CIRCULAR ECONOMY TRANSITION GAME FINAL WSV REPORT

Circular Economy Transition Game – Final Report

The progress report about the game was submitted on June 2021. This final report builds upon the documents provided with the progress report and represents the final version of the game.

The game took place on December 2021 in the CET minor in an MS Teams environment as an Excel game with success. The instructions for the Excel environment is provided in Appendix 1. The students' feedback on the game and suggested improvement strategies are summarized in Appendix 2.

The developments on the interface being improved by the BMS Lab are reported in Appendix 3. As a part of the long term planning, these improvements will be addressed during three years.

1. Short game description

The game has a simple story line developed in the fictitious Circular Economy Transition (CET) City. CET City is composed of **houses**, **companies**, and **municipality**. Citizens living in houses sustain their lives via working in companies and have different lifestyles with different consumption patterns. Houses are two types: the ones in the urban area and the ones in the rural area. Companies are also two types: the product companies and the service companies, each producing a final product or service via adopting a **technology** that uses **resources** from the **resource bank** and emits **wastes** into the **waste bank**. Resource bank provides **materials**, **energy**, and **water** to companies while waste bank receives **material wastes**, **air emissions**, and **wastewater** from companies (Figure 1). Furthermore, resource bank provides energy to houses and waste bank receives air emissions from houses (Figure 2). Municipality has the role of regulation-making via imposing taxes or providing subsidies to companies or houses.

