UNIVERSITEIT TWENTE.

# SMART ENVIRONMENTS PROJECT

## DOCUMENTATION REPORT

**LADA F1 TEAM**

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# Chapter 0: Introduction

The world is being destroyed by us, humans, who believe that making all the changes we desire will not cost anything in return. Unfortunately, climate change is hitting hard and the longer we take to come up with solutions on how to stop it, the more we are going to suffer in the future. As a young generation, we still have a chance to make a change in this world and hopefully for the good. However, smart moves are required to succeed in such important mission.

Electricity has become a daily need, but not being aware of the consequences makes us part of the problem. Such energy is obtained from fossil fuels, and when burnt, large amounts of carbon dioxide (CO2, a greenhouse gas) and smaller, yet relevant amounts of methane and nitrous oxide are emitted into the atmosphere. On the other hand, renewable natural resources such as sunlight, wind, water and many more, are at our disposal all the time. So why not make the best use of it?

Accordingly, we, as students, want to highlight this problem and offer a solution. In this module we are preparing a device prototype, in order to combat climate change. Therefore, the purpose of this report is to document the process of building a Smart Sunflower. This Smart Sunflower will be located on the user's rooftop, and behaves like a regular solar panel – it generates renewable energy for the household. The difference is that this device moves towards the best position. It is meant to emphasize the advantages of producing your own energy through light sensors, and encourage more people to help climate change in this way. This project will make use of the most optimal angles for which the Sunflower can attain maximum efficiency and high energy yield. It can also be used to provide users with all the essential data for them to install a solar panel.

Furthermore, in this document reside the choices we made, how we came up with this idea and all the steps behind it.

# Chapter 1: Literature Review

## How does climate change affect biodiversity?

One of the emphases of this video is the global consequences of human activities done locally. Anything produced, even local, which pollutes, on a higher scale will have a negative worldwide effect, including an effect on biodiversity. One of the main issues is the large amount of greenhouse gases produced, especially CO2. These gases have a property that prevents the infrared radiations (which are the result of sun rays refracted by the earth's surface and which are basically heat) to go to outer space. Hence, the global warming, which has multiple effects on biodiversity:

- The rise of the water levels (as a result of ice melting at the poles), which places countries such as the Maldives or the Netherlands under the risk of being submerged under the water. Implicitly, the organisms that dwell only in these areas will go extinct.

- The high-temperatures force organisms to migrate and invade other habitats, causing disbalances (such as forests that can alter other ecosystems).

- Organisms that are unable to adapt or unable to move to a better place (such as corals) are at an even higher risk

- Even plants are at risk, because of the unequal ability of absorbing the CO2. Plants with a better ability will eventually overgrow, absorbing all the other important chemicals and the rest will simply die.

In conclusion, the ecosystems become less and less functional as the richness in diversity diminishes. This creates a loop between the unused CO2 and the climate situation, which becomes worse and worse. [1]

## Differences in carbon emissions reduction between countries pursuing renewable electricity versus nuclear power

While carbon emission is a very popular problem worldwide, 2 solutions for this may be nuclear power and renewable energy. This analysis shows the relationship between either of these approaches and the levels of CO2.

Firstly, it states 3 hypotheses: The nuclear climate mitigation hypothesis, the renewables one and the crowding out one. The first 2 mention that emissions are expected to drop if either of the methods are approached, respectively. The third one is about their incompatibility. Based on 2 tables that show empirical evidence, one about the correlations between research variables on carbon emissions and electricity pathways and the other

about the results of multiple regression analyses for carbon emissions and electricity pathways, the first hypothesis gets rejected, the second one gets confirmed and the third gets partially confirmed.

In conclusion, renewable energy remains the safest, most sustainable and ultimately best solution in overcoming climate change. A 100% renewable energy system is achievable, can provide low-carbon electricity and is not socially disruptive. [2]

## Climate Change and Individual Behavior

Since climate change is a result of human intervention, human intervention is also needed to mitigate it. The primal root of the problem is, however, often overlooked: individual behavior. The psychology behind people's decisions and lifestyle prevents them from being proactive against this urgent matter. There is a long way until there, and here some problems are addressed:

Concern does not mean understanding – This is mainly a result of how this problem is (or used to be, but the topic is still relevant) communicated and also how our minds work. People are not fully aware of the effects on the large scale of climate change and, despite being concerned to a certain extent, the obvious, visible and close problems will have priority. This is unless they actually know about the problem. If people know, they act differently and a more effective form of communication is needed to convey an even emphasized sense of urgency. This leads to the second problem.

Understanding does not lead to action – The idea is again, that we need to understand how to make a decision. However, even if we were indeed fully rational, knowledge would not necessarily lead to action. This has to do, again, to human psychology and how it prioritizes the problems.

Whether it is by better information communication or by institutional measures, a change in behavior should be highly encouraged.

In Conclusion, a change in behavior that would make us more responsible is one way of overcoming climate change. Consuming less energy and implicating actively into the mitigation process of climate change may be the key towards a healthy world. [3]

# Chasing coral (2017) – Netflix documentary

The ocean on earth is a source of life and it controls a lot of things: the weather, the climate, the oxygen we breathe. Without a healthy ocean there will be no healthy planet.

A big part of the ocean are corals. They may look like a big carpet on the bottom of the sea or a giant rock formation, but coral reefs are actually living animals. They live and grow while they are connected to one another. Coral reefs provide a great source of the seafood we eat. It is an income and a source of food for more than 500 million people. But something terrible is happening. In the last 30 yeast, 50 percent of the world's coral was lost and a lot more will follow if humans don't change anything about their behavior.

