

SELF-SUSTAINABLE CITY



SELF-SUSTAINABLE CITY.....	3
Skills:	3
Learning goals	3
Lesson plan	3
Class 1: Deciding the location	4
What do we need to know?.....	4
What do we need to prepare?.....	4
Class session	4
Class 2: Providing food	5
What do we need to know?.....	5
What do we need to prepare?.....	5
Class session	5
Class 3: Pumping up water	7
What do we need to know?.....	7
What do we need to prepare?.....	8
Class session	8
Class 4: The physics behind the pump	9
What do we need to know?.....	9
What do we need to prepare?.....	10
Class session	10
Class 5: Electric circuits:	10
What do we need to know?.....	10
What do we need to prepare?.....	12
Class session	13
Class 6: Renewable sources of energy:	14
What do we need to know?.....	14
What do we need to prepare?.....	15
Class session	15
Class 7: Housing solutions:	15
What do we need to know?.....	15
What do we need to prepare?.....	16
Class session	16
Classes 8 and 9: Building the city	17
What do we need to know?.....	17
What do we need to prepare?.....	17
Class session	18
Exam.....	18
Showcase	18
EXTERNAL RESOURCES.....	19

SELF-SUSTAINABLE CITY

Creating a model of a city, making all the decisions that need to be made to provide the citizens with everything that they would need, from food to electricity.

This is the most interdisciplinary and hands-on project that we designed. It does not go deep in any kind of theoretical knowledge, so it can be easily followed by students that do not fully understand the vehicular language. Besides, it requires no previous knowledge whatsoever, so it is accessible for students with any kind of background.

It is mainly practical and there is a tangible goal to reach. This can make the project much more attractive to students that are not driven by a desire of learning but are more into doing and building.

Skills:

- Decision making by voting or consensus
- Arguing a choice to convince others
- Finding the optimal solution among several options
- Analysing costs and benefits
- Linking theoretical knowledge with the real life
- Doing online research
- Presentation skills
- Talking in public
- Working with Excel

Learning goals

- Having a vary diet: different types of malnutrition
- Physics behind a manual water pump
- Renewable sources of electricity
- Simple electric circuits

Lesson plan

Through this project we are intending to build a model of a city. Our aim is not only to put together a bunch of houses and install a motor, but to go deeper on the needs of the population and how to make the society as flourish as possible given the resources available.

We will play the revolution game through the project. As city planners, the students will make decisions on where to build the city, what kind of accommodations to provide, what kind of public services to have in place, etc. All those decisions will affect the happiness of their citizens. If their happiness rate goes low, they might decide to start a revolution against the city planners. After every class, attending to the decisions made, the happiness ratio, that goes from one to ten, will be updated and a random number will be generated. If the number is higher than the happiness rate, the students will face a revolution.

It is up to the teacher and the students to decide the consequences of a revolution. They can affect the game, forcing for new decisions to be made, or they can be punishments for the students.

When we carried out the project, the students would have to clean Habibi. Works if they faced a revolution. Lucky for them, they didn't.

Class 1: Deciding the location

The students will discuss, in pairs, where to locate the city among different possibilities, given their pros and cons. Then, all the class together will have to vote for one place.

What do we need to know?

This class is focused on presenting different options and letting the students choose what they consider best. There is no previous knowledge needed for the teacher.

What do we need to prepare?

- An info sheet for each location that we will present. We used four. The info sheets can be found in a document together with this file.

Class session

We will introduce the topic as the class starts and then we will present the first question: what does a city need? We want to get a list of needs from the students. We can let them raise their hands and give ideas, or we can ask one by one in a round. This depends on how the specific group works.

The topics that we will focus on the following days and, therefore, we want to appear in the list are: a place, energy, water, food, and buildings. Once the brainstorm is finished and we mentioned that we will work mainly on those five elements, it will be time to make the first decision: the location of the city.



Picture 1 Students checking the characteristics of each location

We will present the four different places that we can choose and explain the different characteristics of each of them. The space available, the water resources, the quality of the soil, the climate, the material available for construction and the animals that can survive on it. There is not an optimal choice, places with wide spaces might have a lack of water, while a location with big amounts of water could have no good construction material.

We will divide the students into pairs to discuss what option they prefer, and why. This discussion could be done in one big group, but

then those students more confident talking in public might take over the decision making, while those that tend to be quiet would not interact. Finally, after ten minutes of discussing, we need to make a final decision. Every team will present their conclusions to the class and then everyone will vote independently for the location they prefer.