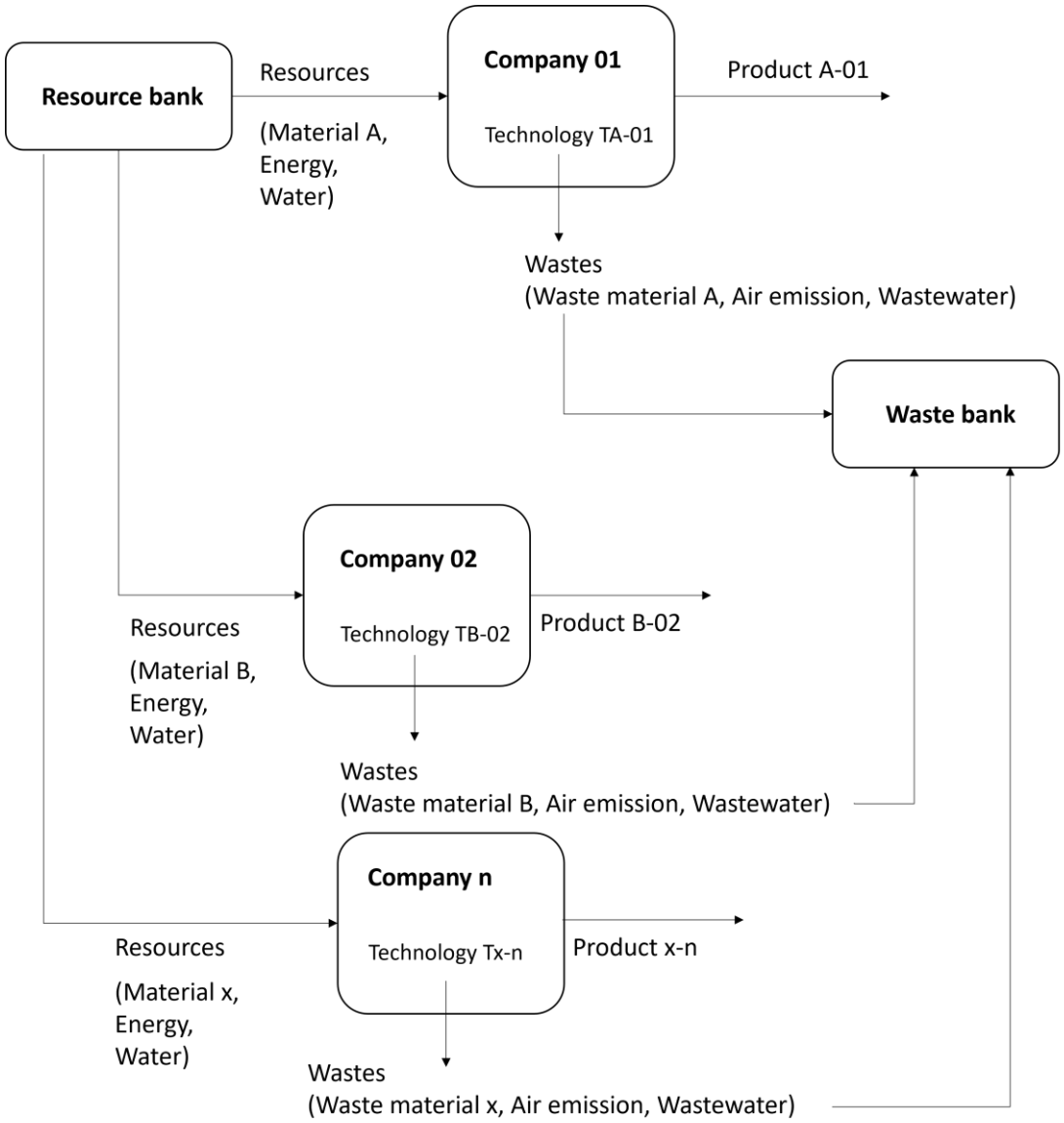

Figure 1. The game set-up for companies

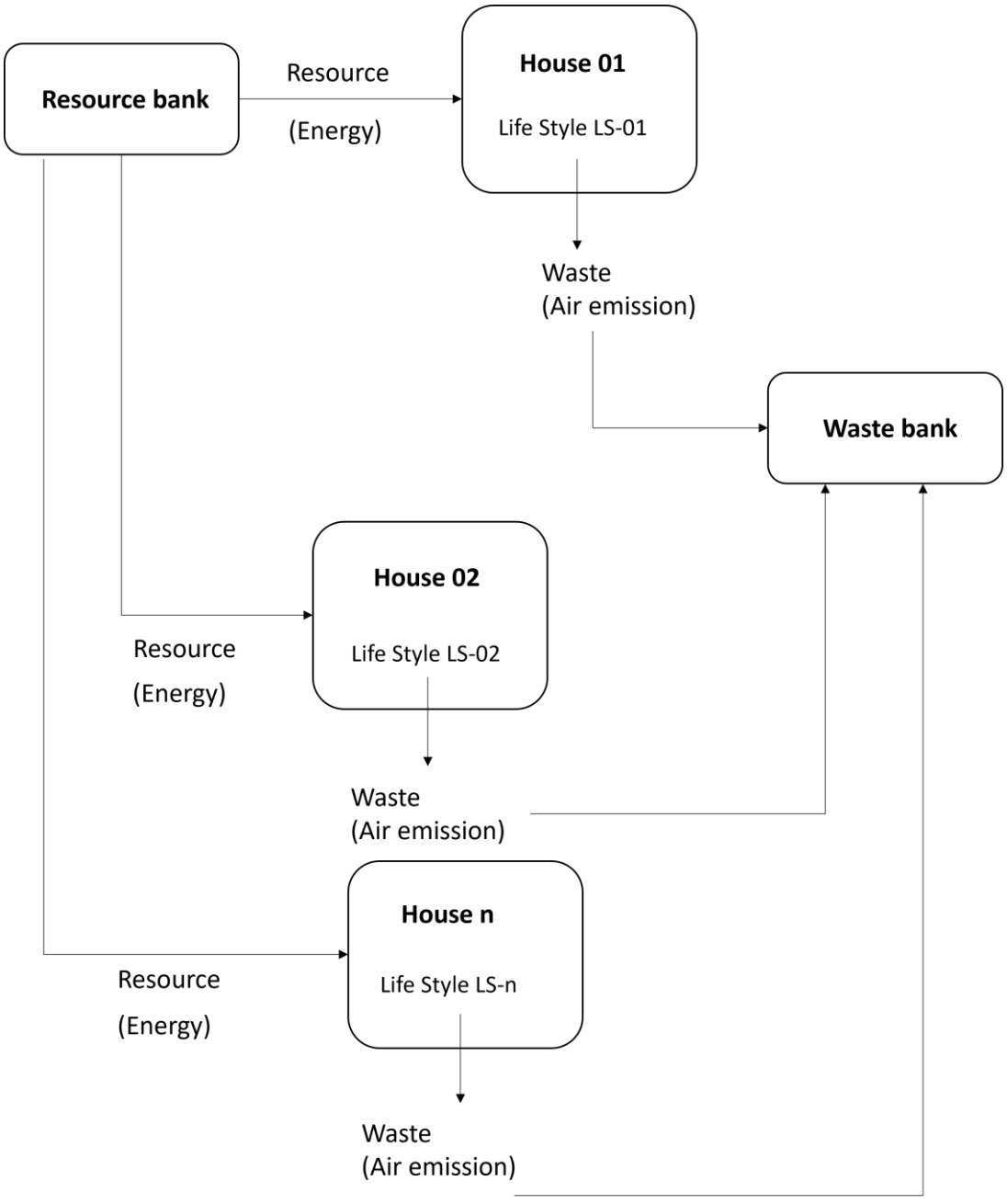

Figure 2. The game set-up for houses

2. The challenge and the goals of the game

Challenge: The game is played over four rounds during which a total number of 10 questions are directed to all groups (2 years of game time pass between two consecutive rounds). However, resource bank provides limited amounts of resources which are not sufficient for companies to run their businesses and for households to keep the consumption at the current level without applying changes for the entire four rounds. The same applies also to the waste bank which has limited waste capacity, less than the total waste emissions of all households and companies at their initial state for the entire four rounds. So, companies and houses are expected to take 'circular actions' during the game and keep the resources in the 'loop' in order to sustain their main business and not to let the resource bank and waste bank bankrupted. Actions are taken based on 10 questions from the game master.

Goals:

The ultimate **collective goal** of the game is that companies run their businesses and households continue their lives without the resource bank and waste bank becoming bankrupt.

The **individual goal of the game for each company** is that it is capable of continuing its production/service activities by consuming minimum resources, emitting minimum wastes, and having maximum profit (measured as a ratio of company revenues).

The **individual goal of the game for each household** is that they are capable of sustaining their life by consuming minimum energy, emitting minimum air emissions, and having maximum household savings (measured as a ratio of household income).

3. Players

