UNIVERSITEIT TWENTE.

# SMART ENVIRONMENTS PROJECT

## DOCUMENTATION REPORT


**Snow White (Smart Window)**
Team 9

Lieke Zoetelief
Nienke Dik
Milou de Zwaan
Julia Kersten
Anne van Esch
Hana Šinković
Ewoud Janus

UNIVERSITEIT TWENTE.

UNIVERSITEIT TWENTE.

UNIVERSITEIT TWENTE.

## Table of Contents

## Chapter 0: Introduction

Welcome to the project report of team Snow-white of Year 1 Creative technology. This quartile project focuses on battling climate change. To battle this problem there has been focused on lowering the energy consumption within households. The topic has a strong connection with fossil fuel consumption, which is one of the largest causes of climate change, as households, along with being numerous, often rely on them as sources of energy. By making a window that automatically shuts itself, there has been aimed to optimize the household heating system (less use of fans, radiators, air conditioners, etc.) and to properly handle breathability of a room, in the hopes that energy is used more conservatively.

When looking at energy consumption from households in the Netherlands, 19% of the energy is used for the house. 62% of the house energy is used for heating or cooling the house. This will be further discussed in Chapter 3 on the energy consumption of households in the Netherlands.

Furthermore, a calculation has been made to look at the effect of the solution. The calculations have been made for a normal student house. The amount of energy waste from a room depends on these things: the size of the window opening, the time length the window is open and the heat transfer velocity. The calculations can be found in Chapter 7. The result from the calculation is that by using openable windows a household can use 1212 Liters less fuels in a year and this saves a household €2396. If the cost of our product will be beneath this price, the solution will be favorable.

## Chapter 1: Literature Review

| about | summary |
|---|---|
| [1] Extreme wetter | This text is about understanding the link between climate change and extreme weather. The writer states that: “An understanding of the meaning of risk and how it relates to changes in the climate system is crucial to assessing vulnerability and planning for a future characterized by rising risk.” Rates from Historic and recent extreme weather shows that extreme weather becomes on an average more destructive over time. Trends show that climate change will lead to long periods of relative heat, drought and rain. The increasing number of melted glaciers, wildfires, floods and droughts make the climate change visible. The future risks of extreme weather can be reduced by reducing the emission of greenhouse gasses and adapting to unavoidable changes. |
| [2] Global energy consumption | The demand for energy is growing by 1 to 2% on average every year around the world. This happens because people get richer and populations increase, but not in every country is this the case. In some of these countries the energy consumption is falling (, in the Netherlands with 1%), but it is not enough to make up for the rising energy demands in other countries. The rising demand for energy is an issue when we want to switch to sustainable solutions. |
| [3] Biodiversity redistribution due to climate change | Many different species are relocating due to climate change which affects human communities as well. Because they are relocating, key interactions between species are now disrupted and new ones are forming which could also have an effect on humans in the long run. It also creates a divide between regions that are more affected than others and also causes migration of people which can cause overcrowding in some areas as everyone tries to escape their habitats. Species such as mosquitos which sometimes carry diseases are also relocating, thus affecting human health as they now appear in regions that are unprotected / weren’t affected before and millions of people will be at risk. Current policies and agreements do not take into account this shift in biodiversity and therefore it is likely to be inevitable unless new policies are made. |
| [4] Algae filtering co2 out of the air | In order for algae to be grown only 3 elements are needed: co2, light and water. Algae produce and contribute 50% of the oxygen we humans breathe. The company Hypergiant has built a machine called the EOS-bioreactor which utilizes the ability of the algae to convert co2 into oxygen. According to them, the machine is able to convert as much co2 into oxygen as 4000 square meters of forest. After the algae have absorbed co2 they can be used for animal food or food supplement. |

| | |
|---|---|
| [5] Role played by universities in negotiations of climate change should improve | Universities across the world perform research on matters related to climate change, both in respect of mitigation and adaptation. Yet there is much room for improvement in the role played by universities in the negotiations and in influencing decision-making on a matter of such a global importance. The book is written after a symposium about Universities and Climate change organized by Manchester Metropolitan University. |
| [6] Sustainable Water Management in Agriculture under Climate Change | Water is considered as the most critical resource for sustainable agricultural development worldwide. Due to climate change water availability will decrease in some areas. Furthermore, the efficiency of irrigation is very low, since less than 65% of the applied water is actually used by the crops. The sustainable use of irrigation water is a priority for agriculture in arid areas. |
| [7] Generating energy with plants | Living plants are able to generate energy for LEDS. In this article it is explained how whole plants are used for energy conversion.<br>A plant converts mechanical stimuli by inverting electrical signals.<br>The power outputs on a single leaf are approximately 15 µW $cm^{-2}$*N<br>This also depends on plant species, leaf structure and type of material that touches the leaves.<br>For the first time it is shown that plants could harvest natural mechanical stimuli like wind energy. This makes plants a sustainable living harvester of wind energy.<br><br>company: https://www.plant-e.com/en/<br>This is a company that generates energy by living plants. This energy source could be used where the plant is placed. Furthermore, the plant will reduce methane emission and store C02. How it works: bacteria surrounding the roots of the plants break down organic material made by the plant. By breaking down this organic material protons and electrons are formed. The electrons are connected in the anode of the plant battery, and flow through a wire to the cathode. |
| [8] Greenhouses in cities | Climate change is one of the biggest challenges facing humanity, seriously impacting production, life and the environment on a global scale. This will have influences on processes such as energy, clean water, food, accommodation, employment, diplomacy, culture, economy and trade.<br><br>Cities in Vietnam are growing fast, this has led to a polluted atmosphere. By increasing the green area, the absorption of emissions increases. Furthermore, the quality of life of residents could be positively changed. Some applications are explained: covering buildings with plants, vertical gardening, roof gardening. |