This first session there will not be a happiness rate yet, so there is no need to generate a number to check if a revolution would happen.

Class 2: Providing food

After learning about malnutrition, the students will decide what food to provide to their villagers and in what amounts. They will do that through a card game.

What do we need to know?

The first concepts we will introduce are related with malnutrition. Malnutrition does not only refer to a deficiency on nutrient intake, but also to an excess or an imbalance. This means that both undernutrition and overweight can be related to malnutrition. In fact, it is not uncommon to find undernutrition and overweight in the same community or even in the same person.

The lack of any needed nutrient can lead to nutritional deficiencies. For example, an iron deficiency in children under two years of age can affect their brain function chronically. Undernutrition can also affect children before they are even born, through their mothers. Deficiencies in the mother's nourishment can lead to growth stunted in the child. This is a reduction in their growth rate.

Serious deficiencies on iron, iodine, zinc and vitamin A can lead to marasmus, a serious disease that affects mainly areas under famine. It affects mainly children. The patients might be up to 60% under the normal weight for their age, losing muscle and under skin fat. It can cause chronic diarrhea, respiratory infections and even intellectual disability. Another common disease in famine areas is kwashiorkor, caused by a diet based in carbohydrates with a lack of protein intake. It causes the abdomen to bulge, and gives a swollen appearance to the patient due to fluid retention.



Picture 2 Child suffering from kwashiorkor

So, not having access to all the needed nutrients a person requires can lead to diseases, but having access to an unbalanced diet, even if abundant, can lead to malnutrition as well. A diet based on fats, sugars and salt, lacking fresh fruit, vegetables, legumes and meat (or other protein sources) can produce overweight while still not providing all the nutrients that the person needs.

What do we need to prepare?

- A set of food-game per team. They can be found in a separated file together with this one. It is only needed for the students to know the costs, needs and nutrient value of each item, so it is enough to provide one of each type of food resource. The number and type of land cards will depend on the location chosen in the previous session. *We provided 60 land cards in total.*
- One laptop per team
- An excel sheet ready to automatically make the calculations. It can be found together with this document.

Class session

To begin with, now that we have the land chosen we will start making decisions that will affect the happiness of our citizens, so we will introduce the students to the game that we are going to be playing throughout the cycle. Then, we will move to the first decision to be made: food.

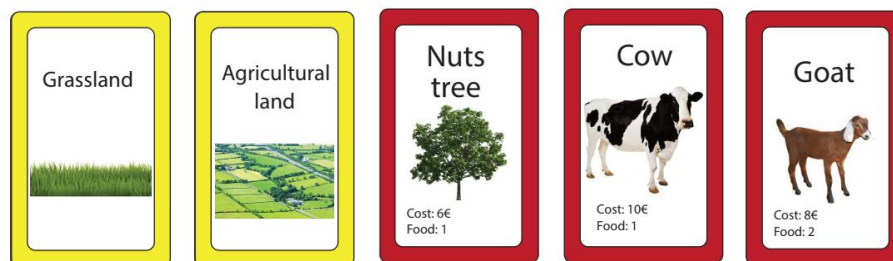
We can start having a brief discussion about what different sources of nutrients our citizens will need. That can be fresh vegetables, meat, dairy, sweets... Once the students have shared their thoughts, we will present the information about malnutrition and explain the importance of having a varied and rich diet, not necessarily abundant, but sufficient. When that is understood, we can present the game through which the students will design the diet of their citizens.

Instructions:

The students, in teams, will receive a set of land cards that depends on the location they chose in the previous session. A grassland area will have many grass cards but few rocky or water cards. A wetlands area will have many water cards but not so many grass ones. In total they should get around 40 cards.

About the time size, we divided our students into groups of six. It was too much, and sharing the decision making among everyone was too complicated. We think that teams of four would work well.

The land cards can be used, together with money, to purchase different types of food. Vegetables or fruits have low requirements, while animals will require more land and even other sources of food. However, animal based products might provide more nutrients.