Students are split in 12 groups, each composed of four or five students. Each group holds the responsibility of two houses (one rural houses and one urban house) and two companies (one product company and one service company). It is assumed that one house hypothetically represents 1000 houses (that is why the consumption of some houses is higher than some companies). It is also assumed that people living in these houses are also the managers of the product company and the service company. In addition, each group is assumed to have one representative in the municipality council who can vote for regulations. Municipality actions are taken collectively (for a regulation to be changed, 7 out of 12 votes are necessary). Table 1 displays the groups' role distribution for an **exemplary** game of four groups.

Groups	Houses in Rural areas	Houses in Urban areas	Product companies	Service companies	Municipality
Red	Rur house 01	Urb house 01	Pro company 01	Ser company 01	Mun 01
Orange	Rur house 02	Urb house 02	Pro company 02	Ser company 02	Mun 02
Yellow	Rur house 03	Urb house 03	Pro company 03	Ser company 03	Mun 03
Green	Rur house 04	Urb house 04	Pro company 04	Ser company 04	Mun 04

Table 1. Exemplary groups role distribution

4. Game set-up for companies

Each company initially uses a **technology** that consumes a specific type of **material**, **energy**, and **water**, in order to produce its product or service. Depending on its efficiency, the technology causes **material waste**, **air emissions**, and **wastewater**. Each type of technology might bring in a **subsidy** (as an income) for the company using it or might take away a **tax** (as a cost) from the company using it. Each technology represents an **investment cost** for the related company. Data, related to each type of technology, is provided in the **exemplary inventory of technologies** (Table 2). Data type for each technology is explained with the example of Technology TA-01 in Figure 3. Data related to each technology are **given values** in the inventory of technologies**. The groups will receive a game data sheet with all the given data.**

