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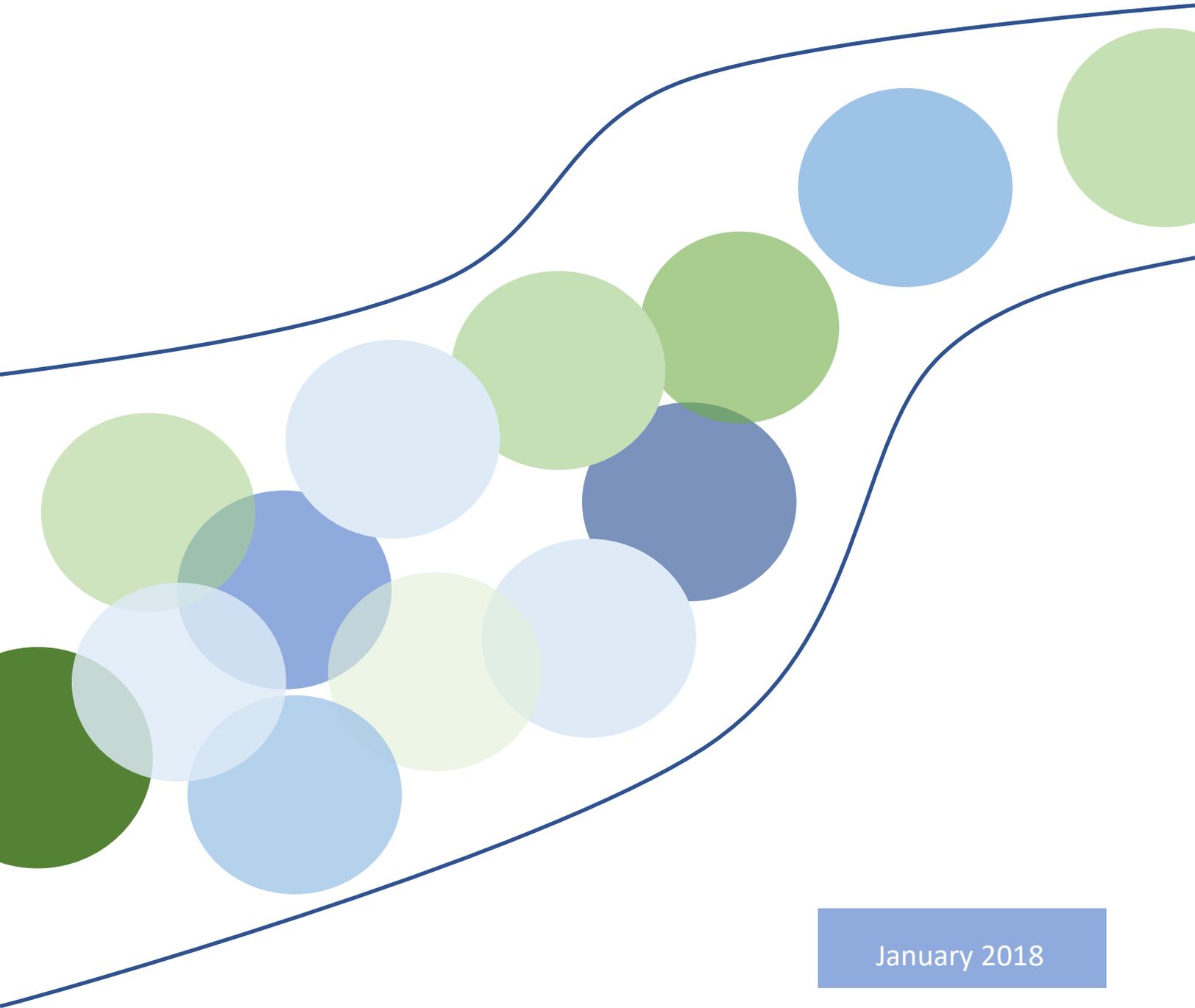
## Online Energy Systems Learning Simulation

January 2018

About this report

The current report is a description of the Energy System Learning Simulation called REEEMgame, which is deliverable 7.4 of REEEM project (http://www.reeem.org/). The Energy System Learning Simulation is the prototype developed within the project. REEEMgame is open source and link to the Github repository containing the REEEMgame is provided.