Picture 3 Land cards and food cards

The students will also have a limited budget of 300 (thousand) euros to try and find a way to use their land in a way that they maximize the amount of nutrients that they can provide while making a varied diet. To measure the success of their diet, we will attend to the following:

- If the diet reaches 1500 calories, their city will have a 5/10 happiness rate
- If the diet reaches 2000 calories, the average need for a person per day, their city will have a 8.5/10 happiness rate.
- If the diet covers 200 calories in each category, they will get one extra happiness point:
 - o cereals: orange cards
 - o vegetables and fruits: green cards
 - o dairy: blue cards
 - o proteins: red cards
- If the diet includes fats, they will get 0.5 extra happiness points

When we carried out this game, there was an extra step to go from food resources to processed food. It was too complicated to adjust the diet and too many calculations were needed. We think that even now it is still quite complex. For that reason, we prepared a sheet that makes the calculations automatically where they only need to fill in different options. This way they can test different approaches and choose the one they consider better. In the Excell sheet they just need to fill in the columns "Quantity bought" for each element, and the number of cards that they will use to provide that element in the columns "Grassland", "Agricultural", "Rocky land" or "Water".

Our intention is not necessarily to train their math skills with this session, but their decision making and their analysing skills to choose among different, yet valid solutions. Therefore, we

think it is worthy to avoid the calculations if they would lead the students to try to find one solution and stay with it to avoid redoing calculations.

Category	Product	Quantity bought	Nutrient value	Cost	Animal food cost	Grassland	Agricultural	Rocky land	Water	Missing grassland	Missing agricultural land	Missing Rocky land	Missing Water land
Meat	nuts tree		0	0	0					0	0	0	
Meat	chicken		0	0	0					0	0	0	
Meat	cow		0	0	0					0	0	0	
Meat	goat		0	0	0					0	0	0	
Dairy	Cow milk		0	0	0					0	0	0	
Dairy	Goat milk		0	0	0					0	0	0	
Dairy	Egg Chicken		0	0	0					0	0	0	
Cereal	Wheat		0	0	0					0	0	0	
Plants	Vegetables plant		0	0	0					0	0	0	
Plants	Fruit tree		0	0	0					0	0	0	
Meat	Fish		0	0	0					0	0	0	
						0	0	0	0				
Meat	0	200	Total cost without fat	0		15	20	5					
Dairy	0	200	Fat (yes/no)	No									
Cereal	0	200	Total cost with fat	0		225							
Plants	0	200											
Fats	0												
Total	0	900-1200											

Picture 4 Excell sheet

Once every team comes up with a solution, we can let all of them present the happiness they reached and briefly explain what nutrients their solution would be providing. Then, we can choose the one that reaches a higher rate. Finally, we will generate a random number and if it is higher than the happiness rate, then the students will face a revolution.

Class 3: Pumping up water

Their water resource will be underwater, so they will have to build a manual pump to pump it up. They will do so in pair following a video tutorial.

What do we need to know?

Earth is known as the blue planet because there is so much water on our surface that the planet looks blue. However, we do not have so much water available for our consumption as we might think. Only 3% of the water on Earth is freshwater -the rest is salty-. Out of this 3% of possibly consumable water, 69% is frozen in glaciers and the ice caps, which leaves us with 31% of the freshwater. This is, only 1% of the water that is on Earth. We can find water in rivers, lakes, swamps, and underground. Besides, this water is in constant flow throughout the water cycle, so it can be also taken from the clouds as it rains.

To make use of this water, humans have taken multiple approaches. Piping systems that take water from rivers or lakes. Pumps that take water from underground. Dams to accumulate water from rain, changing the flow of rivers. We even desalinate sea water to make it drinkable.

The problem with desalinating is that it requires too much energy. Currently there are 18.000 desalinating plants working, and they cover only 1% of the water need of the world. There are many investigations going on this direction. Right now, there are two main techniques. One is evaporating the water, so the salt stays, and then condensing the steam into freshwater. The other one is to make the water pass through a membrane that doesn't allow salt to go through. The second approach requires less energy, and there are several researches going in that direction to make it more efficient. However, this has disadvantages, mainly due to how it can

affect the environment. For example, taking water from the sea in big amounts causes organisms to be pulled out from the sea together with the water.

Once a water source has been found and the water flow has been directed to a city through the piping system, the used water needs to be brought back to the source. For this, it first needs to be treated and cleaned. In the class we will not go deep on this process. We will only mention the need and maybe do a brief brainstorm about ideas the students might have.

What do we need to prepare?

- A big plastic syringe per team
- A bike tire
- A bike spoke per team
- Wooden flat sticks
- Thin plastic tube
- A closed Tupper per team
- A soldier for every two teams
- A driller for every two teams
- A device to see a YouTube video per team. It can be a laptop or their own phones



Picture 5 Desalting plant

Class session

We focused this class on making a pump to take underground water because the place that our students chose for their city had underground water. Besides, it is a feasible project to carry out in a class. In case the place your students chose does not have underground water you could consider finding a different approach for the water class, or just present this option so they get the knowledge even if it would not be the one their city would have to take.

