level of participants' skills. If, however, the learning objectives require calculations then more time may be required. Finally, if the instructor perceives that the participants are having difficulties and get stuck or the show inattention, it is fine to stop the role play and call a time out. In order to start the game the instructor distributes to the players, depending on their role, the accounts that have been pre-built.

3.4.2. After playing the game

After the end of the game start a discussion. The instructor and the participants can discuss the game, e.g. what strategy they followed, what was effective from a learning point of view, etc. To facilitate the discussion the instructor may also ask some general or specific questions, such as:

- What were their concerns as regards their roles?
- Did they change their strategy as the game progressed based on the results they received?
- Were they affected by what other households did?

- What was the most important issue for them towards selecting a specific strategy (e.g. maximisation of environmental benefits, minimisation of cost, etc.)?

It's also useful to provide some concluding remarks at the close of the session (e.g. summarise again the aim of the game, present your viewpoint about the success of the game, etc.).

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