Due to climate change, the sea temperature is getting warmer. 93 percent of the increasing temperature is absorbed by the ocean. This is the main reason corals are bleaching, other reasons are:pollution, too much sunlight or extremely low tides. An individual coral is made up of thousands of polyps, each polyp is a mouth surrounded by tentacles. In their tissues they have small plants (microalgae), a million per cm2. Those micro algae photosynthesize when there is light, corals can use that energy as a source of food. In the night, tentacles come out of their polyps and  everything that swims by is getting caught by the tips of the polyps, so that the coral has energy in the night too.

Coral bleaching is a stress response of the corals. The coral expels the algae living inside their tissues. The corals will lose their strong colors and become fully white. Corals can survive this event but they will experience a lot of stress and lose their most important food source that they have, so they often die.

Corals contain a high level of marine life. A lot of species depend on them, sponges, oysters, clams, crabs, sea stars, many species of fish and a lot more. So without reefs, a lot of other organisms will not be able to survive, resulting in a reduction of biodiversity, reducing sources of sea food and a lot more. It is actually a really big chain reaction, triggering one consequence after another. [4]

# The environmental impact of clothing returns

In the last few years, a lot of companies are offering their customers a free and easy returns system. This is a way to convince cautious consumers to buy something. Surveys showed that customers are less likely to order and buy something from a company that has negative reviews on their return system. But sending back articles is getting out of hand now, people are for example ordering 4 t-shirts in 3 different sizes in multiple colors, this phenomenon is called bracketing. Bracketing is a term for people who already know that they will send some of the products back.

Returning clothes is not only a concern for the company itself but it also has a really big impact on the environment. Most clothes are transported by heavy trucks running on diesel, they emit a lot of CO2. Sending an item back will double the amount of emission.

The returned items need to be checked before being restocked, which costs lots of work and lots of space. For many companies this is not profitable. Products which do not justify being restocked are either sold off to discounters, will be sent to a dump or will be burned. The last option is not very advantageous for the environment.

All those returns generate approximately 15 million metric tons of CO2 going into the atmosphere. While 50 percent of the returned articles will not even be restocked, according to the sustainable returns company Optoro.

Another consequence of buying different sizes of a specific article is overproduction. The specific article will get the label “high demand” which results in lots of clothes which probably end up in landfills or incinerators. [5]

## Environmental Effects of deforestation

Deforestation is the clearance of forests that can be done by removing or destroying trees which could be deliberately, accidentally or naturally.

Environmental consequences of deforestation:

- The loss of various animal and plant species. 70 percent of land animals and plant species live in forests. Also, the as yet unknown species will lose their habitat.
- The canopy of the trees in rainforests regulates the temperature. Deforestation leads to drastic temperature variations, which could be fatal for lots of organisms, even the ones outside that particular area.
- When plants and trees are lost, less $CO_2$ will be converted into oxygen.
- Trees and plants regulate the amount of water in the air. Without them, there will be less water in the air to be returned to the soil. Soil will erode and will wash away, which causes barren land with no ability to let grow food or any other plants. [6]

## Agriculture

Food production accounts for one-quarter of the world's greenhouse gas emissions and takes up half of the planet's habitable surface. The production of animal products takes longer than plant-based products. A lot more food is needed, therefore more land and water are used. In comparison to meat and dairy, plant-based foods have much smaller carbon footprints. On average, emissions from plant-based foods are 10 to 50 times smaller than those from animal products. [7]

## Collaborative economy

Platforms to share products of services, such as Airbnb, Blablacar and Peerby, have changed the ways in which goods and services are offered and consumed in the economy. This allows people to buy less products, lower production of certain products. The future environmental impacts of the collaborative economy are in general likely to be small when compared to the overall economy. Towards 2030, the collaborative economy will likely lower carbon dioxide emissions by 0.05 to 0.27 percent. [8]

## Agriculture

Meat and dairy have a much bigger impact on climate change than plant-based food, beef has the biggest impact. This is mostly because of the impact of land use and the farming process. Methane is a byproduct of the digestion of for example cows. This is a powerful greenhouse gas which traps more heat than carbon dioxide. Excluding high-emission foods from our diet has the potential to reduce greenhouse gas emissions per person by 28 percent.

*Vox. "Why beef is the worst food for the climate"* [9]

## Regulated greenhouse

Open field farming has been the primary farming method for centuries. But given the limitations of the amount of arable land and the increased awareness of sustainable development. A solution to both of these problems is indoor farming in the form of regulated greenhouses.

Regulated greenhouses can significantly decrease the number of greenhouse gases emitted. Research has shown that in the United States, agriculture accounts for about 10 percent of the emitted greenhouse gas. Globally this percentage rises to about 24 percent coming from agriculture and related uses. Greenhouses are much more efficient in the use of their energy and water. Computers monitor precisely what the plants need, and based on that. It gives more or less water and heat to the crops. Another benefit is the lack of pesticides used in greenhouses. The use of pesticides in open field farming accounts for about 70 percent of the globally emitted NO2.

To conclude, regulated greenhouses can significantly reduce climate change problems. This can be achieved because these greenhouses are much more efficient at using the given resources. Indoor farming also mitigates the impacts of water run-off, soil erosion, pesticide use, and nutrient loading (Shatokha, 2016). [10]

## Energy use in the iron and steel industry

The iron and steel industry is one of the worst polluters accounting for 6.7% of the global anthropogenic and 31% of industrial CO2 emissions. This is a lot; therefore, it is vital to

reduce this to avoid the 2 degrees rise of global temperature that is the cause of such excessive amounts of pollution.