To begin with, we will talk about the next decision we need to make for our city. How to provide water. We want our city to be self-sustainable, so we need to find ways to get our own water but, also, we need that water to come back to the system. We can let our students brainstorm about how they would provide water given their location. Maybe creating a dam, maybe redirecting a river, or desalting water sea, or pumping it from underground. Then we will ask them what they would do with the used water. They could think about using it for agriculture, or filtering it to be reused.

After the brainstorm it will be time to create a pump so we can take water from underground to our piping system. For that we will make pairs and each group will get a set of material and a link to the video that is on the external resources section of this chapter. They will need to build a functional pump by following the instructions.

We made couples for this activity pairing people that didn't speak the same language, since following instructions is something that can be handled easily without communication and not much discussion is needed. It actually proved itself a good approach.

Before dismissing the class, we need to check if we are going to face a revolution. If all the pumps were working by the end of the class, the happiness rate will stay as it was in the previous class. Otherwise, we can decide to reduce it by a factor related to the proportion of working pumps. For this, we would do the following operation:

$$\text{current rate} \cdot \frac{\text{working pumps}}{\text{total amount of pumps}}$$



Picture 6 Student working on his pump

If all pumps are working, the rate will stay the same. If no pump worked, the happiness will drop to 0. If half of them worked, the happiness will be reduced to a half.

Class 4: The physics behind the pump

Once the pumps are built we will look at them and discover how they work. We will investigate what would happen if we do different changes on them.

What do we need to know?

This class will be focused on understanding how the pump that they built in the previous session works.

There are two major points in the pump that allow it to work:

- The marble that blocks the flow from the syringe to the water source
- The small piece of rubber covering the whole on the syringe seal



Picture 7 Pumps built by the students

As the syringe plunger goes up, the space available inside the syringe increases. The rubber prevents air from flowing from outside, so the pressure inside the syringe decreases and air and water coming from the Tupperware pushes the marble and enter the empty space. Then the syringe seal goes down. Then the rubber piece flips up letting air and water from inside the syringe to flow outside of the seal. Nothing can go back to the water source because the pressure of the seal coming down pushes the marble against the hole.

Now if we make different modifications in the pump, it will not work for different reasons:

1. If we remove the rubber from the seal and leave it open.

In that case, air can go from inside to outside the pump when the syringe plunger goes up. This will make the pressure level to be constant on both sides, so no extra space will be available for the water to come up. In this case, we will make the syringe go up and down with no visible effect.

2. If we completely glue the rubber piece, closing the hole.

Now air cannot move from inside the syringe to outside when the plunger goes down. When it goes up the pressure will decrease inside and water will come up. Then, we will try to push

down, the marble will not let the water go back to the Tupperware. This means that we will be trying to push water and air on a space that is already full. We will not be able to push down. Imagine if you fill a normal syringe, then put your finger on the exit and try to push down. Your finger will prevent the syringe plunger from moving. The same happens now, and the marble is acting as your finger.

3. If we remove the marble.

Without the marble, the water that comes up has a way to come back as soon as we push down, so the water will not stay up.

What do we need to prepare?

- One of the pumps built in the previous session.
- A pump without the rubber piece on the syringe seal.
- A pump without a whole on the syringe seal.
- A pump without the marble inside.

Class session

During the first part of this class we will, together with the students, deduce how the pumps that they built in the last session work. For this, we will have a working pump to look at. To begin with, we will pull the syringe plunger up, and then ask the students what they think happens. With guidance if needed, they will deduce that the rubber piece prevents air from going inside, and that there is extra space created inside that makes the water come up. Then, we will push the seal down and help them deducing what happens then.

Once the functioning of the pump is understood and any questions that come up are answered, to help them fully understand the role of each part of the pump and to train their deductive skills we will present the three modified pumps. We will ask them what they think will happen when we try to pump water with each of them. After a round of brainstorming, and after reasoning the different ideas that might come up, we will check if those theories were right by trying to use the pumps.

When we carried this class out we discussed the three cases all together, one by one. Another option that could be a good idea if the amount of students is too big, is to make small teams and assign one of the pumps to each team to discuss and later present to the rest of the class.

The happiness rate from the last session will be kept, so at the end of the class we will check if we face a revolution by generating a number and checking if it is higher than the happiness rate from the previous class.