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REEEM partners
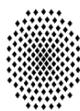
About REEEM

REEEM aims to gain a clear and comprehensive understanding of the system-wide implications of energy strategies in support of transitions to a competitive low-carbon EU energy society. This project is developed to address four main objectives: (1) to develop an integrated assessment framework (2) to define pathways towards a low-carbon society and assess their potential implications (3) to bridge the science-policy gap through a clear communication using decision support tools and (4) to ensure transparency in the process.

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Introduction to REEEMgame

REEEMgame has been created as part of the REEEM project. The REEEM project is an EU funded project which aims to gain a better understanding of how energy strategies can help the transition to a low-carbon EU energy society. The purpose of REEEMgame is to learn about energy systems. Participants will learn how different decisions affect the energy systems and the outcomes for other stakeholders.
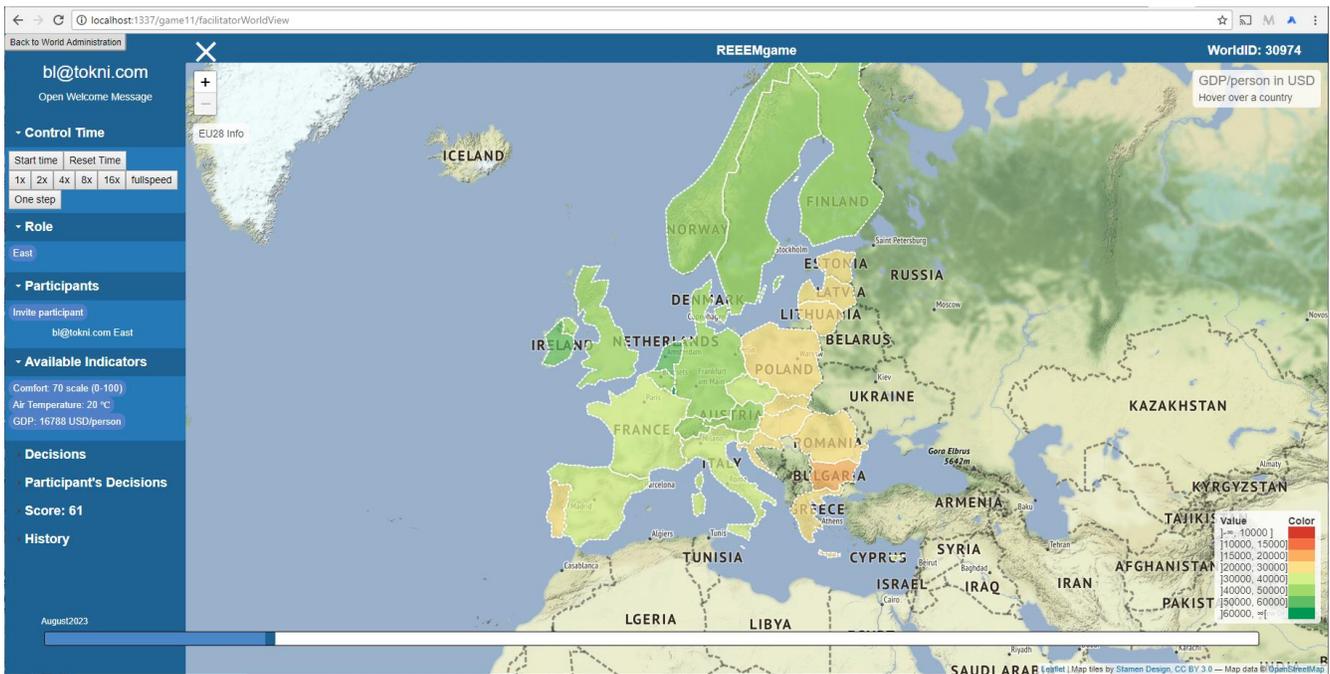
How to Play

The game is a simulation of how the future will look depending on how participants decide to act. In the defaut scenario there are three roles: EAST, WEST and OBSERVER. The participant who creates the game is the one who is controlling the game. The creator can invite more participants to the game and has the option to change participant's roles. Furthermore, the creator is in control of the time. The game is intended as a multiplayer game where one participant or team acts as EAST and another participant or team acts as WEST. As the name indicates the OBSERVER role is intended for participants who only observe the game. EAST and WEST can make decisions that influence the outcome of the game and participants have access to different indicators which can be used to gain insights into current statistics. The aim of the game is for participants to maximise their overall combined score, which is calculated as the average of three components: social score, economic score and environmental score. After each game is finished the simulation is saved and the score is registered.