| | |
|---|---|
| [9] Phytoremediation | Soil salinization affects 1–10 billion ha worldwide, threatening the agricultural production needed to feed the ever-increasing world population. Phytoremediation may be a cost-effective option for the remediation of these soils.<br><br>salinization is oversalting = salt in soil |
| [10] Kite power | A kite is used to convert wind energy to electricity. It is transportable and could be used at open areas like the seas. The kite floats at 800 meters height. A wind turbine is around 100 meters tall. At 800 meters the wind blows twice as hard as at 100 meters, because of that you can generate more electricity. You can also use these kites at sea-going vessels to replace propulsion from the main engine. You have kites with an output of 200 kw already today and outputs in the Mw range will come soon. |
| [11] Impact cement industry on the climate change | The cement industry produces about 5% of carbon dioxide emissions. When producing 100 kg of cement, the industry will emit about 900 kg of CO2. because of changing policies due to climate change, the cement industry will be at financial risk, because of producing so much carbon dioxide emissions. The industry is now facing challenges to reduce its emissions and its dependence on fossil fuels, dependence on limestone based clinkers. |
| [12] Impact of climate change on human diarrhea | Climate change will have a large impact on many things such as human health. The objective of the study was to find a method that could show the health impacts of climate change while handling certain uncertainties. They used 5 studies and a model that shows future greenhouse gas emissions and they analyzed 6 geographical regions. The results were that with a temperature increase of 4 degrees the risk of diarrhea in the six regions was 8-11% for the first half-century and 22-29% for the second half-century. |
| [13] Can developing countries adapt to climate change and extreme weather | Developing countries are more vulnerable to extreme weather. The extreme weather conditions will increase because of climate change. To be able to adapt to climate change is dependent on the capacity and the development models that the countries will have to adapt. When developing countries get support from others, it is usually for recovering from a disaster rather than a creation of adaptive capacity. By changing that support and investments from other countries you get a long-term solution for the problem instead of this temporary solution. So donors and lending agencies should change their investments to capacity building instead of recovering problems. |

| | |
|---|---|
| [14] Water Scarcity | Around the globe 1.2 billion people lack access to clean drinking water. For most people in the western world water scarcity is one of the smallest problems they have to deal with because of climate change. But for a lot of people it is the biggest. Some causes are the overuse of water, especially in agriculture; water pollution, like oil spills; Droughts, because of the rising global temperature.<br><br>A solution for the agricultural sector could be the use of water on meats instead of products that use less water (bread for example) |
| [15] Bees disappearing | Due to multiple factors of climate change bees are losing their habitat. Forests that are destroyed/burn down, meadows that get destroyed and more. Together with the increase of pesticide use the amount of bees have decreased from 6 million in 1947 to 2.5 million in 2019.<br><br>Bees having an influential role in the earth's ecosystem, would mean catastrophic effects if they would vanish. Plants would no longer be pollinated which includes fruits, vegetables, nuts and grains we rely on. |
| [16] *C*limate change effect on food supply | A global assessment of the potential impact of climate change on world food supply suggests that doubling of the atmospheric carbon dioxide concentration will lead to only a small decrease in global crop production.<br><br>But developing countries are likely to bear the brunt of the problem, and simulations of the effect of adaptive measures by farmers imply that these will do little to reduce the disparity between developed and developing countries. |
| [17] Consequences of Climate Change | The ice caps are melting due to the earth warming up and thus sea level rises as the ice becomes water. This results in flooding and erosion of low-lying lands. Floods caused economic losses of more than 90 billion euros and affected more than 5.5 million people in the EU between 1980 and 2011. Furthermore, many wildlife species are struggling to cope and hence are relocating. Another issue: sectors such as agriculture, forestry, tourism and energy who rely on certain temperatures are particularly affected by climate change economically. |
| *[18]* Consequences of the lockdown on the global environment and energy consumption | This publication talks about the consequences that the COVID -19 pandemic of 2020 and its lockdown had on the global environment, and the fossil fuel and energy consumption. The gathered results show that the lockdown had a positive outcome, lowering the impact of; ozone formation, terrestrial acidification, freshwater eutrophication, marine eutrophication, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, land use, mineral resource scarcity and cumulative exergy demand by ~ 11% to ~ 25% (with respect to the 2019 results). The publication acknowledges that the pandemic is still an evolving scenario and suggests that time could contribute to lessening the consumption of fossil fuels, and by doing that intensifying the environmental benefits. The limitations are the ways in which the industries plan to restart the economies, as it could easily lead us to a worsening trend. Further, |

| | |
|---|---|
| | intentional “environment oriented” lockdowns are something the publication would encourage to study further. |
| *[19]* How will the fossil fuel industry progress | The topic of this publication is how the COVID-19 pandemic creates an opportunity for phasing out fossil fuels. It states that while fossil fuels will be phased out in compliance with the climate objectives, like the 2015’s Paris Agreement, it is also important to note that a push must be created to discourage future investments and growth of the unsustainable industries. Their findings suggest that this pandemic was indeed that push, retiring fossil- infrastructure, devaluing the financial assets and generating mass unemployment of the fossil fuel industries. It is said that “Political leadership could avoid a socio-ecologically and relationally exclusive and reformist recovery” [1]. The COVID – 19 pandemic is still ongoing, and governments are doing anything to warrant an economic recovery, this publication predicts 4 of the possible scenarios. Firstly- A reformist recovery, revitalizing the fossil industry. Secondly – A social recovery that focuses on the social needs of the people, at the expense of ecological development. Third – An ecological recovery that focuses on climate policies even if it’s at the expense of the people. Fourth – An inclusive and transformative recovery that promotes social, ecological and relational inclusiveness. |
| *[20]* Employment transition from fossil fuel industries | While this publication focuses on the employment rates of Canada, I believe that as a developed country, we can still gather meaningful data and info from it. Only 1% of total payroll employment falls under the sectors of fossil fuel industries (which is about 170,000 jobs). From the data gathered they saw a significant decrease since 2014, with around 33,000 jobs permanently disappearing. We also have to note that overall employment in Canada is strongly growing, and the unemployment reached a record low in 2019. During Covid, another 17,500 jobs disappeared, which is more than in other aspects of the economy. The writer predicts that the industries will slowly become insignificant as a source of new jobs and that the governing bodies should embrace the change. |

| | |
|---|---|
| *[21]* Recent Advances in Understanding the Effects of Climate Change on Coral Reefs | Ongoing increase in ocean temperatures and the acidification of the water are altering the function and structure of coral reefs. The change in temperature seems to be the factor that impacts coral reefs the most over short-medium timeframes. Although there is some evidence that coral reefs can change and adapt to warming climates, it largely depends on the rate of chance and if they can keep up with it. The effect of climate change is also affecting the coral reef fishes as it directly affects their physiology and behavior in a negative way as they are losing their habitat on a large scale. |

.

## Chapter 2: Identification of General Problems and Challenges

In this Chapter problems & challenges of Climate change are explained.

**Extreme weather [1]**
Climate change will lead to long periods of relative heat, drought and rain. This is caused by the accumulated heat due to the increase of atmospheric greenhouse gas. Measurements show that there are already extreme periods of rainfall and intensifying heatwaves. The increasing number of melted glaciers, wildfires, floods and droughts make climate change visible. The future risks of extreme weather can be reduced by reducing the emission of greenhouse gases, this falls under mitigation. Mitigation is taking action to reduce the severity. Furthermore, adapting to unavoidable changes is already necessary.