Class 5: Electric circuits:

The students will learn about the basic components of an electric circuit and its functions by building a circuit with a battery and a small light bulb

What do we need to know?

The aim of this lesson is not necessarily to give a deep insight into the nature of electricity itself. However, to face possible questions it is good to have a clear understanding of it.

We need to begin by having a closer look at the inside of atoms. They are built out of protons, with positive charge and neutrons, that are neutral, on their core. Around the core, electrons, with a negative charge, orbit. In the most balanced state of an atom, the number of protons and electrons are the same. In other cases, the atom will have charge. This will be a positive charge if it is lacking electrons, or a negative charge if it has too many.

While changing the number of protons would change the nature of the atom itself, becoming a completely different matter, the electrons can escape. Depending on the atom, it will be easier or more difficult for the electrons to escape. A flow of electrons moving through a material from a negatively charged place to a positively charged one is what we call electricity. This flow happens because matter will always tend to be in the most balanced state possible. The flow of electrons from negative to positive will make both places become neutral on charge, what is the most balanced state possible.

When this flow of electrons encounters a resistance, that is, a device such as a light bulb, the electric energy will be transferred into some other form, such as light or heat. In simple words, the electrons flowing from a negative pole to a positive one will *turn on* anything they find on their way.

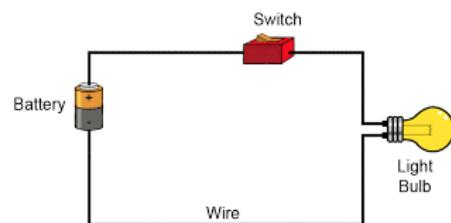
Now that we know the basics of electricity, we can focus on the topic of the class: simple circuits.

An electric circuit consists of:

- A source of energy, that in our case will be a battery.
- A conductive material, such as a cable or a wire. A resistance, that is, an element that needs the electricity to work, like a light bulb. If the resistance is broken, the electrons cannot flow through, and this will cause the circuit to close
- A resistance, that is, an element that needs the electricity to work, like a light bulb. If the resistance is broken, the electrons cannot flow through, and this will cause the circuit to close.
- A switch. This element is usually found in circuits, while not indispensable. It allows us to stop and continue the flow of electrons whenever we need.



Picture 8 A battery, with its positive and negative poles



Picture 9 Diagram of a simple circuit

The reason behind the conductivity of certain materials is that these lose their own electrons easily. Imagine copper, it has one electron on its last layer that is easily ejected. If we introduce a new free electron in a copper wire, it will attach to the first atom it finds, so this atom of copper will be negatively charged. Copper can eject one electron easily, so the extra electron that is provoking this negative charge will be pushed out of the atom, and it will attach to the next one. Then a new electron will be released from this atom and it will move to a third copper atom. This will continue through the whole wire. We have created a flow of electrons through the copper. Elements like these are called conductors.

As we add extra paths and extra resistances to a circuit, it can become as complicated as we want, but each additional element will affect the flow of electrons. The first idea we can come up with is to have no resistances, and directly connect the positive and negative poles. In this case we will have a shortcut. Electrons will have no obstacles on their way, so they will move through the wire producing a huge amount of energy that will turn into heat on the wire, what can turn into melting or even fire.

Now, there are two basic types of circuits that include more than one resistance:

Serial circuit

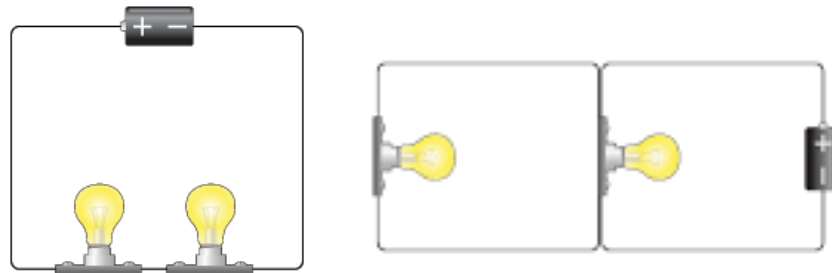
The resistances are placed one after the other. In this case, all the electrons that leave the battery will have to go through every resistance. This will reduce the *power* of the current. If we are using light bulbs, the more we add to the circuit, the less bright they will shine.

If in a serial circuit one element breaks, then the path for the electrons to move will be cut, and the flow will be stopped. These kind of circuits are appropriate when one faulty device should produce everything to shut down.