Development process

The software development process used in developing REEEMgame is called Scrum. Scrum development is based on a number of sprints. In the development of REEEMgame 11 sprints were performed. Each sprint had the following structure:

- 4 weeks long

- starts with a sprint start meeting, where it is decided which feature should be implemented in the coming sprint

- ends with a demo, which is a demonstration of the current state of REEEMgame. After the demo there is a test, where everyone in the consortium is invited to try out the REEEMgame. The feedback from the demo and test, is then used in the sprint start meeting for planning the next sprint.

Repository

The repository containing REEEMgame-local is located on GitHub at the following URL:

https://github.com/ReeemProject/REEEMgame-local

In the REEEMgame-local repository is a link to a demo version of REEEMgame.

The repository is where technically advanced stakeholders can get instructions and all necessary source files to install the game on their own computers, make amendments and new game models in local or forked versions of the source code.

Getting started

Following is the installation guide which can be found in the repository. In this report there is a short explanation added after each point.

Prerequisites

Node.js and npm Node.js ^6.9.5, npm ^3.10.10

webpack webpack ^3.7.1

In the repository there are links to the libraries used to install and build REEEMgame-local, node.js and npm and webpack.

Installation
`npm install`
After downloading the repository from GitHub to a folder on a local computer, by typing 'npm install' in the command prompt, third party libraries used by REEEMgame-local are installed.

Build the server and client
`npm run build`
In the same command prompt as before, typing 'npm run build', will build REEEEMgame-local.

Start server at port 6011
`npm run start`
Make sure port 6011 is not in use

In the same command prompt, typing 'npm run start', will start a local server running REEEMgame-local.

Browser
Go to url localhost:6011/game11

Login with name: user1, and password: 123

Game model

The game model and game logic are built up around indicators and participants' decisions, and the score which is based on these factors. There are four indicators:

- Air temperature
- Comfort level
- CO2 emissions
- GDP

Each role has two decisions:

- Energy subsidies
- Investments in renewable energy

The score is a combination of three factors:

- Social score
- Economic score
- Environmental score

The indicators have an initial value defined by the developer and they change during the simulation based on participants' decisions. The score is then calculated based on these indicators. The indicators and the score are calculated on a monthly basis. The relations between the indicators, decisions and scores are explained in the next section.

The spreadsheet

The game logic is defined in this spreadsheet ([2]). On the left-hand side all the indicators, decisions and scores are listed for each role as well as some auxiliary values. Furthermore, a list of constants has been defined. The constants are defined manually while the auxiliary values are calculated based on indicators and decisions.

Along the X-axis we have the time with each column representing one month. The initial values for the indicators are defined manually. These columns are marked by a yellow colour in the image below. For comfort level, CO2 emissions and GDP this is just the very first value while for air temperature these are the values for the first year.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	REEEMgame game logic version 0.3														
2															
3			Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18
4	EAST		1	2	3	4	5	6	7	8	9	10	11	12	13
5	Available data														
6	Air temperature		17.3	19.6	19.3	15.9	11.0	5.6	1.3	-0.6	0.4	3.9	8.8	13.6	17.3
7	Comfort level		30.0	47.422	57.988	64.971	66.216	63.724	59.637	56.394	54.676	55.692	59.174	64.075	68.824
8	CO2 emissions (t/capita)		5.400	5.408	5.416	5.424	5.432	5.441	5.449	5.457	5.465	5.473	5.5	5.5	5.5
9	GDP/person (USD)		17,512	17,459	17,407	17,354	17,302	17,250	17,198	17,176	17,170	17,161	17,152	17,142	17,133
10															

The rest of the indicators are calculated based on previous values and the decisions and/or the auxiliary values. For instance, it can be seen on the next page how the value for GDP for role EAST for the second month is calculated based on the value of the previous month, the values of the two decisions, one auxiliary value and five of the constants. The images below show how this is calculated in the spreadsheet.

fx | =C9*(1+C12*$B$58+C13*$B$59+(C18-$B$61)*$B$60)*(1+$B$67)