**Decrease in food supplies, because of the decrease of nutrients in soil [9] [30] [31]**
Increase of CO2 levels in the atmosphere is a big part of climate change, increasing levels of CO2 in soil can have effects on availability of nutrients in soil. When CO2 increases, decomposing organisms need more N, this reduces N mineralization. N mineralization is an important factor in making N available for plants. So reduced N mineralization can negatively affect plant activity. The effects of an increase in temperature are not sure. A study found that an increase in temperature improved N mineralization, but another study found that this effect started to diminish after approximately 1 year.

**The development of fossil fuel industries [18] [19] [20]**
We found out that the COVID-19 pandemic gave us a push that we needed to further reject fossil fuel industries. The employment rates and financial assets for those industries are experiencing a decline, so the question for the future is whether the investors / governments will embrace the positive change or if they will seek to reform back to normal. It is important that ecological industries continue to be embraced and popularized, so that the fossil fuel sectors die out, but of course this comes with its own problems, such as the different impact it will have on the developed and the developing countries.

**Changes in Biodiversity [3] [21]**
Due to large increases in temperature and increasing levels of carbon dioxide, mother nature is having difficulty coping with it. Especially for wildlife, species are relocating to other parts of the world as their living habitat continues to decrease. Some species go extinct because there is no place on the earth for them to live on, which also affects the ecosystem in the long run. Now certain key interactions between species are disrupted and new ones are formed which we do not know what the Longterm effects of it are. One of the ecosystems that is heavily affected are coral reefs. Due to rising temperatures and acidification of the ocean due to carbon dioxide combining with water, many corals are struggling to survive and the fish that depend on them also are starting to disappear. This can also have an effect on humans as coral reefs often reduce the impact of large waves such as tsunamis and so without them tsunamis and such will cause a larger amount of damage to the human population. Therefore, changes in biodiversity are one of the big problems occurring due to climate change.

**Water scarcity [14]**
Most developing countries deal with water scarcity every day. Where for most western countries water is something almost nobody has to worry about, developing countries face water shortages every day. Because of climate change that causes droughts, inconsiderate usage of water, and much more, people in developing countries do not have access to clean drinking water. This causes more than most would think.
Lack of access to the drinking water means that people dehydrate, a human body can barely survive without water. Livestock will die which can cause hunger. People resort to drinking unclean water which will result in diseases.

**Adaptability of Developing Countries [13]**
Developing countries face a lot of problems due to climate change. For instance, because of extreme weather conditions, there might be floods or droughts that will affect the country. Because these developing countries cannot deal with all the problems themselves, they will need support from other countries or donors, which they get. But the problem is that the support that the countries give is to help recover from a flood or drought, instead of financing for developing solutions that will help against the next flood or drought or any other type of problems that climate change will give.

**The impact of the cement industry on climate change [11]**
The cement industry emits 5% of all carbon dioxide emissions that affect climate change. When the industry produces 100 kg cement, there will be 900 kg of CO2 emitted. The changing policies on climate change will put the cement industry at risk because they produce a lot of carbon dioxide, and carbon dioxide has a huge impact on climate change. The industry struggles with reducing its carbon emissions and dependence on fossil fuels which will eventually disappear.

**Climate change migration [22]**
In the present, only 1% of the earth's landmass is a barely livable hot zone. Due to climate change, this could go up to 19% in 2070. If a landmass where now many people live become a hot zone they would have to migrate. The zone for the temperature for abundant food production moves north. That is the niche the humans lived in for thousands of years. In 2070 one third of the human population will live outside these niches if they don't migrate. Researchers found that in 2100 places on earth, like India and East China, it could become so hot that it would be deadly even for the fittest humans to go outside for a few hours. People are already fleeing from some places due to droughts and floods. If nations welcome climate migrants with the preparation they could be a huge help with the aging workforce in most of the western countries. If nations choose to seal off their countries, they will trap the migrants in unlivable circumstances which will most likely result in war in different regions. The competition and poverty in some barely livable hot zones already break down some cultural and moral boundaries. A model suggests that the amount of climate migrants will rise each year regardless of the range in temperature, but when it actually rises it increases substantially. Countries WILL HAVE TO PREPARE for climate change. Migration can cause population shifts. Rising sea levels will also be the cause for even more migration. The migration will most likely move to big cities in their own country, which will cause rapid

urbanization. Only if the city itself fails the migrants, they will start to move to other countries and take even riskier journeys.

# Chapter 3: Identification of Relevant Problems

In this chapter 5 new relevant, urgent and interesting problems are explained.

**Inorganic waste management in industry [23] [41]**
Gas and leachate formation are unavoidable byproducts of solid waste disposal in landfills, at both existing and new sites, they pose major environmental problems. These problems, in addition to possible health risks, include but are not limited to fires and explosions, vegetation damage, disagreeable aromas, landfill settling, groundwater contamination, air pollution, and global warming. Because of that, we should aim for optimal waste management programs. One of the aspects of it is waste sorting. While it is present, further improvements and regulations should be made. [23] The Netherlands now dumps 1.5 to 2 million tons of trash into landfills every year. That is barely 2% to 3% of total garbage creation, which is around 60 million tons per year. Landfilling is mostly used for garbage that cannot be recycled or incinerated. While it is not a considerable amount when looking at the global scale, for a small country, some changes should be made. [41] A way that we can promote better waste management is to give people the option to put even less waste into the gray bin, they would also be further motivated by the price of the waste tax getting lower (since they would need to empty their gray container less often).

**Types of Energy in Households in the Netherlands [25]**
Currently our homes are powered with energy from nonrenewable sources such as fossil fuels which makes up 80% of the world's energy supply. It is estimated that fossil fuels will run out in about the year 2060. By the time we run out of fossil fuels, it will have made a huge impact on the climate as fossil fuels also contribute to the large amounts of greenhouse gasses in the air. This thickens our atmosphere and causes the temperature of the Earth to rise as sunlight gets trapped inside. The reason why not everything has been moved to renewable sources of energy yet is because governments and people in power have not taken drastic measures to counter it and because they don't invest in the right incentives. In the US, the fossil fuel industry receives at least $20 billion in direct federal subsidies and so it encourages the industry to keep going with what they're doing. But the people themselves have also power to help the planet and choose sustainable energy sources in their own homes.

The average household in the Netherlands consumes 2.730 kWh in a year. [37] The households use 20% of the total energy consumption in the Netherlands. [38] An average household will in theory need around 10 solar panels to generate all the electricity needed. [40] In the Netherlands. At august 30$^{th}$ 2021 the 1,5 millionth house had placed solar panels on their roof. That's a beginning but not all houses have 10 solar panels on their roof. In the Netherlands there are 38 energy suppliers. 5 of them are 100% sustainable. Energy suppliers in the Netherlands have been given a grade from 0 to 10 (10 best) about their sustainability. The big energy suppliers are sadly not the biggest. To name a few: Essent (4,8), Nuon (4,3), Eneco (8,1) and Engie (7,7). So you see that households in the Netherlands are mostly not that sustainable jet. Even though this is the part where you the consumer can

actually decide to make the world a little better by choosing where your energy comes from

**Met opmerkingen [DB1]:** is this good enough? I really couldn't find much households and sustainable energy is just to specific to find....