Parallel circuit

The resistances are placed in different paths. In this case the electrons will divide among each path, so each electron will pass through one resistance or another, but not through all of them. In this case the bulbs will shine as much as they can, because the *power* of the current will not be reduced by passing through several resistors.

When one element breaks in a parallel circuit, the electrons still have another path available to go from the negative pole to the positive one, so the rest of devices will still work. These circuits are suitable when one faulty element should not make all the system to shut down.



Picture 10 Serial system (left) and parallel system (right)

Both types of circuits can be combined. We can have, for example, two paths with two resistors on each of them. However, in these cases we need to take into account that electrons are *intelligent* enough to always take the easiest way. If a parallel circuit is set and in one branch we have one light bulb while in the second branch we have two, all the flow will move through the branch with only one resistor, since it is an easier path.

What do we need to prepare?

- One 4.5V lantern battery per team. It can be any other 4.5V battery, but in these ones it is very easy to attach the cables.
- Circuit wire
- A set of at least four 4.5V light bulbs with bulb base per team
- One cable peeler per team



Picture 11 Set of material to build circuits. These batteries are not easy to find anymore, so we used lantern batteries instead

Class session

In this class we will still not make decisions on the sources of electricity that we will implement in our city. We will start learning the basics of electric circuits so the students can install them during the city building process. To begin with we can introduce electricity as a flow of electrons, or a flow of negative charge towards a positive pole.

How deep to go here is up to the teacher and the students. We didn't plan to go any deep, and then the students forced us by making questions that went deeper and deeper into the nature of electricity. We ended up using half of the class to explain the concept of charge in atoms and how electrons move in a conductor.

We will then move to a more practical side, understanding and building simple circuits. We will place all the elements on the table so students can see them. Then, we will present each element that forms a circuit: source of energy, conductor and resistor. With a painting we can illustrate how the electrons will move from the negative side of the battery to the positive one going through the light bulb and illuminating it on the way. Now it is important to make clear to our students what a shortcut is, and the importance of not connecting the battery to itself.

Without further explanations, we can divide the class into pairs or groups of three, give out material and ask them to build a first simple circuit with one resistor.

We didn't provide switches. Instead, the students simply joined or separated the cable from the base of the light bulb or one of the poles of the battery.

Now that they have seen how the circuit works, we will present two challenges:

- Build a circuit using two bulbs. If one breaks, the circuit should stop working
- *Build a circuit using two bulbs. If one breaks, the other one should still work*

Having bulbs and bulb bases, we can pretend that a bulb broke by just taking it out of the base.

The first case is a serial circuit, and probably all teams will get it fast since it is the most natural way of joining the bulbs. Even if they build it, we will ask them to reason why the second bulb cannot turn on. The second case, a parallel circuit can be more challenging, so we might need to guide some groups if we see them struggling. We can, for example, ask them to make a painting in a paper of where they need the electrons to go for the second bulb to still work after the first one breaks.

It is likely that some teams need less time to finish than others. For this is good to have extra challenges prepared so they don't get bored and they can expand their knowledge. These challenges can include decisions about where to include switches. The switches can be made by simply cutting the wire at specific places. Extra challenges can be:

- Three bulbs are controlled by a switch. If one breaks, everything stops. The solution is a serial circuit with a switch at the beginning
- Three bulbs are controlled by a switch. If one breaks, the other two still work. The solution is a parallel circuit with three paths, and a switch on the main wire, either before the wire splits or after the wires join back together
- A switch controls only two bulbs. If one of them breaks, the other still works. A third bulb is independent and always on. The solution is a parallel circuit with three branches, but the switch is placed after the main wire splits and only controls two of the branches.
- The system has three bulbs, but only one turns on. If it breaks, the other two will turn on. The solution is a parallel circuit with two branches, one with one bulb and another with two. The electrons will choose the path with only one resistor if it is available.

Once every team has at least finished the first two challenges, we can generate a number to check if the city will face a revolution. Before dismissing the class, we will ask our students to do some homework for the next class. They have to make research on the differences between renewable and non-renewable sources of energy, and find several sources of each kind.

Class 6: Renewable sources of energy:

The students will present their knowledge of renewable sources of energy and, given the location of our city, will decide which one to implement

What do we need to know?

Renewable sources of energy are those that are constantly and naturally replenished. This stands in opposition to non-renewable energy sources, that are those that cannot be replaced by natural means quick enough to keep up with the consumption. In this sense, non-renewable sources are finite resources of energy.