Nearly 95% of the CO2 emissions in primary steel production are being created by fossil fuels. There are several innovative technologies in development aimed to improve or substitute the blast furnace. Some of these innovations are Top Gas Recycling Blast Furnace (TGR), HIsarna, and FINEX. It is also essential to try and find some alternative ironmaking methods, and if these are found, international instruments shall be applied to give big companies an incentive for modernization.

To conclude, the iron and steel industry is one of the biggest polluters. So it is essential to try to reduce the emissions in this sector. This can be accomplished by investing in innovative technologies and other iron/steel-making methods. After a better technology or process has been found, the world's governments need to give big companies an incentive to modernize (Stein, 2021). [11]

## Climate change on natural disasters

Climate change on natural disasters
Climate change is a phrase that you hear almost every day. But most people still do not know what the consequences of climate change are. The most notable changes are changes in the climate variability resulting in more extreme weather.

Some of the projected changes during the twenty-first century are:

- Higher temperatures; more hot days, and heatwaves
- Higher minimum temperatures
- More intense precipitation events;
- Increased summer drying; decreased crop yields decreased water quantity and quality
- Increase in tropical cyclone peak wind intensities.
- Intensified droughts and floods.

All these events have an enormous effect on everyday life. Changes include people having to leave their homes due to floods and extreme storms or people having less food due to droughts resulting in massive famine. These changes are most noticeable in Africa where people are leaving their homes due to these phenomena. These climate immigrants have already been showing up all around the European border.
In Europe, the change of temperature is less noticeable than in Africa but if you look closely then you will notice that the number of extreme disasters is coming much more

frequently. Disasters such as the flooding all around the Netherlands and Germany. Or extreme heat in parts of Spain.

To conclude, the global climate is changing rapidly and will continue to change over the coming decades and centuries. This climate change is resulting in a lot of extreme weather, which will be extremely dangerous to the continuation of the human race. It is vital that we find solutions to this change in temperature to avoid a lot of economic damage and people's lives being affected horribly (Van Aalst, 2006). [12]

## Water waste

Water is one of the most precious resources humans need to survive, but as climate changes and population rises, up to 5.7 billion people could be living in areas where water is scarce for at least one month a year in 2050. [13]

However, everytime water is used, a percentage of it is wasted, therefore by reducing water consumption it can help to strengthen the ecosystems and the risk of extreme weather events that make water more unpredictable, polluted and scarce. On top of this, using less warm water reduces greenhouse gas emissions because it avoids the energy to heat the water.

Everyone can help, from taking a shorter shower or washing at a lower temperature; small changes add up to make a big impact.

## Energy in agriculture and fishing

**Energy in agriculture:**

Food is a basic human need, and a healthy diet is a key component of our health and wellbeing. A complex and increasingly globalised system of production and delivery has developed over time to meet our needs for food and different flavours. Between 2001 and 2011, greenhouse-gas emissions from crop and livestock production grew by 14%. The demand for food is expected to grow by up to 70% in incoming decades. [14]

Before reaching our plates, food is being produced, stored, processed, packaged, transported, prepared and served. At every stage greenhouse gases, such as methane, carbon dioxide and nitrous oxide, are released into the atmosphere.

In order to reduce greenhouse-gas emissions from agriculture there can be:

- better integration of innovative techniques
- greater efficiency on meat and dairy products
- capturing methane from manure
- reducing food waste
- more efficient use of fertilizers
- consuming less meat and products with high carbon footprint

**Fishing:**

Population growth is accompanied by increasing demand for food fish. Seafood's carbon footprint is primarily affected by fuel consumption, a large boat travelling the high seas to catch a migratory species like tuna is going to burn a lot more fuel than a small boat travelling less distance to catch a local species. Where the seafood is processed can also increase its carbon footprint, because shipping seafood for foreign processing and then importing it for sale can skyrocket fuel and energy consumption, leading to higher emission rates. [15]

Furthermore, by expanding consumers' culinary pallets, there is less pressure on overfished stocks. Underutilized and/or invasive species typically tend to be more climate friendly than those seafoods oftenly consumed.

## Comercial

Greenhouse gas emissions from homes and businesses are often correlated with seasonal fluctuations in energy used primarily by weather conditions. Greenhouse gas emissions from this sector come from direct emissions including fossil fuels combustion for heating and cooking needs, management of waste and wastewater, and leaks from refrigerants in homes and businesses as well as indirect emissions that occur offsite but are associated with use of electricity consumed. [16]

Direct emissions:
Combustion of natural gas and petroleum products for heating and cooking needs emits carbon dioxide, methane and nitrous oxide.
Organic waste sent to landfills emits methane
Wastewater treatment plants emit methane and nitrous oxide
Anaerobic digestion at biogas facilities emits methane

Fluorinated gases used in air conditioning and refrigeration systems can be released during servicing or from leaking equipment.
Indirect emissions:
Burning fossil fuels at a power plant to make electricity, which is then used in residential and commercial activities such as lighting and for appliances

We can make a change by reducing energy use through energy efficiency, making water and wastewater systems more energy-efficient, and reducing solid waste sent to landfills. Also, capturing and using methane produced in current landfills, reducing leakage from air conditioning and using refrigerants with lower global warming potentials help to this problem.