**CO2 emissions caused by passenger road vehicles**

In 2018 one-fifth of total global $CO_2$ emissions was caused by transportation where most (45%) is contributed by passenger road vehicles [24].

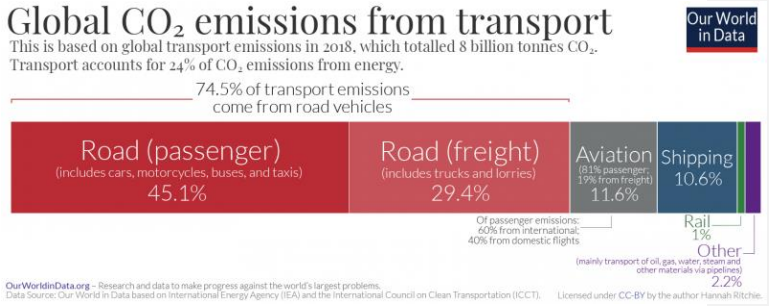


*Figure 2: Global CO2 emissions from transport []*

The transport demand is expected to grow across the world in the coming decades, as the global population will also most likely increase. The International Energy Agency expects global transport to double and car ownership to increase by 60% and passenger and freight aviation to triple by 2070 [26]. Of course, this leads us to the question, how will we be able to reach net-zero emissions?

**Energy consumption in Netherlands households[?]**
In the diagram below you can see what causes the CO2 emissions in Dutch households.

Met opmerkingen [DB2]: this is not really energy consumption though but it is interesting (:

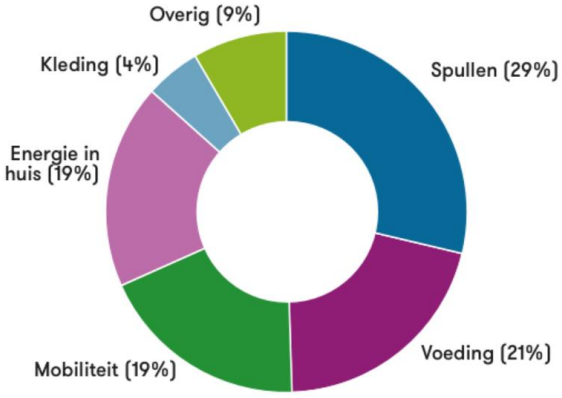


*Figure 3: Causes of CO2 emissions in Dutch households [39]*

Translations : Spullen (29%) = stuff, Voeding (21%) = food, mobiliteit (19%) = mobiliteit, energie in huis (19%) = energy in homes , kleding (4%) = clothes & overig (9%) = other

In this diagram you can see the general energy consumption of a household in the Netherlands.

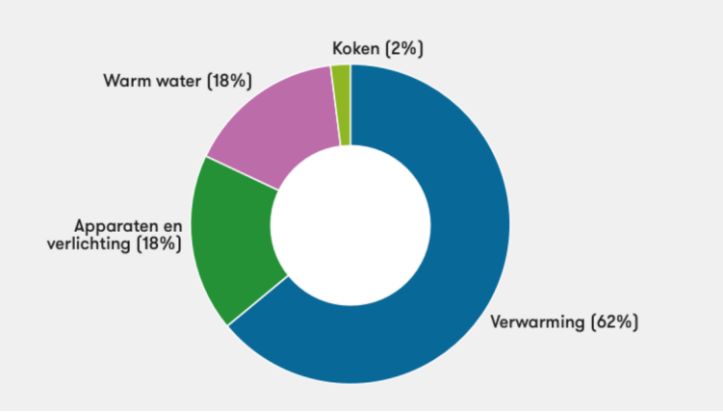


*Figure 4: General energy consumption of a Dutch household [39]*

Translations: verwarming (62%) = heating apparaten en verlichting (18%) = machines and lighting warm water (18%) = hot water koken (2%) = cooking

Heating seems to be the biggest energy consumer at home and thus the biggest problem. After that it will be hot water or either the machines and lighting.

**Reducing food waste in households [27][28][29]**

Food waste is a problem, in the Netherlands only, 589 million kg
food was wasted in households in 2019.The foods that are the most wasted are bread, dairy and vegetables. When this food is wasted all (fossil) energy and greenhouse gas emissions put into its production and distribution serve no purpose. On average, food waste prevention reduces greenhouse gas emissions by around eight times more than diverting the same food waste from landfill to anaerobic digestion.
In the future food waste will be an even bigger issue because it is expected to be more challenging to produce food for the also growing population. producing food will be harder due to for instance, potentially less nutritious soil and drought or in other parts of the world floods. More awareness has been raised, in the future food waste will be a significant problem and way to help reduce food waste should be developed.

*Table 1: Most wasted solid and thick liquid foods in 2019 [?]*

| Top ten | Absolute waste per product group (kg PPPY and % of total waste) | | | Top ten | Relative waste per product group (% waste of purchased quantity)[a] | |
|---|---|---|---|---|---|---|
| 1 | Bread & bread-based products | 7.3 | 21% | 1 | Rice[b] | 39% |
| 2 | Dairy products | 5.1 | 15% | 3 | Pasta[b] | 34% |
| 3 | Vegetables | 3.7 | 11% | 2 | Bread & bread-based products | 21% |
| 4 | Fruit | 3.0 | 9% | 4 | Sauces and fats | 17% |
| 5 | Potatoes | 2.9 | 8% | 5 | Potatoes | 14% |
| 6 | Sauces and fats | 2.7 | 8% | 6 | Dairy products | 14% |
| 7 | Meat & meat products | 2.3 | 7% | 7 | Pastry and cake | 9% |
| 8 | Pasta | 1.0 | 3% | 8 | Vegetables | 9% |
| 9 | Pastry and cake | 1.0 | 3% | 9 | Fruit | 8% |
| 10 | Sweets and snacks | 0.8 | 2% | 10 | Fish | 8% |
| 11 | Rice | 0.8 | 2% | | | |

## Chapter 4: Problem Selection and Motivation

### Problem: Using fewer fossil fuels for House Holds

The problem that has been chosen is the use of fewer fossil fuels in households, because, first, it is a current growing problem that needs to be solved. Secondly, there are lots of ways to solve this problem, so there can be found the best solution that will be doable, and easy to adapt to almost every household.

The use of fossil fuels is a big issue with climate change because energy demand and consumption keep growing. These fossil fuels are a big cause of climate change because they pollute the air with emissions.