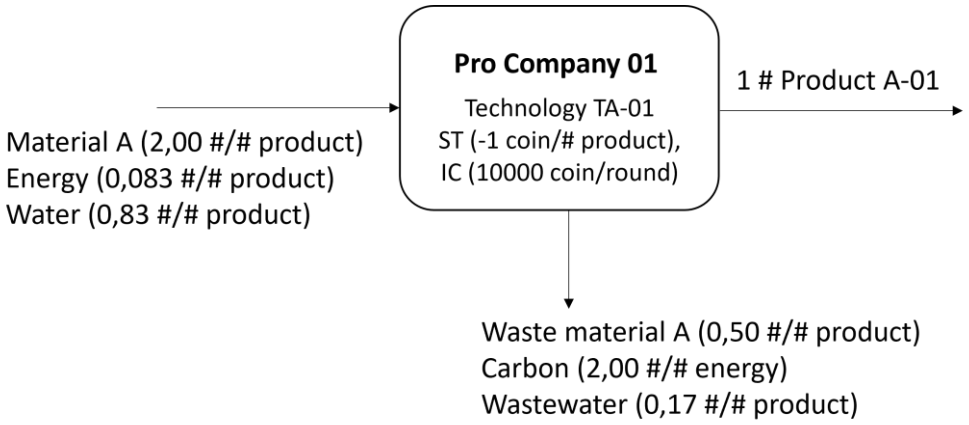

Figure 3. Components of a technology

Coefficient	Material coefficient	Energy coefficient	Water coefficient	Waste Material coefficient	Carbon coefficient	Wastewater coefficient	Subsidy/tax coefficient	Investment cost/ round
Technologies	M-cof (#/#)	E-cof (#/#)	W-cof (#/#)	WAM-cof (#/#)	C-cof (#/# energy)	WW-cof (#/#)	ST-cof (coin/#)	IC (coin/round)
TA-01	2,00	0,083	0,83	0,50	2,00	0,17	-1	10000
TB-01								
TC-01								
TD-01								
TA-02								
TB-02								
TC-02								
TD-02								
TA-03	1,50	0,167	0,00	0,50	0,50	0,00	10	40000
TB-03								
TC-03								
TD-03								
TA-04								
TB-04								
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TB-07								
TC-07								
TD-07								
TA-08								
TB-08								
TC-08								
TD-08								

Table 2. Inventory of technologies (empty cells are given filled in the Excel game data sheet)

Each company produces only one type of product/service. **The amount of the product/service and its unit sales price are given fixed values to companies** (Table 3).

Companies	**Produces and sells product/service**	**Unit sale price of product/service (coins)**	**Total amount of product/service (#/round)**
Pro company 01	Pro-A-01	200	1200
Pro company 02	Pro-B-02		
Pro company 03	Pro-C-03		
Pro company 04	Pro-D-04		
Ser company 01	Ser-A-01	400	250
Ser company 02	Ser-B-02		
Ser company 03	Ser-C-03		
Ser company 04	Ser-D-04		

Table 3. Unit sale prices and total amount of products or services (empty cells are given filled in the Excel game data sheet)

Figure 3 is explained as the following. **Production Company 1** (sketched as Pro Company 01) belonging to the Red group uses the **technology TA-01**, i.e., type#1 of technology **using Material A** in the production of Product A-01, i.e., product type **A produced by Pro Company 01**. In order to produce one unit of Product A-01, the TA-01 consumes 2 units of Material A (i.e., **Material Coefficient**), 0,083 units of energy (i.e., **Energy Coefficient**), and 0,83 units of water (i.e., **Water Coefficient**). Similarly, in order to produce one unit of Product A-01, the TA-01 causes 0,50 units of Waste Material A emission (i.e., **Waste Material Coefficient**) and 0,17 units of wastewater emission (i.e., **Waste Water Coefficient**). In the use of TA-01, the consumption of one unit of energy causes 2 units of carbon emission (i.e., **Carbon coefficient**). The use of the technology TA-01 in order to produce one unit of Product A-01 is taxed by the government by -1 coin/# product (i.e. **Subsidy/tax coefficient**, note: subsidy/tax coefficient is a positive value if the technology receives a subsidy from the government, it is a negative value if it is taxed by the government). Finally, the use of TA-01 has an **investment cost** (i.e., IC) of 10000 coins/round. **Each technology has the above-mentioned parameters as given values in the inventory of technologies which will be provided in the Excel Game Datasheet**.

Each resource represents a **purchase cost,** and each waste emission represents a **discharge cost** displayed in Table 4 (all **given values**).