## Energy use in buildings

CO2 emissions have surged over the last few years since it remained leveled between 2013 and 2016. Umbark et al. (2021) states that over one third of electricity produced in the world is utilized by the residential sector. This is due to the increasing demand for heating and cooling systems as well as unpredictable weather conditions. IEA (n.d) argues that the ongoing usage of fossil fuels, absence of energy-related policies and the lack of investments in sustainable construction is what prevents the mitigation of carbon emission. In order to improve energy efficiency in building, a yearly decrease of 2.5% in energy intensity per m2 is required to keep within the Sustainable Development Scenario (SDS) (IEA, n.d).[17][18]

## Transportation Energy

In today's day and age, it is necessary for all modes of transport (land, sea and air) to utilize energy. Moriarty & Honnery (2016) states that transport energy makes up almost a quarter of the world's energy resources. In order to reduce carbon emissions, a sustainable change in the transport industry is essential (IEA, 2009). IEA (2009) states that transportation is primarily responsible for 24% of CO2 emissions from the consumption of fuel. Furthermore, the majority of road vehicles produce almost three quarters of the transport sector.[19][20][21]

## Electric cars

Electric cars are on the rise, as a more environment friendly solution than cars that rely on fossil fuels. There remains a great flaw in the electric car industry however, and that is the cost and the life cycle of the battery. Scientists have recently been experimenting with super capacitors, which has an interesting way of storing energy. It has a vast superiority in life cycle and charge time as opposed to the battery. Unfortunately, the SCs now are not a viable solution, the energy density and the cost are just too high. But the SCs are still actively being researched, and one day there might be a great transition from lithium ion to SCs as our main energy storage. [22]

## Plant based diet

The university of California and Vox have collaborated to make this video that visualises the environmental effect of your diet here a small table according to the video:

| | |
|---|---|
| 1 steak: | 330g of CO2 |
| equivalent piece of chicken: | 52g of CO2 |
| equivalent piece of fish: | 40g of CO2 |
| equivalent amount of vegetables: | 14g of CO2 |

As you can see, the amount of carbon emissions that comes from meat is significantly higher than that of vegetables, not only is it better for the environment, it is also healthier for you as well. But you don't have to cut meat out entirely, you can just reduce your meat intake, a good example is the Mediterranean diet. It is estimated that if everyone switched to the Mediterranean diet it would have solved 15% of all carbon emissions by 2050.

(interesting subject for project: behavioural psychology in supermarkets and restaurants) [23]

## Renewable energy

Vox created a video on the practicality of implementing renewable energy in America. Which is not as straightforward as it seems. The major cities which are the greatest energy consumers and are mostly located to the west and the east. While the best places for renewable energy farms are more to the middle of America. This brings the problem of the transportation of said power, which consists of a lot of money to build it, a lot of time to go over building it, convincing the small remainder of people who don't want to sell their private property and a lot more. Meaning the renewable energy transition in America will become an expensive, time consuming and risky project. [24]

# Chapter 2: Identification of General Problems and Challenges

1. Individual responsibility awareness - individual consumption
2. Deforestation (The canopy of the trees in rainforests regulate the temperature. Deforestation leads to drastic temperature variations → global warming)
3. reduction of biodiversity
4. Greenhouses as an alternative farming method → more sustainable farms
5. Ordering food/products from abroad → encouragement of buying local supplies
6. Electricity usage → More sustainable cities and communities
7. Water waste → use less (warm) water
8. More efficient delivery methods
9. Meat and dairy consumption → more plant-based diets

# Chapter 3: Identification of Relevant Problems

1. Renewable energy in households
2. Delivery emissions
3. Greenhouse agriculture
4. Household waste management/recycling
5. Reducing energy use in buildings

# Chapter 4: Problem Selection and Motivation

The problem we wish to work on for our project is renewable energy in every home, as a way to mitigate the energy generated conventionally. Not only are the conventional ways the most influencing factor for climate change, but also their absence would solve this issue the most directly. Moreover, this would allow each person to play their part in solving the climate change. Since we would like to operate at the root of the problem, we find this problem the most “appealing”.

# Chapter 5: Potential Solutions

The problem of waste of energy and water in households may be diminished using one of the following potential solutions:

**1. Sun seeker / Solar searcher -** A little car, similar to a toy car, has a small solar panel on top of it. Instead of wheels, the car has tracks, so it has better grip. The car rides around on a roof for 2 or 3 days, for example. It rides towards the place on the roof where the most sun is. It senses when it is near the edge of the roof, so it won't fall off. In the short period of a couple of days, the car collects a lot of data about how much sunlight it catches and what position on the roof would be the best for a bigger, permanent solar panel. After this 'trial period', people would get a handy overview of where to place the solar panels and how much money the installation of solar panels could save them.

**2. Smart solar panel** - This device is made out of a solar panel mounted on top of a rod, that allows the panel to rotate by a few degrees in order to have the sunray perpendicular to it. The panel rotates throughout the day, in a similar manner to a sunflower, in order to capture the maximum amount of sunlight possible. The energy captured can be used to contribute to powering the house's facilities.

**3. Movable reflective surface** - Solar panels are heavy and it takes energy to make it tilt some degrees in order to be at the most efficient angle. However, by adding a movable reflective surface containing sensors, we can redirect the sunlight towards the solar panel and the solar panel can absorb the direct sunlight in a similar way to the previous solution. The benefits of this is that a reflective surface (e.g. Aluminium) is less heavy compared to the solar panel and requires less energy for moving.