	A	B	C	D	E	F	G	H	I
1	REEEMgame game logic version 0.3								
2									
3			Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17
4	EAST		1	2	3	4	5	6	7
5	Available data								
6	Air temperature		17.3	19.6	19.3	15.9	11.0	5.6	1.3
7	Comfort level		30.0	47.422	57.988	64.971	66.216	63.724	59.637
8	CO2 emissions (t/capita)		5.400	5.408	5.416	5.424	5.432	5.441	5.449
9	GDP/person (USD)		17,512	=C9*(1+C12*$B$58+C13*$B$59+(C18-$B$61)*$B$60)*(1+$B$67)					
10									
11	Decisions								
12	Energy subsidies		0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	Investment in renewable energy		0.0	0.0	0.0	0.0	0.0	0.0	0.0
14									
15	Running average subsidies		0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	Running average renew invest		0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	Comfort factor		70.0	69.8	69.6	69.4	69.2	69.0	68.8
18	6 month min avg hous temp comfort		30.0	30.0	30.0	30.0	30.0	30.0	47.4
19	Distance to base temperature		0.3	2.6	2.3	1.1	6.0	11.4	15.7
50									
51	Variables								
52	Base comfortable housing temp	17.0000000							
53	Max discomfort difference	17.0000000							
54	Subsidies impact on comfort	1.0000000							
55	GDP impact on comfort	0.0040000							
56	Comfort factor impact on comfort	0.3000000							
57	Historic impact on comfort	0.6000000							
58	Subsidies impact on next year's GDP	-0.0000200							
59	Renew invest impact on next year's GDP	-0.0000200							
60	6 mo min housing comfort impact on GDP	0.0001000							
61	6 mo min housing comfort impact on GDP thresh	80.0000000							
62	Subsidies impact on next year's CO2	0.0000070							
63	Renew invest impact on next year's CO2	-0.0002000							
64	Base air temperature	17.0000000							
65	Environm. impact on air temperature	0.0800000							
66	Env. imp. convergence threshold	80.0000000							
67	Monthly GDP growth	0.0020000							
68	Monthly CO2 growth	0.0015000							
69									

The two roles share the score, meaning that they have to cooperate. The scores are calculated based on the values of the indicators that month as well as a benchmark based on the initial values of the indicators. For

instance, the social score for the second month is calculated based on the comfort level of EAST and the comfort level for WEST and the benchmark which is sum of the initial comfort levels of EAST and WEST. The image below shows a screenshot of this calculation. The combined score is the average of the three score factors: social, environmental and economic score.

	A	B	C	D	E	F	G	H	I	J	K
6	Air temperature		17.3	19.6	19.3	15.9	11.0	5.6	1.3	-0.6	0
7	Comfort level		30.0	47.422	57.988	64.971	66.216	63.724	59.637	56.394	54.67
8	CO2 emissions (t/capita)		5.400	5.408	5.416	5.424	5.432	5.441	5.449	5.457	5.46
9	GDP/person (USD)		17,512	17,459	17,407	17,354	17,302	17,250	17,198	17,176	17,17
10											
11	**Decisions**										
12	Energy subsidies		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
13	Investment in renewable energy		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
14											
15	Running average subsidies		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
16	Running average renew invest		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
17	Comfort factor		70.0	69.8	69.6	69.4	69.2	69.0	68.8	68.705	68
18	6 month min avg hous temp comfort		30.0	30.0	30.0	30.0	30.0	30.0	47.4	56.4	54
19	Distance to base temperature		0.3	2.6	2.3	1.1	6.0	11.4	15.7	17.0	16
20											
21	**WEST**										
22	**Available data**										
23	Air temperature		14.6	16.5	16.5	14.2	10.5	5.9	3.9	2.1	2
24	Comfort level		70.0	81.706	88.729	91.591	91.131	88.149	85.184	82.345	80.64
25	CO2 emissions (t/capita)		10.1	10.122	10.144	10.167	10.189	10.212	10.234	10.257	10.27
26	GDP/person (USD)		48,459	48,410	48,362	48,313	48,264	48,216	48,167	48,175	48,18
27											
28	**Decisions**										
29	Energy subsidies		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100
30	Investment in renewable energy		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
31											
32	Running average subsidies		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100
33	Running average renew invest		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
34	Comfort factor		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100
35	6 month min avg hous temp comfort		70.0	70.0	70.0	70.0	70.0	70.0	81.7	82.3	80
36	Distance to optimal temperature		2.4	0.5	0.5	2.8	6.5	11.1	13.1	14.9	14
37											
38				64.6 ×							
39	**SCORES**	Benchmark									
40	Social	100.0	50.0	=IF((D7+D24)/$B40*50>100,100,IF((D7+D24)/$B40*50<0,0,(D7+D24)/$B40*50))							67
41	Economic	65,971	50.0	49.9	49.8	49.8	49.7	49.6	49.5	49.5	49

Implementation

The game logic has been implemented in the game based on the spreadsheet. There are four files that define the game logic:

- availableData.ts contains the indicators, the auxiliary values and the constants
- decision.ts contains the decisions
- keyPerformanceIndicators.ts contains the score
- mainGameLogic.ts is resposible for binding it all together.