Resource or waste type	Unit purchase/discharge cost (coins/#)
MatA	50
MatB	
MatC	
MatD	
WasMatA	20
WasMatB	
WasMatC	
WasMatD	
Energy	120
Carbon	30
Water	5
Wastewater	2

Table 4. Unit resource purchase costs and unit waste discharge costs (empty cells are given filled in the Excel game data sheet)

Resource consumption and waste emission computations:

Production Company 01 consumes the following total amount of resources using TA-01:

Material A: 2 (# Mat A / # Pro-A-01)* 1200 (# Pro-A-01/round) = 2400 # Mat A/round

Energy: 0,083 (# energy / Pro-A-01) * 1200 (# Pro-A-01/round) = 100 # energy/round

Water: 0,83 (# water / Pro-A-01) * 1200 (# Pro-A-01/round) = 1000 # water/round

Production Company 01 causes the following total amount of waste emissions using TA-01:

Waste Material A: 0,50 (# WasMat A / # Pro-A-01)* 1200 (# Pro-A-01/round) = 600 # WasMat A/round

Carbon: 0,083 (# energy / # Pro-A-01) * 2 (# carbon / energy) * 1200 (# Pro-A-01/round) = 200 # carbon/round

Wastewater: 0,17 (# wastewater / # Pro-A-01) * 1200 (# Pro-A-01/round) = 200 # wastewater/round

Economic computations:

The total profit of a company is computed as the following:

TP = RE + ST – PC – DC – IC

where

TP is the total profit, **RE** is the revenues from product/service sales, **ST** is the subsidy or tax (negative value means tax and positive value means subsidy), **PC** is the resource purchase cost, **DC** is the waste discharge cost, and **IC** is the investment cost of technology.

Production Company 01 has the following economic computations:

RE = 1200 (# Pro-A-01/round) * 200 (coin/# Pro-A-01) = 240000 coins/round

ST = 1200 (# Pro-A-01/round) * -1 (coin/# Pro-A-01) = -1200 coins/round

PC = 2400 (# Mat A/round) * 50 (coin/# Mat A) + 100 (# energy/round) * 120 (coin/energy) + 1000 (# water/round) * 5 (coin/# water) = 137000 coins/round

DC = 600 (# WasMat A/round) * 20 (coin / # WasMat A) + 200 (# carbon/round) * 30 (coin/ #carbon) + 200 (# wastewater / round) * 2 (coin / # wastewater) = 18400 coins/round

IC = 10000 coins/round

TP = 240000 + (-1200) – 137000 – 18400 – 10000 = 73400

Percentage of the profit is then 73400/240000 = %31

5. Actions of companies and example questions

There are multiple types of individual company actions in the game such as technology replacement, new product design, new service design, waste recycling, etc. In this manual, in order to assist students with computations and in order not to reveal all questions before the game, only two example actions are provided: technology replacement and new product design.

5.1. Technology replacement

A company can switch from one technology type to another one in order to achieve resource or waste savings. Companies who are consuming a specific type of material can only switch in a technology type that uses that specific material. **So, a company can switch from TA to TA; from TB to TB, from TC to TC, or from TD to TD.** For example, switching from TA-01 to TA-05 is possible while switching from TA-01 to TB-01 is not possible. **Technology change does not influence the total amount of product or service sold per round. The price of the product or service does also not change. These two are given fixed values.**

Let's assume that Production Company 01 would like to switch from TA-01 to TA-03. Following Table 2, we are able to observe that there would be consequences of such a switch in terms of resource consumption and waste emissions (see the differences in resource and waste coefficients). In addition, in contrast to TA-01 taxed by the government, TA-03 is able to receive a subsidy from the government while its investment cost is higher than that of TA-01. **This is a trade-off to be observed by the company and accordingly it decides whether to switch the technology or not.**

Technologies	M-cof (#/#)	E-cof (#/#)	W-cof (#/#)	WAM-cof (#/#)	C-cof (#/# energy)	WW-cof (#/#)	ST-cof (coin/# product or service)	IC (coin/round)
TA-01	2,00	0,083	0,83	0,50	2,00	0,17	-1	10000
TA-03	1,50	0,167	0,00	0,50	0,50	0,00	10	40000

Example question from the game master: Thanks to technological innovations, in the market there are multiple available technologies which can produce your product or service. Do you want to replace your technology with another one?

a) No
b) Yes, switch to technology TA-03 (specific to example above)

If (a) is selected no change occurs in the company's excel page.