Every household uses a lot of energy every day to use the television, the fridge, and the lamps. This costs a lot of money but also because they use a non-sustainable energy source, the pollution of the air keeps growing, which is not good for the earth.
This problem needs to be handled immediately because fossil fuels are getting less and less. It's a problem that touches every human being because we all consume a lot of energy these days in our households and with finding a solution to make sure that we use fewer fossil fuels we can solve this major problem a little bit and make the air a bit cleaner.

# Chapter 5: Potential Solutions

Met opmerkingen [ZB3]: **Reduce energy consumption:** Promote to work at home with smart environment
**sustainable energy:** Waterpipe transferring electricity from falling down water into energy
**handling waste:** compost bin with the exact right temperatures to get good soil, you can use the warmth to reduce energy consumption (
**adjusting to climate change:** A smart environment against energy consumption. closing windows when it's hot enough or cold enough. turning off and on different machines.
**Shoes that capture energy from walking**

Find 5-8 potential solutions to your problem. Explain how these solutions could work

1. **Promote working at home**

A way to improve climate can be to work from home. By working from home, you don't have to commute to your work, mostly car rides. Global Workforce Analytics estimates that if everyone who works in an office, would work from home just half of the week, this reduces the emissions by 54 million tons per year. Another advantage of working from home is that it improves air quality because less cars pollute the air.
So, working from home at a greater scale could improve our climate, but there are still a few drawbacks. The first disadvantage is that at home there are more distractions and it's easier to give in to these distractions because personal and work life are less separated.
A worse connection with coworkers could also be a problem, at a common workplace you can just walk up to a colleague and ask a question and get an immediate response most of the time. When this is not possible communication is less efficient. You must wait before someone sees your message and eventually responds to it; this slows down the speed tasks get done. [35]
To solve those problems more employee engagement should be created when they work from home.
A solution could be making a smart environment that makes it easy to communicate. This could be done by incorporating sensors in the smart environment.
Eventually you could make a virtual version (digital twin) of a workplace:
A few examples of functions you can add to this virtual workplace.
You can zoom in and see what a person is working on and maybe comment on it or you could make a function that determines whether an employee is busy or is free to answer a question.
In real life everyone can be working remotely, but in this online environment everyone will appear to be working collectively on their tasks.
A second solution could be that you make an app that shows you how much positive impact you have had on the climate by working from home, this is also a function that could be incorporated in the smart environment.

[36]

**2. Hydro energy**

Capturing energy from water is not a new idea, even more, one of the first types of energies humans were able to use was hydro energy with the waterwheel. However, with the rising interest in sustainable energy, a great place to look is everybody's own home and their drainpipes.

Where the average roof surface in the Netherlands is around 60 $m^2$ per household and an average rainfall of 800 liters per square meter we can calculate an average of 48.000 liters of water with wasted energy per year. If a small and not too expensive device could solve this problem, then this would be a great addition to every household which is looking to go green. We made a prototype animation of what this product could possibly look like, of course far from finished since were still in the potential stage. (The full animation can be found on YouTube: Prototype 1.0 Waterpipe)

A wired gate would be added around the wheel to shield it from external forces and debris, as well as catching leaves that go through the pipe so the device would be easy to clean regularly. (This might be unnecessary and only make the wheel work less efficiently so some experimenting is needed) Together with a small box besides the waterpipe to regulate, store and transmit information and energy to the house will be a smart solution to waisted energy problem.

**3. Shoes that capture energy from walking**

You probably have heard of shoes with LEDs in them before. They give of shiny light when you jump, run or stomp. They have batteries in them. They use the energy, but don't give energy back. Another thing you might not have heard of yet is kinetic floor tiles. This energy is rather new and quite expensive with the cost of about 1170 euro per square meter. Kinetic floor tiles convert the pressure of someone standing on them into electricity. If people walk or run over it generates electricity. Of course, weight that causes the pressure on the tiles doesn't have to come from humans per se. It can also be something different like a car or something else with a much weight.

*Figure 5: Tile generating energy from pressure[]*


*Figure 6: System pressure tile []*

So what if you could combine these two products? What if you made a shoe that could generate electricity when you walked with the technology of the kinetic floor tiles? You could power a battery in a shoe. What you do with the battery is a second thing. You can connect them to lights as in the product described above or you can just charge the battery for use later. You could basically use the kinetic floor tile itself, cut it in the shape of a shoe sole, connect it to a battery and stick it under the shoe itself. WOW you are now generating electricity by walking!!! O: [32]

**4. Windows adjusting to temperature in room**

We all want our homes to be warm in the winter and cold in the summer to be comfortable to live in. We all use our thermostats for to measure the temperature and we use air-conditioning and a heating system to make sure it is warm or cold enough. But before we had all this fancy equipment, we would just open a door or a window to regulate the temperature. But what if we combine these two solutions into one in a smart environment?

We make all the windows in the house to be able to open with the use of a motor so the windows can be opened and closed by a computer system. Then we also make sure that the heating system and the air-conditioning system will be turned on and off by a computer system. By using sensors inside and outside the house we can measure the temperature. With the thermostat someone can choice what temperature it should be in the room. The sensors will look if the temperature is right, or something should happen. If the room should be colder than it is, the outside sensors will measure the temperature outside. If outside is colder than inside the house, the windows will be opened until the temperature is either reached or the house is the same temperature as outside. Then the windows will be closed again and if the asked temperature isn't reached the air-conditioning or the heating system will do the rest. They're will also be sensors outside that can measure the weather so when it's raining or snowing, the windows will stay closed, so it doesn't become a mess inside.

But why is this smart environment a solution to our problem. It helps against the energy consumption because it takes a lot of energy all day to make sure your home is the temperature you want it to be. By first opening windows instead of using the heating or air-conditioning you will use less energy which is a solution for energy consumption

**5. Smart compost bin [45][46]**

The Smart compost bin will promote the proper handling of waste. It is no secret that creating your first compost bin is a daunting task, the aim is to make it available and plausible for every household.

The result should be a rise in the amount of waste that is properly stored/ and lessen the volume of landfills (even by a little). It would also promote gardening, and that way the plants that get the composted soil also absorb CO2.
Since compost bins are outside, they would mostly get charged through the power of the sun (and possibly the gas/temperature), having chargeable batteries supporting it while there's not enough nature's power.