They are located in the gamelogic folder ([3]). The initial values of the indicators are defined in the file Overlay.ts.

The calculations of indicators and scores are the same as in the spreadsheet. For instance looking at how the GDP is calculated again it can be observed that five constants are used and these correspond to the constants defined in the spreadsheet. Going into the CalculateValue function the first three variables: gdpLastMonth, energySubsidiesLastMonth and investmentInRenewableLastMonth, are the GDP from last month and the values of the two decisions. The auxiliary value, sixMonthMinComfort, called 6 month min avg hous temp comfort in the spreadsheet, is then calculated. Using these values the GDP is calculated as in the spreadsheet. The code is listed below.

```
export class GDPperPerson extends AvailableData {
    protected m_name = "GDPperPerson";

    private subsidiesImpactOnNextYearsGDP: number = -0.00002;
    private renewInvestImpactOnNextYearsGDP: number = -0.00002;
    private sixMonthMinComfortImpactOnGDP: number = 0.0001;
    private sixMonthMinComfortImpactOnGDPthreshold: number = 80;
    private maxPastMonths: number = 6;
    private defaultGrowth: number = 0.002;

    CalculateValue(month: number, energySubsidies: EnergySubsidies, investmentInRenewables: InvestmentInRenewables,
        comfortableHousingTemperature: ComfortableHousingTemperature) {
        let gdpLastMonth = this.getMonthsValue(month - 1);
        let energySubsidiesLastMonth = energySubsidies.GetMonthsDecision(month - 1);
        let investmentInRenewableLastMonth = investmentInRenewables.GetMonthsDecision(month - 1);
        let fromMonth = ((month) > this.maxPastMonths) ? (month) - this.maxPastMonths : 0;
        let sixMonthMinComfort = comfortableHousingTemperature.GetPastMinimum(fromMonth, month - 1);
        let gdpValue = gdpLastMonth * (1 + energySubsidiesLastMonth * this.subsidiesImpactOnNextYearsGDP
            + investmentInRenewableLastMonth * this.renewInvestImpactOnNextYearsGDP
            + (sixMonthMinComfort - this.sixMonthMinComfortImpactOnGDPthreshold) * this.sixMonthMinComfortImpactOnGDP)
            * (1 + this.defaultGrowth);
        this.valuePush = gdpValue;
    }
}
```

Looking at how the social score is calculated it can again be observed how this is the same as in the spreadsheet. The benchmark has been hardcoded in the code but is the same as in the spreadsheet. It can then be seen how the calculations are carried out using the comfortableHousingTemperature, which is called comfort level in the spreadsheet. The code for the calculations is listed below.

```
export class SocialKPI extends KeyPerformanceIndicators {

    private benchmark: number = 100;

    CalculateScore(month: number, comfortableHousingTemperature: Array<ComfortableHousingTemperature>) {
        let calculatedSum = 0;
        for (var organizationID = 0; organizationID <= 1; organizationID++) {
            calculatedSum += comfortableHousingTemperature[organizationID].getMonthsValue(month);
        }
        let calculatedScore = calculatedSum / this.benchmark * this._multiplier;
        let score = calculatedScore > 100 ? 100 : (calculatedScore < 0 ? 0 : calculatedScore);
        this.scorePush = score;
    }
}
```

It is possible to change the model by changing the code and rebuild the software. Instructions for changing the model are found at the following URL:

https://github.com/ReeemProject/REEEMgame-local/wiki/How-to-Change-the-Model-of-the-Game

The URL is a link to the wiki page, which is a part of the GitHub repository containing the Learning simulation. The wiki page will be extended as the project progresses.

References

[1]   https://www.atlassian.com/agile/scrum

[2]   Link to google calc. containing the game logic:
https://docs.google.com/spreadsheets/d/1WWxBkI6OPv6eId3cHN6Vgm-76XhIfRCmyGRfuMe3VbM/edit?usp=sharing
[3]   https://github.com/ReeemProject/REEEMgame-local/tree/master/ServerModel/gamelogic