4. **Energy generating floor -** This energy generating floor can generate power. By being walked over, it converts kinetic energy into electrical energy.
The floor consists of different panels, if you take a step on such a panel it will sink down. A specific kind of dynamo is placed between the floor and the panel and converts the kinetic energy of the moving panel to electrical energy. The energy that is generated can be used to make a lamp light up in the room, since there is someone in there. If the person doesn't move anymore, because he or she for example sat down on the couch, the normal electrical source could be used to keep the lights turned on. By applying sensors at the door frames or a movement sensor on the ceiling, the system will know if there is someone in the room. If not, the lights can be turned off automatically.

5. **Solar water heating system** - This is a "device" that turns solar energy into warm water without the use of excess heating. You can envision it as a kind of solar panel on your roof but instead of a solar panel it is a really isolated box with pipes running next to each other in a zigzag pattern with glass on top so the sun rays can shine in and heat the pipes. The heated pipes will then heat the water which can be sent to the rest of the house. You could then add a smart interface in your house that sees or you tell when you need warm water. It then sends water through the panel which will then get heated and sent to the desired place. It

can also be used constantly for heating your house this can also be made smart by telling it when you want to have your houses heated and when cold.

6. **Green gym equipment** Gym machines, such as treadmills or rowing devices are connected to dynamos which generate power while used. This way we can generate electricity at home while working out and this way we preserve some of the effort put into the exercises and we transform it into energy that can be used for various purposes.

7. **Smart irrigation system** – This system is meant to sprinkle water in a garden in a sustainable way. This consists of four main components: a hydro generator, a water pump, a sprinkler and a humidity sensor. The hydro generator, which is a water dynamo, is located inside drain pipes and is supposed to generate energy every time it rains. This is connected to a water pipe that pumps water into the sprinkler if the humidity sensor is below a certain level. The idea is that as soon as it rains, we store the water and the energy generated by it and we use them to irrigate the garden after some time without rain. The system is triggered by the humidity sensor.

# Chapter 6: Solution Selection

Our selected solution is the smart solar panel system (Smart Sunflower). The purpose of the Smart Sunflower is to rotate according to the sun position and harvest the maximum amount of light energy. The Smart Sunflower's small form factor makes it convenient for users to install it anywhere on rooftops. We believe that this approach is a better way to tackle climate change compared to our other solutions as it is easier to implement, while being equally relevant. Avoiding tedious work to build the prototype may buy us some time that we can use to assure that the device is working or maybe even improving it. Moreover, this device can have multiple applications, from simply behaving like a regular (yet more effective) solar panel, to assessing how effective it would be to install bigger solar panels, together with the optimal angle for them.

We have split the work as following:

Matei:
- Team leading and management
- Research on materials needed and how to apply them
- Building the device
- Purchasing the extra equipment

Eva:
- Research on materials needed
- Programming 1
- Building the device

Simon:
- Updating the documentation
- Data collection and analysis

Allard:
- Purchasing the equipment
- Programming 2

Lucas:
- Testing and validation
- Programming 2

Natalia:
- Updating the documentation
- Testing and validation

Odyl:
- Research on how to build the device
- Building the device
- Marketing

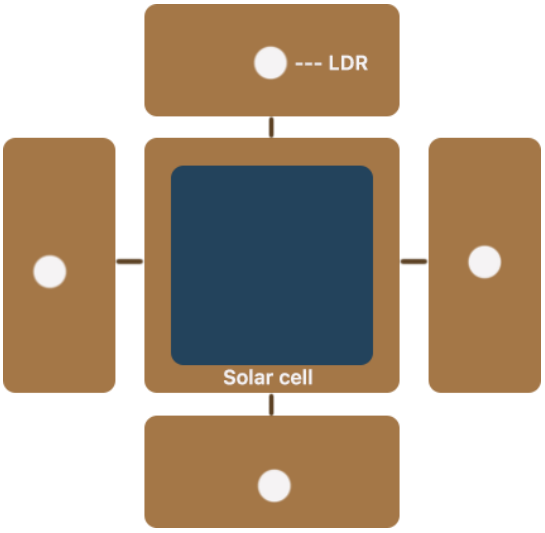
# Chapter 7: Methodology

## Overview

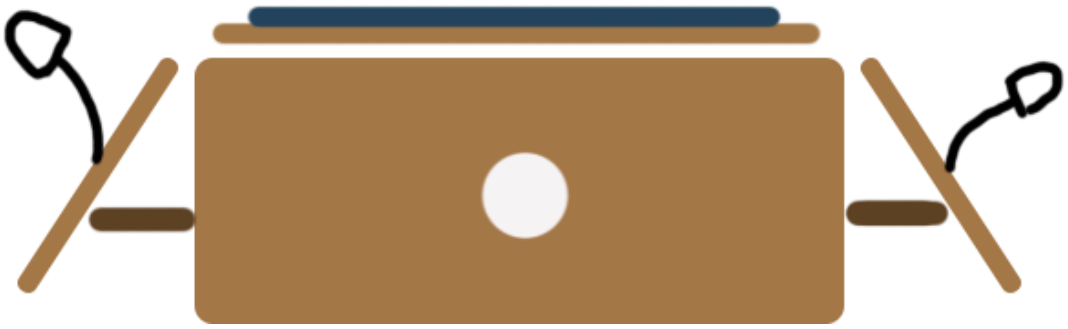
Our idea consists of a solar panel mounted on a movable support that rotates according to the sun position, in order to have the sunrays perpendicular on the surface of it, in a similar way to a sunflower. It is positioned on the roof of the house and in this way, the solar panel will generate the highest amount of electricity for the household usage.