If (b) is selected, the game master processes the computations on behalf of the group in group's Excel file before the next round (official computation cells are locked in the Excel file for the groups).

5.2. New product design

A product company can make a new product design which can have different impacts on the technology parameters. Each design impact is provided in the exemplary inventory of new product design (Table 5), which are **applicable to all technologies**.

New Product Design	% of M-cof	% of E-cof	% of W-cof	% of WAM-cof	% of C-cof	% of WW-cof	% of ST-cof	IC (% of T's IC)
NP-01								
NP-02								
NP-03			-0,15					0,10
NP-04				-0,15				0,10
NP-05								
NP-06	-0,25					-0,15		0,10
NP-07								
NP-08								
NP-09								
NP-10								

Table 5. Inventory of new product design options (empty cells are given filled in the Excel game data sheet)

Let's assume that Product Company 01 is using TA-01 and tries to decide whether to make new product design NP-06. As shown below, NP-06 reduces material consumption and wastewater emission while it has an extra cost of investment. This is a trade-off to be observed by the company and accordingly it decides whether to make new product design or not.

Technologies	**M-cof (#/#)**	**E-cof (#/#)**	**W-cof (#/#)**	**WAM-cof (#/#)**	**C-cof (#/# energy)**	**WW-cof (#/#)**	**ST-cof (coin/#)**	**IC (coin/round)**
TA-01	2,00	0,083	0,83	0,50	2,00	0,17	-1	10000
NP-06	-0,25					-0,15		0,10
Impact of NP-06 on TA-01	2,00-(2,00*0,25) = 1,50					= 0,17-(0,17*0,15) = 0,14		10000+(10000*0,1)= 11000

Example question from the game master: The product design team of your company have been working on multiple product design since a long while. Now, they completed a number of newly designed product. Would you like to make a change in your existing product design via selecting one of the options provided by your design team?

a) No
b) Yes, switch to product design NP-06 (specific to example above)

If (a) is selected no change occurs in the company's excel page.

If (b) is selected, the game master processes the computations on behalf of the group in group's Excel file before the next round (official computation cells are locked in the Excel file for the groups).

6. Game set-up for houses

In the game, houses are represented by lifestyles of people living in the houses. Each lifestyle consists of five major consumption activities, namely, **space heating**, **water heating**, **electrical appliances use**, **cooking**, and **mobility**. A person living in a house is initially given the total hours spent for each of these consumption activities. Each activity has an **investment cost** and an **operational cost deriving from energy use and carbon emissions**. Each activity leads to different **energy consumption** and **carbon emission**, depending on its **efficiency** and **duration of use**. Activity efficiencies are given by **coefficients of energy consumption and carbon emission**. Besides, each alternative might bring in a **subsidy** depending on its efficiency. Information/data, related to each type of alternative, is provided in the inventory of lifestyle alternatives (Table 6). Data type for each alternative is explained with an example of Space-heating SH-01 in Figure 4. These data are **given values** in the inventory of lifestyle alternatives.

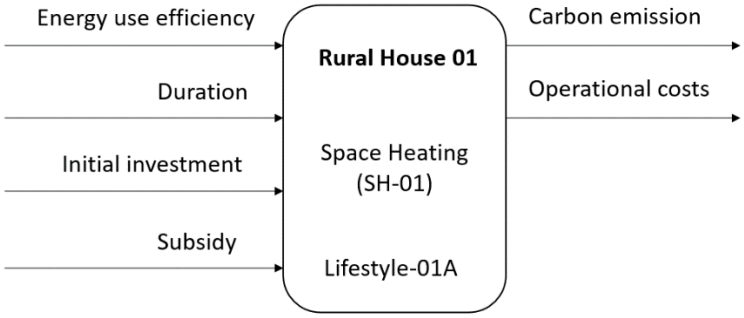

Figure 4. Components of a lifestyle alternative – space heating (same applies to other lifestyle alternatives of water heating, electrical appliances use, cooking, and mobility)

The total environmental and economic performance can be calculated by summing up the environmental and economic results of five alternatives based on operation duration. Specifically, the operational duration of each alternative ranges from minimum 1 to maximum 8 hours per day. **The sum of total hours dedicated to activities has a maximum value of 12 hours.** Each round is assumed to be 365 days. For all activities the unit energy cost is given by e, which is equal to 120 coins/# energy consumption and the carbon cost is given by **c**, which is equal to 30 coins/# carbon emission.