It would monitor the heat, humidity, CO2, methane and other gas levels, and other components related to creating the perfect conditions. It would be linked to an app (thus making it a smart environment). In the app, you could monitor the readings and read in which ways you could enhance the conditions of the bin (Example, move it to a place further from the road, show shops with items that help the composting process (such as worms), show foods and solutions that lead to quicker composting, etc.). There could also be an option to select if you have added any animals to the bin and the required conditions would adapt according to that

## Chapter 6: Solution Selection

Met opmerkingen [ZB4]: Select 1 solution. Motivate your choice. Explain why you selected this solution over the other candidate solutions you found
Please present a modular approach to your project, i.e. your project should be composed of modules (ideally, each of you will work on 1-2 modules); the final product should be a merging/composition of the modules together.
Please add EXPLICITLY who does what in your project: Divide the tasks required among the members of your group.

In this chapter will be motived why, solution 4: Windows adjusting to temperature in the room, is chosen for further implementation.

After a reevaluation, the project that will be implemented is solution 4: **Windows adjusting to the temperature in the room.** This Idea will be more doable and could have a bigger impact energy-wise. Together with a temperature sensor and maybe a weather forecast API, a smart-environment window could open to cool a room down (through the internet maybe even before you get home). This can have a great influence of energy consumption as can be seen in figure 4 chapter 3 where 62% of the household energy consumption in the Netherlands is heating.

Sensors would measure the temperature of the room to reach the desired temperature put in by the user. The forecast API could be used to close windows automatically when rain is coming to prevent water entering the house. For safety reasons a small buzzer could be added to make beeping sounds to indicate the window will start to move.

The windows opening and closing could be realized with either motor(s) or a piston moving, most likely a servo motor since there will be worked with a miniature window and only showing the capabilities a smart system like this could have (a piston can cost a lot and getting a full-sized sliding window to tinker with is going to be hard).

# Chapter 7: Methodology

In this Chapter the Methodology will be described. The needed equipment, the collected data and the data analysis for the temperature sensitive windows will be explained in this chapter.

To build the prototype for the solution selected in chapter 6 the following equipment is needed:

**Mechanical parts**

- Openable miniature Window
- Screws
- 3D printed Linear actuator [42]
- Wood to make a wall/house
- Wood glue to attach the house parts

**Electrical parts**

- Arduino + all the parts in the box like wires and resistors for needing to make the circuits
- 2 Temperature sensors.
- 1 humidity sensor
- LEDs from Arduino kit
- Continuous servo motor
- Wi-Fi control?

Met opmerkingen [ZB5]: I believe has to be a continuous servo (360), I don't know if you guys have one but mine can only turn 180 degrees

Met opmerkingen [ZB6R5]: good point

**Explanation**

These materials are needed to build temperature-sensitive windows. First, there needs to be an window which can be manually opened. This is the first step in the process. When knowing the size of the window, the size of the other parts can be determined. To open and close the window a linear actuator can be used. A linear actuator moves in a straight line. Electric energy is used to extend the arm. This is done by sliding the parts from or to each other. The linear actuator that can be attached to a servomotor will be 3D printed.

The movement of the linear actuator will be controlled by the code. The Arduino is used to process the code. The Arduino uses temperature sensors as input, the output will be the movement. To make the control efficient, the inside and outside temperature must be measured. The window should open when the temperature inside is too hot, and the temperature outside is lower. The window should close when the temperature inside is too cold and outside it is even lower. These conditions will be written in the code.

## Calculation: effect of the solution

To show how the effect of the solution the following calculation is made. To make it interesting for students, a normal student house will be used for the calculations. The amount of energy waste from a room depends on the size of the window opening, the time length the window is open and the heat transfer velocity.

For example, take a normal size window (just like in all the campus houses on UTwente) with a size of 120 cm * 62 cm. The surface will be 7440 cm^2 = 0.74 m^2.

The time length the window is open depends on the window opening behavior. This differs with different dwellings/houses and occupants. On average the window will be open for like 2 hours a day. If you take the people that open it and will not open it into account. 2 hours/ day = 2*60*60 = 7200 s (about 2 hours)/day = 7200 s/day* 30.42 days/year = 219024 s (about 2 and a half days)/year.

The heat transfer velocity depends on the temperature difference between inside and outside. The average temperature difference is calculated with T_desired-T_measured . The desired temperature is 20 degrees Celsius and the average T_measured is calculated from the average temperature in each month. DT = 8.14 degrees. Furthermore, it depends on the medium of energy transfer. Thermal conductivity of air = k = 1.4
q[J/s/m^2] = -k * dT = -1.4* (T_desired-T_measured) = -1.4 * 8.14 deg = 11.3 J/s/m^2.

A*t*q = 0.74 m^2* 219024 s/year * 11.3 J/s/m^2 = -1847416 = -1.8 MJ
Efficiency = 65%, due to heat loss[43]
(-1.8/65) * 100= -2.8 MJ
The amount of Megajoules per cubic meter is used to calculate the amount of used liters [44].
2.8 MJ / (35. 17 MJ/m^3) =0.08 m^3. = 80.8 dm^3. So that's 81 liters of extra gas per year per each small window with a surface area of 0.74 m^2. Although this is a rough calculation, that's calculated with estimations. It shows that implementing this idea is sufficient. An house has like 10 to 20 openable windows. So if we take 15 windows. That means that an household can buy 15*80.8 = 1212 liters less in a year. This could save an household with 15 openable windows: 1212 * 1.977 €/L [45]=€2396. If the costs of our product are beneath this price it will be favorable for residents to buy our product.

## Data collection

Data is collected to create context awareness of the environment.

**Collected data**

- Temperature
- Air humidity

**Optional other types of data that can be collected**

- Light levels

## Data use/analysis

**Temperature**
We will use a temperature sensor to sense the temperature inside and outside the house. There will be a setting where you can set a specific temperature you want in your house. The windows will close according to this temperature.

*Optional*: if the temperature sensor works more sensors can be incorporated into our window

**Air humidity**
The sensor will sense the air humidity and when it rains it will be able to automatically close the windows. No rain will enter the house, so no water damage when you are not able to close your windows when it rains.
This function could also be executed in different ways,
Instead of an air humidity sensor you could link it to the weather forecast.