### It consists of:

- An upper platform divided into 5 segments – one in the middle (B) and 4 around it (A). The middle segment is horizontal (in the initial phase) and contains the solar cell(B). The rest are inclined and each of them contain light sensors. (A)
- 2 RC servo motors, mounted perpendicularly. This combination allows the upper platform to move in all the necessary directions. (B)
- An Arduino board and all the necessary circuitry to perform the data reading, processing, analysis and writing. (B & A)
- LCD to display the values and the efficiency of the device. (B & A)
- Other building materials – wood, nuts and bolts. (B & A)
- Temperature sensors – for even more accurate analysis (A)




*Upper platform – view from above*



*Upper platform - sideview*

How it works:

The main idea is about measuring or inputting the light intensity for certain angles. The data is analyzed and processed and the Arduino sends it to the motors that perform the actual rotation. The data read from the solar panel is processed with the help of a program and then displayed in terms of solar irradiance.

## Extra equipment needed:

- Extra photoresistors
- Photovoltaic cells
- Extra Arduino board
- Wooden platforms
- Bolts and nuts or screws
- 360 degrees – continuous rotation – servo motor

## Basic scenario (B)

The implementation of the rotating part of the device, together with the data displaying on the LCD are present in both scenarios (B & A). The main difference will be about the factor that actuates the device. In the basic scenario, data regarding the sun angle and azimuth for specific places on Earth and at specific moments are inputted in the device. The program then sends the data to the servo motors that performs the rotation according to an

algorithm. Using another algorithm, the data read from the solar cell is processed and displayed on an LCD.

## Advanced scenario (A)

For the advanced scenario, light sensors will be used as the factor which sets the motors off. Each sensor generates data. The data provided by each sensor is processed using a program, then compared with the data from the rest of the sensors. Finally, the device rotates towards the position of the LDR which generate the highest values.

### Extra ambitious plan

The data provided by the solar panel may sometimes fluctuate too much. In order to have more consistent values and if the time allows us, temperature sensors will also be fitted together with the solar cell and the data provided by all of them will be combined using another algorithm and finally displayed on the LCD.

## Testing and Validation

The testing and validation will be done in 2 different ways, depending on the scenario. Both of them are based on the same principle: comparing the values provided by the rotational solar cell to the values provided by a stationary solar cell.
Since the sun in this period cannot provide accurate information for a device of such small caliber, an alternative light source will be used and the position of it in terms of angles and azimuth will be manually inputted.
For the ambitious scenario, an alternative light source will be used again, but this time, the light source is movable. This way, we can present an immediate demonstration, compared to the almost unnoticeable rate at which the sun actually moves.

# Keeping track

In order to ensure that everyone knows what they have to do, we are using agendas to present updates on our progress and also track it.

## AGENDA WEEK 6&7

**Date:** 23/12/2021 ~
**Start Time:** 12:00 ~
**End Time:** 12:50
**Location:** Discord ~

**Present: Matei, Eva, Odyl, Simon, Natalia, Allard**
**Not present: Lucas**

**Steps for this week due Thursday 23th:**

- chapter 6
- chapter 0
- chapter 7

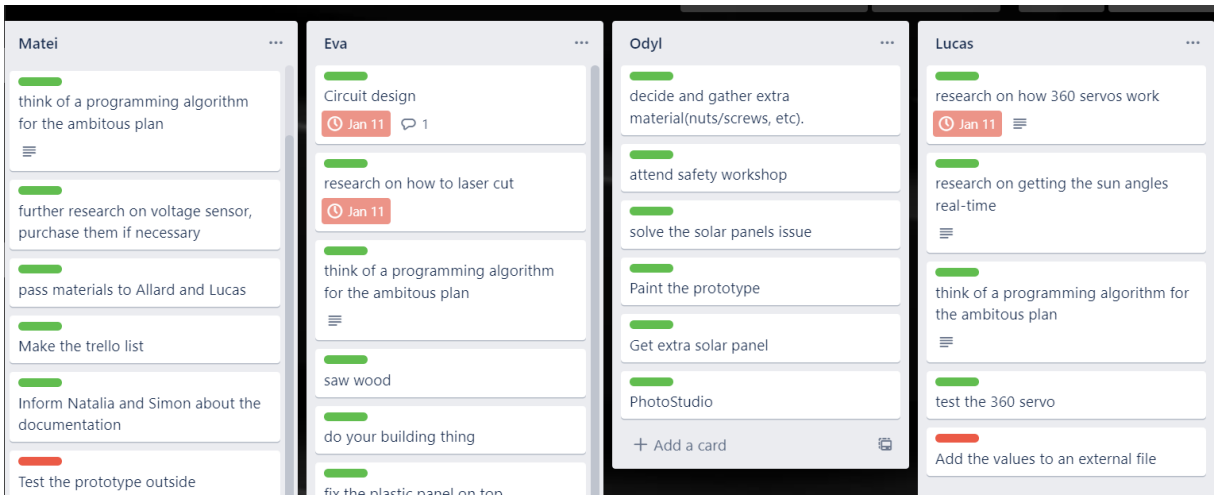
**Agenda:**

- change what needs to be changed

**Tasks:**

- Natalia and Simon change chapter 6 with better arguments, chapter 0
- Matei and Allard order the components
- inform Lucas on what he missed

Additionally, we decided to make use of Trello for an even better overview and understanding of the tasks.



# Chapter 8: Validation

We decided to resort to the ambitious plan as our final result. We created the Smart Sunflower that behaves, to a certain extent, like a sunflower, which means that we managed to make it rotate towards the position of the most powerful light source.