Space-heating	Energy coefficient (E)	Carbon coefficient (C)	Subsidy coefficient (S)	Investment cost (/round) (i)
SH-01	0,005	0,500	0,050	1000
SH-02				
SH-03				
SH-04				
SH-05				
SH-06				
Water heating				
WH-01				
WH-02				
WH-03				
WH-04				

WH-05				
WH-06	0,001	0,500	0,005	200
Electrical appliances				
EA-01				
EA-02				
EA-03	0,025	2,600	0,001	200
EA-04				
EA-05				
EA-06				
Cooking				
CO-01				
CO-02				
CO-03				
CO-04				
CO-05	0,005	0,050	0,050	1000
CO-06				
Mobility				
MO-01				
MO-02				
MO-03				
MO-04	0,200	0,500	0,050	500
MO-05				
MO-06				

Table 6. Inventory of lifestyle alternatives (empty cells are given filled in the Excel game data sheet)

Energy consumption and carbon emission computations are explained with an example of space heating in the rural house below.

Personas	**Lives in**	**Life Style**	**Space heating (SH)**	**Duration (D) SH**	**Energy use (#E)**	**C-eq emission (#C)**	**Operation cost (#O)**	**Subsidy SH (#S)**
Red-a	Rur house 01	LS-01A	SH-01	5	9,13	4,56	1232	62

Energy consumption and carbon emission computations:

The environmental performance is calculated based on energy and carbon emission coefficient of each alterative and operational duration. First of all, the energy use (***#E***) of space heating is computed as follows:

E*D*365 = #E_space heating

0,005*5*365 = 9,13 (example for Rural house 01)

where ***E*** denotes the energy use coefficient of the space heating system (SH-01), ***D*** stands for the operational duration of space heating, and 365 refers to the days that are accounted in one round.

Then, carbon emission (***#C***) is computed as follows:

E*C*D*365 = #C_space heating

0,005*0,500*5*365 = 4,56 (example for Rural house 01)

this computation is based on the energy use consumption where ***C*** denotes the carbon emission coefficient of the SH-01.

Therefore, the total energy use (***TE***) and total carbon emission (***TCE***) can be computed as:

#E _space heating + #E _water heating + #E _electrical appliances + #E _cooking + #E _mobility = TE

#C _space heating + #C _water heating + #C _electrical appliances + #C _cooking + #C _mobility = TCE

Economic computations:

In terms of economic results, the operational cost is computed based on the energy consumption and carbon emission. The total operational cost (***#O***) is computed by:

#O = #E*e + #C*c

Where ***e*** and ***c*** denote the unit costs of energy and carbon.

Then, the subsidy (***#S***) is computed by:

#S = S*i

Where ***S*** stands for the subsidy coefficient of applying such a kind of heating system, and ***i*** denotes the initial investment.

Therefore, the total cost of a lifestyle activity (***TC_space heating***) is:

TC_space heating = #O + i - #S

It simply stands for the sum of investment and operational costs minus the subsidy in each round.

Next, the total lifestyle cost (***TC***) of five alternatives can be summed up as:

TC = TC_space heating + TC_water heating + TC_electrical appliances + TC_cooking + TC_mobility

Finally, the total household saving (***TS***) is calculated by:

TS = TI – TC

where **TI** is the given value of total household income.

Below is an example of the final result of total household savings of a rural house.

Personas	**Lives in**	**Life Style**	**Total LifeStyle Cost (TC)**	**Total household income (given) (TI)**	**Total household savings (TS)**	**TS %**	**Total energy use (TE)**	**Total carbon emission (TCE)**
Red-a	Rur house 01	LS-01A	7510	12000	4490	37.41%	22.27	12.05

7. Actions of houses

There are multiple types of actions that houses can take such as change of lifestyle associated to each consumption activity. Instructions are given via each question you are going to receive from the game master.

8. Collaborative actions

Collaborative actions are categorized in three in the CET city: (i) government actions, (ii) neighbourhood actions, and (iii)) chamber of companies actions.