**Safety**
Before the window closes or opens there is a warming sound (beeping). The project should also be cybersafe.

### Time plan

| | |
|---|---|
| Week 7 | - Start building the house<br>- Start programming<br>- Start building circuits<br>- Test the circuit and the program |
| Week 8 | - Finish the house mostly<br>- Finish program (test)<br>- Finish circuit (test) |
| Week 9 | - Final touchups (making sure works for demo presentation)<br>- Make a presentation for demo<br>- Validation |
| Week 10 | - Final demo |

## Chapter 8: Validation

After the project is finished, the project will be validated. To validate the project the following demands have been set. Each demand is given an important value between 1 and 5. the checkmarks show if the demand has been met or not.

| **Demand** | **Description** | **Importance** (scale 1:5) | **Validation value** |
|---|---|---|---|
| 1 | The window should open or close without human interference. | 5 | ✅ |

| | | | |
|---|---|---|---|
| 2 | The window should be closed and opened in 10 minutes | 5 | ✓ |
| 3 | The mechanism is autonomous | 4 | ✓ |
| 4 | The price should not be more than 40 euros per window. | 2 | ✓ |
| 5 | The mechanism/computer should be hidden. This could be solved by making a small box for the Arduino. It could also be hidden in a flowerpot or in a book. | 3 | ✓ |
| 6 | The product should not cost people money in the long term. | 4 | ✓ |
| 7 | The product should be implementable on various kinds of windows. | 1 | ✗ |
| 8 | The product should be cybersafe. | 3 | ✓ |

**The window should open or close without human interference**
The window opens and closes without human interference. A code has been made that makes sure the window will open and close at specific temperatures. This way the window does not need any human interference. You do get to choose what the target temperature for in your house is so there is some optional human interference. You can also open the window with a button if you need to open it for cooking or any emergencies.

**The window should be closed and opened in 10 minutes**
The servo can rotate 360 degrees fast enough for the window to open and close. It takes 3 seconds to open the window. this is less than 10 minutes, so we meet that demand. Of course, with a real window it will take a bit more time than with a prototype.

**The mechanism is autonomous**
The Arduino operates autonomously once the code is uploaded, and it reacts to the inputs from the dashboard in processing.

**The price should not be more than 40 euros**
The Arduino itself costs about 21 euros and one humidity sensor is 4.95 euros + a cheap window frame costs about 3 euros which amounts to only 34 euros in total.

**The mechanism/computer should be hidden**
The user will only interact with the dashboard made with processing so the computer with will be hidden. The circuits with the Arduino and the sensors are be hidden in two boxes. One on the outside and one on the inside of the house. The only part that will not be hidden

is the dashboard where you can change the target temperature of the house and see all the additional information (time, date, outside and inside temperature).

**The product should not cost people money in the long term**
The product will reduce the energy cost to warm up or cool down the house. The product might break, and some parts might have to be renewed but the cost of fixing the product will be less than the energy cost you get back because of the product. The calculations that were made earlier said that a house with 15 openable windows will save €2396 per year so the product will not cost people money in the long term and probably even earn people money.

**The product should be implementable on various kind of windows**
The product only works for a sliding window. The prototype uses a sliding window to the side but if the motor is powerful enough a sliding window upwards can also be opened and closed by the product. This does mean that the product is not implementable on various kind of windows, it is only implementable on two kind of windows which both use the same type of mechanism to open and close.

**The product should be cybersafe**
By not connecting the window mechanism with Wi-Fi, it will be more cyber safe because hacking the system will be very hard. It will only be hackable by putting a new code on the Arduino that will open the window, but if someone wanted to break into your house it will probably be easier to just break the window. So, the product is cyber safe.

# Chapter 9: Results and Conclusion

## Results and findings

7 out of 8 demands that have been set for the product are met. The smart window opens and closes when the conditions for it are met and when the window closes, a light will switch on and a buzzer will sound for safety. There is a dashboard that shows all the information that is handy for the user like the time, the date, the inside and outside temperature and the target temperature. The target temperature can be changed, and the window will open or stay closed depending on the temperature outside, inside and the target temperature. The prototype looks nice and gives a good example of how the product should work.

Our findings are that the project was easier to build and make work than we initially thought. This way we could work on making it look nice and make an entire dashboard for all the information, so it is more user-friendly.

## Conclusion

After gathering, analyzing, picking, and troubleshooting we managed to create an efficient and money-saving smart environment. We have built and programmed an interactive, modern and self-adjusting smart window. Our goal was to regulate temperature and humidity in a space by using the measured difference between the outdoor and indoor values and allowing them to regulate each other by automatically opening or closing the window. All of this (including all the readings and some useful info like the time and date) can be accessed and viewed by the user with our digital interface. While we did experience some challenges, like picking an alternate route for our project, adjusting to other window types, hiding our electronics, etc. They proved to be a useful tool for engaging and bringing the team together.

## Bibliography

[1] Huber DG, Gulledge J. Extreme Weather and Climate Change Understanding the Link, Managing the Risk. Sci Impacts Program Cent Clim Energy Solut 2011:1–13.
[2] Global energy consumption, https://ourworldindata.org/energy-production-consumption
[3] Pecl GT, Araújo MB, Bell JD, Blanchard J, Bonebrake TC, Chen IC, Clark TD, Colwell RK, Danielsen F, Evengård B, Falconi L, Ferrier S, Frusher S, Garcia RA, Griffis RB, Hobday AJ, Janion-Scheepers C, Williams SE. Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. Science (80- ) 2017;355. doi:10.1126/science.aai9214. https://www.science.org/doi/10.1126/science.aai9214
[4] Algae filtering co2 out of the air, https://www.businessinsider.nl/algen-klimaatverandering-co2/
[5] Filho WL. Climate change research at universities: Addressing the mitigation and adaptation challenges. 2017. doi:10.1007/978-3-319-58214-6. https://link.springer.com/content/pdf/10.1007%2F978-3-319-58214-6.pdf
[6] Chartzoulakis K, Bertaki M. Sustainable Water Management in Agriculture under Climate Change. Agric Agric Sci Procedia 2015;4:88–98. doi:10.1016/j.aaspro.2015.03.011. https://doi.org/10.1016/j.aaspro.2015.03.011
[7] Generating energy with plants ://www.sciencedaily.com/releases/2018/12/181212093308.htm
[8] Tan Hoi H, Tan Danh N. Greening Houses in the Age of Climate Change. IOP Conf Ser Earth Environ Sci 2020;505. doi:10.1088/1755-1315/505/1/012016. https://iopscience.iop.org/article/10.1088/1755-1315/505/1/012016/pdf
[9] Jesus JM, Danko AS, Fiúza A, Borges MT. Phytoremediation of salt-affected soils: a review of processes, applicability, and the impact of climate change. Environ Sci Pollut Res 2015;22:6511–25. doi:10.1007/s11356-015-4205-4.https://rdcu.be/cBDdG
[10] Kite power, https://www.youtube.com/watch?v=DwiXTye681M
[11] The impact of cement industry on climate change, The Cement Industry and Global Climate Change: Current and Potential Future Cement Industry CO2 Emissions - ScienceDirect
[12] Kolstad EW, Johansson KA. Uncertainties associated with quantifying climate change impacts on human health: A case study for diarrhea. Environ Health Perspect 2011;119:299–305. doi:10.1289/ehp.1002060. https://ehp.niehs.nih.gov/doi/full/10.1289/ehp.1002060
[13] Mirza MMQ. Climate change and extreme weather events: Can developing countries adapt? Clim Policy 2003;3:233–48. doi:10.3763/cpol.2003.0330. https://www.tandfonline.com/doi/abs/10.3763/cpol.2003.0330
[14] Water scarcity, https://www.conserve-energy-future.com/causes-effects-solutions-of-water-scarcity.php
[15] Bees disappearing https://www.greenmatters.com/p/why-are-bees-disappearing
[16] Cynthia Rosenzweig, Martin L. Parry. Potential impact of climate change on world food supply. Nature 1994;367:133–8. https://doi.org/10.1038/367133a0
[17] Consequences of Climate change, https://ec.europa.eu/clima/climate-change/climate-change-consequences_en
[18] A. Rashedi, T. Khanam, and M. Jonkman, “On Reduced Consumption of Fossil Fuels in 2020 and Its Consequences in Global Environment and Exergy Demand,” Energies, vol. 13, no. 22, p. 6048, Nov. 2020 [Online]. Available: *http://dx.doi.org/10.3390/en13226048*