Examples of renewable energy sources are:

- Wind power: big windmills are moved by the energy of wind, producing electricity.
- Solar energy: the heat from the Sun, caught by photovoltaic panels, is turned into electricity.
- Hydropower: a turbine is turned by the strength of a stream of water. These plants can be installed in the flow of a river, but they are usually built in dams. This type of energy includes the one produced by tides. In that case, the turbines are turned by the change on the level of the water.
- Geothermal energy: it uses the difference in temperature between the core of the planet and the surface to produce electricity.
- Bioenergy: biological material can be turned into biofuel that can be burnt and used as a source of energy, as oil.

Examples of non-renewable energy sources are:

- Fossil fuels: this is coal, crude oil or natural gas. These were produced from fossilized remains that were exposed to heat and pressure in the Earth's crust over millions of years.
- Nuclear fuels: nuclear plants take energy from breaking up atoms of unstable matter, like uranium. These materials are finite and not replaceable.

A different way of categorizing energy sources is according to the waste that they produce. Energy can be clean or not. Clean sources are usually identified with renewable ones, but this is not accurate. Biofuel, for example, while renewable is not clean, since its combustion generates polluting gases

Finally, our students will have to decide what energy to install in their city. For it to be feasible, we will focus on sun, hydropower or wind as possibilities. Here are some pros and cons of each of them:

Energy	Pros	Cons
Sun	Very efficient for practical uses such as heating and lighting. Solar panels require low maintenance.	Dependant on the weather. The panels require a big land space. Can cause land degradation and habitat loss for wildlife.
Hydropower	Not dependant on the weather.	Dependant on the availability of water.

Wind	Water can be released to coincide with peaks in demand. Water can be reused to keep on producing energy.	Usually require dams, that can damage the environment.
	Windmills are cheap and easy to maintain. Can be built off shore.	Dependant on the weather. Requires a big space of land. Can be damaging for wildlife. The windmills are too noisy to be close to populated areas.

What do we need to prepare?

There are no needs for this class

Class session

We will start asking our students if they did the research that we asked them to do. Then, different students can come to the whiteboard and explain what they learn about:

- What renewable energy sources are
- What sources are renewable
- What sources are not renewable

Once our students have a clear understanding of the difference between renewable and not renewable, we can introduce the concept of clean energy. When that is understood, we will focus on wind energy, solar energy and hydropower to decide what will be implemented in our city.

You can directly introduce this decision, or let them discuss all the possible sources that they have available, which ones would make sense in a self-sustainable city, and if they want their city to be clean.

To make a decision on what source to use, together with the students we will make a chart with pros and cons of the three possible choices. We can start filling the chart with a brainstorming from the students. Finally, the students will vote which source they prefer.

It is important to take into account the materials that you will have available for the construction. We had small solar panels as well as small engines to which attach 3D printed windmills, so we decided to let the students choose among these two, and also water, since reproducing a water stream could be done with a hose.

Before finishing the class, we will check once more if the students will face a revolution in their city.

Class 7: Housing solutions:

Through a decision game the students will choose what kind of houses they will build for their citizens, what materials they will use and what public services they will provide.

What do we need to know?

There is not theory needed for this session

What do we need to prepare?

- One laptop per team
- The excel sheet for city planning that is available together with this document.

Class session

The last decision that needs to be made before starting the building of the city is what kind of buildings there will be in it. To make this decision we will split the class into teams of two or three people and provide each team with a laptop and the excel sheet for city planning.

This excel sheet has all the different buildings that the students can decide to build, together with their cost and the space they need. Each housing building can host a specific amount of people and will give a happiness level to each person living in that place. There are public spaces as well. Some of them will not increase the happiness rate, but they are compulsory, like one school, one hospital or supermarkets. Extra public spaces will provide a boost on happiness of 0.2 or 0.1 per building.



Picture 12 Some of the buildings designed by the students

Each team will have to try different options using the sheet to find a solution that provides houses for the thousand citizens of their town and has at least the compulsory public services. At the same time, they cannot spend more money than the budget that they have at their disposal and they cannot use more space than the one available in the location that they chose.

The teams will have all the class to experiment different approaches in the laptop. At the end, each team will present the happiness rate that they managed to get, and the solution that provides a better one will be the one chosen. In case of a tie, each team can present the buildings that they decided to build on their solution, and then all the class together will have to make the decision about which approach to take.