8.1. Government actions

Government actions have a direct influence on the companies and houses via the potential changes on subsidies or taxes for technologies and the changes on unit price of resources or unit cost of waste emissions. There are two types of governments in the game: 1- national government and 2- municipality. **The game master acts as the national government and has the right to make updates on these parameters in any moment during the game via announcements. Groups represent the municipality.** In a municipality meeting (where each group has the right of one vote), a discussion about the questions (previously sent by the game master) takes place in order to (or not to) make changes in these parameters. The municipality meeting takes place on the Elements of Environmental Economics class on 14 December Tuesday. The votes are closed, i.e., after the meeting each group provides its vote in the individual Excel file (you won't vote during the meeting but discuss about your opinions). In order a parameter to be changed, minimum 7 votes out of 12 are needed.

8.1.1. Unit Resource Price or Unit Waste Emission Cost Change

Both unit resource prices and unit waste emission costs contain taxes although they are just provided as one parameter each. Considering the situation in the performance dashboard of the entire CET City, the municipality can vote for changing these prices. If the majority approves a change, the change becomes effective starting by the next round of the game. Questions to be voted for are going to be provided to the city council by the game master beforehand.

8.1.2. Tax/Subsidy Change

Taxes or subsidies are given parameters associated to each technology in the beginning of the game. Municipality discusses to keep or change the taxes and subsidies associated to technologies and a voting takes place. If the majority approves a change, the change becomes effective starting by the next round of the game. Questions to be voted for are going to be provided to the municipality by the game master beforehand.

8.2. Neighbourhood actions

Neighbourhood actions can be only taken by houses and have an influence on the performance of houses and/or companies. The actions are categorized in two: (i) lifestyle change with direct influence on house performance and (ii) actions with direct impacts on house and company performance. Potential actions and associated consequences are provided to groups together with the questions from the game master.

8.3. Chamber of companies actions

Chamber of companies actions are company-collective actions. They might have direct consequences for the companies and/or houses via changes achieved in the resource bank and/or the waste bank. Questions from the game master are given together with actions and consequences.

9. Important remarks and technical issues

a) The official game starts on 10 December Friday and runs until 21 December Tuesday. The students should make sure to dedicate enough time to discuss the questions and provide their answers via their group's excel file according to the round deadlines. The week of 13-17 December will be intensive for the game play, please beer in mind.
b) The game is going to be played via Microsoft Teams in an Excel files provided to every group. Please make sure that you have a licensed Microsoft Teams and Excel loaded in your computers before the game starts. If there are any issues with access to Microsoft Teams, please contact r.kugis@student.utwente.nl immediately.
c) The game master is Rinalds Kugis, the teaching assistant of the module. Teachers of the module will have access to group files. Devrim Yazan, Luca Fraccascia, and Yifei Yu will be cross-checking the Excel files.
d) On 3 of December Friday, a presentation will be given by Rinalds Kugis about how to play the game in Excel. Furthermore, a trial of the game will take place via two example questions.
e) All groups are provided a game data sheet in which all commonly given values are provided (e.g., inventory of technologies, inventory of data related to questions to be received during the game, unit costs of resources and wastes).
f) All groups are provided group-specific given values (e.g., the unit price of a product/service, total amount of product/service sale, household income) in their own group sheet.
g) In each round of the game, groups will receive the same questions. In some rounds, more than one question is asked by the game master. Each group declares their answers in their group sheet (in the unlocked section to be shown by the game master). There is a deadline for answering each question (for each round of questions, you might have between 1 to 2 days to reply). Once the deadline is reached, the game master makes necessary related computations in the group sheet of each group (once all groups' files are completed, an announcement follows from the game master). After the deadline, no changes are allowed. There is no one correct answer for one question; there are trade-offs between options which might lead to different economic and environmental performance, to be evaluated by groups depending on group's individual performance and the status of the resource bank and the waste bank.
h) Once the game master processes computations in every group's sheet, then, groups can observe their performance on the performance dashboard located in their sheet (so that, they can take actions in next rounds based on their updated performance status). Furthermore, the status of the resource bank and the waste bank are also continuously visible to all groups. Groups can also see their relative performance to other players displayed in the **Dashboard** file.
i) The computation part of each group sheet is locked; this means that students cannot write any values in those parts.
j) Following questions from students, any clarifications will be provided and updates will be included.