In order to validate our device, we used flashlights of our phone as an artificial light source and input data.

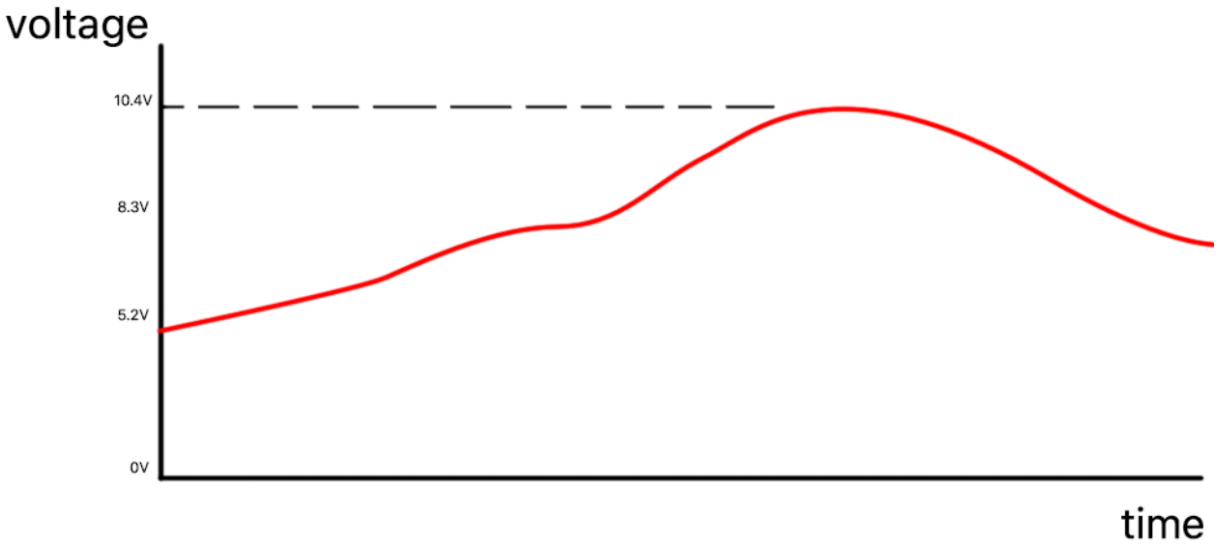
The first step was to check if both servos would work properly. The Smart Sunflower was able to follow the flashlight position. However, it was pointed out to become ineffective after a while, due to the wires, which were getting entangled when the device rotated for too long.

The second step was to measure the data from the main solar cell, situated on top of the device, then measure the data from a lying solar cell and compare how the data fluctuates when we moved the flashlight around it, from a constant distance. Due to the windy and cloudy weather, we were not able to test it outside, as initially planned.

However, we were not able to collect accurate data from the solar cells, firstly because we did not have the 6$^{th}$ voltage sensor for the 6$^{th}$ solar cell (the lying one), and secondly because of the other light sources in the room. Nevertheless, we managed to find a few solutions: for the lying solar cell, we used a multimeter to measure the values and manually collect them and for the solar cell on top of the device we manually collected the values as well. The following graphs are estimations of the data collected.

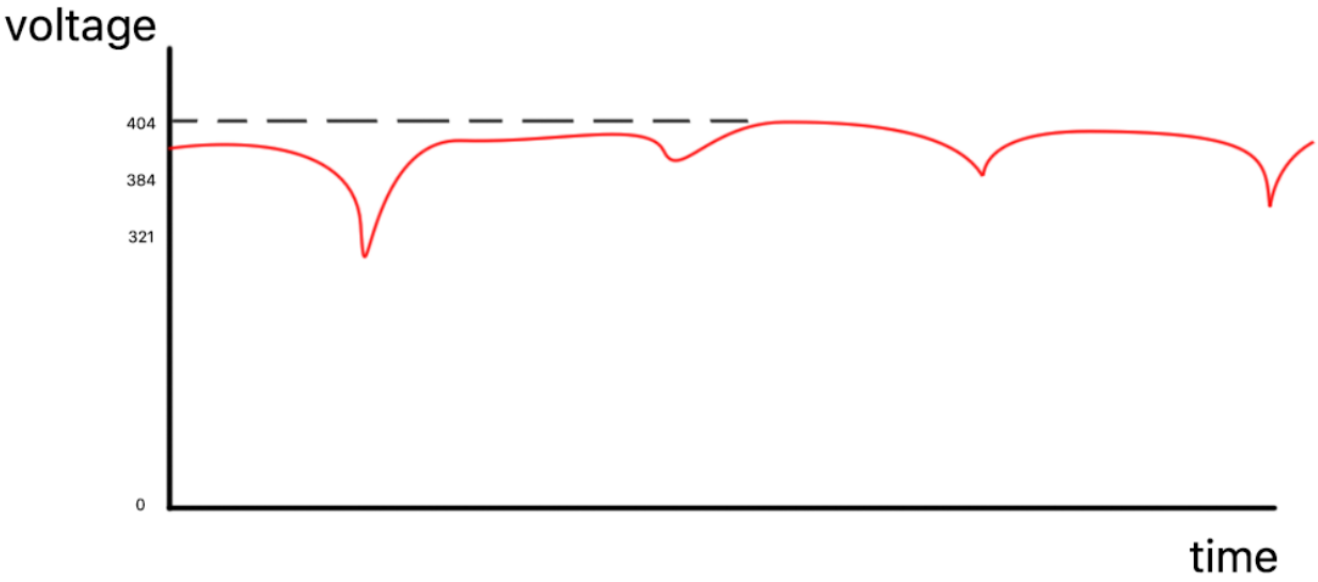
Results:

For the lying solar cell:




*Although the solar cell is a 12V type, the flashlight was not bright enough to generate that voltage.