Before dismissing the class, we will calculate the new happiness rate of our city by doing the average between the previous rate, assigned to food and water, and the new one, assigned to housing. Once we have the new -and final- rate, we can generate a number and see if the students will face a revolution.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Housing	People fitting	Space taken	Happiness	Cost per unit	Amount bought	Money spent	People fit	Space used				
2	1 family house	4	10	8	15		0	0	0		Happiness		
3	1 family cottage	4	30	9	22		0	0	0				
4	4 family flat	16	10	5	15		0	0	0				
5	Skyscraper	150	40	3	45		0	0	0				
6	1 family bungalow	4	10	7	8		0	0	0				
7	2 family bungalow	8	10	4	16		0	0	0				
8	Studio flat	20	10	3	15		0	0	0		SPACE		
9	Studio bungalow	10	10	4	16		0	0	0		Used	0	
10	1 person mansion	1	40	10	49		0	0	0		Available	2500	
11													
12	Public spaces	Amount compulsory	Space	Happiness	Cost per unit	Amount bought	Money spent	Amount needed	Space used		PEOPLE		
13	Hospital	1	60	0	54		0	1	0		With house	0	
14	School	1	60	0	54		0	1	0		Without house	1000	
15	Police station	1	50	0	42		0	1	0				
16	Water plant	1	100	0	65		0	1	0				
17	Energy plant	1	100	0	25		0	1	0				
18	Supermarket	2	20	0	31		0	2	0		MONEY		
19	Open public space	0	40	0.2	39		0	0	0		Used	0	
20	Extra service	0	20	0.1	28		0	0	0		Left	2000	
21													
22													

Picture 13 Picture 13 Excel sheet for the housing decision. Only the two white columns need to be filled in by the students

Classes 8 and 9: Building the city

The students will be free during one week to work on building the city at their own pace

What do we need to know?

There is no theory needed for this class

What do we need to prepare?

- One big flat piece of wood that will be the base of the city. At least 1.5m x 1.5m.
- The rest of materials will depend on the decisions that have been made for electricity, water and housing, and on the resources available.

Here you have the materials and approaches that we took:

- *Electricity: our students built four wind turbines to illuminate four LED bulbs. They followed the instructions that are available in the video in the external resources section*
 - *Four small engines*
 - *Thin cardboard*
 - *Hot glue*
 - *Scissors*
 - *Glue*
 - *Circuit cables*
 - *Four LED light bulbs*
 - *A 3D printer to make the blades of the windmill (they can be done with cardboard, but with plastic they work better)*
- *Water: our students made an electric pump powered by a battery that would push water from a bucket through a pipe around the whole city, and back to the bucket passing through a filter. The instructions for the pump and the filter are in the external resources section.*
 - *Two bottle lids*
 - *3D printed turbine*
 - *Cutter knives*
 - *Strong glue*
 - *Plastic tube*
 - *Sandpaper*
 - *Small engine*
 - *Inside of a pen*
 - *Pliers*
 - *A base to place the engine on*
 - *Hot glue (we used it to glue and seal the plastic tube to the lids)*
 - *A battery suitable for the engine*
 - *Circuit cables*
 - *A plastic bottle*
 - *Sand*
 - *Small rocks*
 - *Charcoal*
 - *Cloth*
 - *A rubber band*
- *Housing: our students designed each building in flat pieces using the software Illustrator. Then, they printed the pieces with a laser cutter in 4mm thick plywood and glue them together*

Class session

We will divide the class in three teams: plumbers, electricians and architects. The first ones will have to build the water system of the city; the second ones will provide enough energy to turn on four LED light bulbs that will be placed in the town. The last ones will design and build all the buildings that were decided in the previous class.

All the teams will need to communicate among each other so everything will fit in the city at the end. For example, the architects need to know how much space the water system will need in the city and how big the energy plant will need to be to fit all the installation.



Picture 14 Fully built city

Once the teams are made, we can give the needed materials to each team, and then the class will be officially dismissed. From now, the students are free to work when and where they want. They will have one week from now to design and build the whole city.

Exam

For this project there is not a proper test. The exam is for the students to have the city finished and working by the deadline.

Showcase

Each team will present the part of the city that they built, explaining to the audience how they did it and how it works.

EXTERNAL RESOURCES

- How to build a pump.

<https://www.youtube.com/watch?v=ZOGkqlju51g>

- How to build a wind turbine

<https://www.youtube.com/watch?v=JXYkjHKakGE>

- How to build an electric pump

<https://www.youtube.com/watch?v=vSJMIxBC-gE>

- How to make a filter

<http://prepperswill.com/how-to-filter-water-in-the-wild/>