[19] Arthur Rempel, Joyeeta Gupta, "Fossil fuels, stranded assets and COVID-19: Imagining an inclusive & transformative recovery", World Development, Volume 146, Oct. 2021, 105608, ISSN 0305-750X, *https://doi.org/10.1016/j.worlddev.2021.105608*. (*https://www.sciencedirect.com/science/article/pii/S0305750X21002230*)
[20] Jim Stanford, "Employment Transitions and the Phase-Out of Fossil Fuels ", The Centre for Future Work, January 2021, Available: *https://centreforfuturework.ca/wp-content/uploads/2021/01/Employment-Transitions-Report-Final.pdf*.
[21] Coral reef, https://www.mdpi.com/1424-2818/8/2/12/htm
[22] Migration and Climate change, https://www.nytimes.com/interactive/2020/07/23/magazine/climate-migration.html
[23] Mutasem El-Fadel, Angelos N. Findikakis, James O. Leckie, Environmental Impacts of Solid Waste Landfilling, Journal of Environmental Management, Volume 50, Issue 1, 1997, Pages 1-25, ISSN 0301-4797, https://doi.org/10.1006/jema.1995.0131. (https://www.sciencedirect.com/science/article/pii/S0301479785701314)
[24] Hannah Ritchie, Oxford Martin school, 06 oct 2020, https://ourworldindata.org/co2-emissions-from-transport
[25] Environmental and Energy institute, Fossil fuels, https://www.eesi.org/topics/fossil-fuels/description
[26] International Energy Agency, Energy technology perspectives, september 2020, https://www.iea.org/reports/energy-technology-perspectives-2020
[27] Janssens Kim, Wim Lambrechts, Annet van Osch JS. How Consumer Behavior in Daily Food Provisioning Affects Food Waste at Household Level in 2019. https://www.mdpi.com/2304-8158/8/10/428
[28] Voedingscentrum. Synthesis Report on Food Waste in Dutch Households in 2019. Heal Sustain Food Syst 2019;36:170–8. https://www.voedingscentrum.nl/Assets/Uploads/voedingscentrum/Documents/Professionals/Pers/Persmappen/Verspilling%202019/VC_Synthesis%20report%20on%20food%20waste%20in%20Dutch%20households%202019.pdf
[29] Quested TE, Marsh E, Stunell D, Parry AD. Spaghetti soup: The complex world of food waste behaviours. Resour Conserv Recycl 2013;79:43–51. doi:10.1016/j.resconrec.2013.04.011. https://www.sciencedirect.com/science/article/pii/S0921344913000980?casa_token=VZsMml7Ej_EAAAAA:8rVohWGIgVcOao4UxM8RPTctrRuRaUHi4ITcjZBKQssaCWz7Jnm6nBnkRP8H4Jpw3XbblXQGcw
[30] St.Clair SB, Lynch JP. The opening of Pandora's Box: Climate change impacts on soil fertility and crop nutrition in developing countries. Plant Soil 2010;335:101–15. doi:10.1007/s11104-010-0328-z. https://link.springer.com/content/pdf/10.1007/s11104-010-0328-z.pdf
[31] Brevik EC. The potential impact of climate change on soil properties and processes and corresponding influence on food security. Agric 2013;3:398–417. doi:10.3390/agriculture3030398. https://www.mdpi.com/2077-0472/3/3/398/htm
[32] Author unknown, Energy Harvesting: Pavegen and the Rise of Kinetic Tile Tech , The switch, place unknown, 11/05/2021 https://theswitch.co.uk/energy/guides/technology/energy-harvesting-tiles#smart-cities-self-sufficient-essentials

[33] Picture water pelton, https://mectips.com/difference-between-impulse-and-reaction-turbine/
[34] Het Compendium voor de Leefomgeving, 24 april 2020, https://www.clo.nl/indicatoren/nl0508-jaarlijkse-hoeveelheid-neerslag-in-nederland
[35] pros and cons working from home, https://kissflow.com/digital-workplace/remote-work/pros-and-cons-of-working-from-home/
[36] image, https://sketchfab.com/3d-models/isometric-office-d31464eed8044190911b221648aca432
[37] writer unknown, nibud, Energie en water, 2021, https://www.nibud.nl/consumenten/energie-en-water/
[38] writer unknown, Energieopwek, updates every day https://energieopwek.nl/
[39] writer unknown, energie cijfers van Nederland, energie in Nederland, date unknown (at least 2020), https://www.energieinnederland.nl/feiten-en-cijfers/energiecijfers/
[40] P. van der Wilt, hoeveel zonnepanelen heb ik nodig, consumenten bond, march 29th 2020, https://www.consumentenbond.nl/zonnepanelen/hoeveel-zonnepanelen#:~:text=Een%20gemiddeld%20huishouden%20gebruikt%20zo,je%2010%20gemiddelde%20zonnepanelen%20nodig
[41] "Landfill: A Victim of dutch Success?", *Waste-management-world.com*, 2021. [Online]. Available: https://waste-management-world.com/a/landfill-a-victim-of-dutch-success. [Accessed: 09- Dec- 2021].
[42] Potent Printables, Diy 3D printed lineair actuator, https://www.youtube.com/watch?v=2vAoOYF3m8U&ab_channel=PotentPrintables
[43] https://www.energy.gov/energysaver/furnaces-and-boilers#:~:text=Replacing%20Your%20Furnace%20or%20Boiler,useful%20heat%20for%20your%20home.
[44] https://www.huisenergieneutraalmaken.nl/gas-energie/
[45] The impact of inorganic waste on the life cycle, https://doi.org/10.1016/j.resconrec.2018.05.030
[46] Improving the sustainability of organic waste management practices in the food-energy-water nexus, https://doi.org/10.1016/j.rser.2018.03.025

UNIVERSITEIT TWENTE.