For the Smart Sunflower:




The values displayed in this graph are the values we collected read in the Arduino serial port from the solar cell. In order to convert the voltage from the solar cell to the Arduino serial port we first divide the voltage by 5 (in the voltage sensor), then we multiply it by 204.6 (the voltage to analogRead() value factor. With this calculation, the highest value on the solar cell is 9.87 V, a lot more consistent. The difference between the 2 maximum values is due to the distance between the solar cell and the flashlight. We needed a higher distance in the second situation so that all the sensors could see the light, hence the apparently smaller value.

As we can see, there is an obvious difference between the 2 graphs. Despite not being entirely accurate, this difference highlights the main idea around which our validation revolves: the fluctuation of the values.

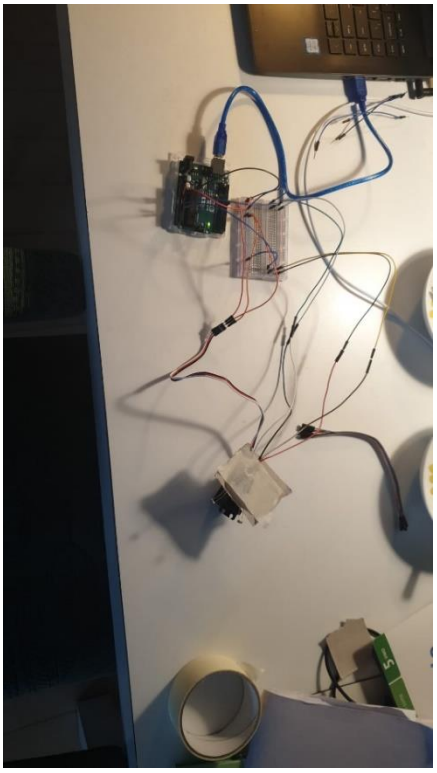
# Chapter 9: Results and Conclusion

As with every project, we had our successes and difficulties as well. We managed to stick to the ambitious plan, we managed to program the Smart Solar Flower to rotate towards light, but we had our downside with the validation process.

## Problems encountered

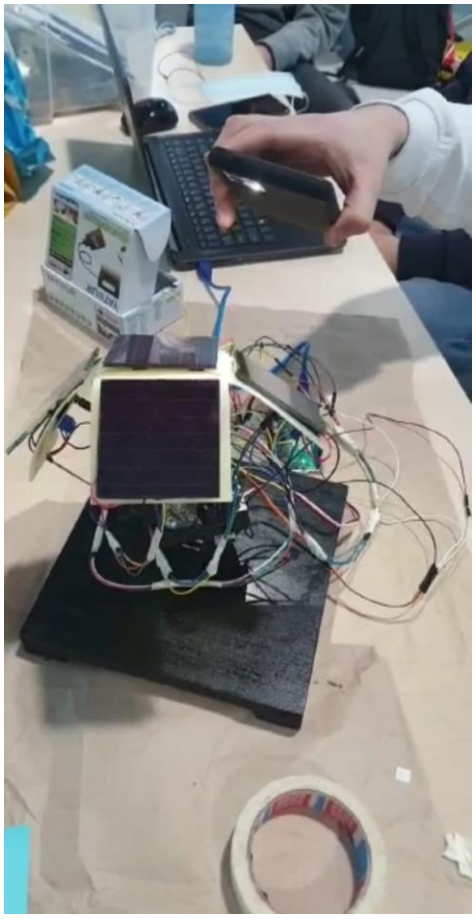
The weather was not favorable for our testing and we did not possess enough materials. This led to improvising, to a certain extent, for our data collection, gathering information and plotting them into graphs manually. Comparing them side by side, we can indeed see that the values from our device are consistent, with small drops which appeared when we moved the light position. Since the device does not instantly rotate, the values can not be 100% consistent. We are, however, confident that our device does generate more energy than a immovable solar cell.

## Pictures



Making the servo rotate according to the data provided by 2 LDRs

Our completed base prototype, without sensors



The full prototype moving, circuitry included,
Moving towards the flashlight of a phone

## Discussion

In a real-life situation, our device may have multiple purposes. Our initial idea was to create a device that collects data about the sun position and brightness, as a trial solar panel, in order to know the best angle for a proper solar panel. We would mount it on top of a house and have it providing us with information that would help the user know how to install a solar panel for his house/building. Our device is still capable of doing this.

However, we decided to change it into a Smart Sun Flower that simply follows the sun in order to generate the highest amount of energy. The problems we faced are easily solvable in reality, by simply using higher quality sensors, using proper cable management and protecting the device properly. Regardless, there are areas of improvement in our projects as well. A potential user may require a more convincing testing and proof that our device works. A better code could also play an important part in making our device even better.

Since the current conventional ways of generating energy represent a significant threat to our planet, switching them to renewable and sustainable one is a great step towards

mitigating global warming. Efficiency is key in this process, and with our prototype (which as a big project can be a lot more relevant) we managed to find a way towards achieving it. The Smart Sun Flower generates more energy than a fixed solar panel, which may persuade people into owning one themselves.

To conclude, we believe that we managed to follow our plans to a decent extent. With more time, more research and more information such a project could be a significant help in overcoming global warming.

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