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How much can Social Dynamics and Mobile Applications Help in the Battle Against Climate Change?

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Wien, 29. August 2023

Markus Janik

Danksagung

Danke natürlich an meine Eltern die mich sowieso mein ganzes Leben lang unterstützt haben und auch danke an Julia, die mich untertsützt hat wo es nur geht und meine Launen auch in den stressigen Situation des Studiums immer ausgehalten und toleriert hat.

Kurzfassung

Ziel der Arbeit ist es, die Auswirkungen einer mobilen Applikation auf die Nutzer hinsichtlich ihrer umweltschädlichen Aktivitäten zu messen. Der Kern des neuen Lösungsansatzes wird eine mobile Applikation sein, die einem Menschen in der Zielgruppe dieser Arbeit, welcher sich für die Umwelt interessiert hilft, etwas für unsere Umwelt zu tun. Um spezifisch zu sein wird die App in Österreich, im Raum Wien verwendet, was heißt, dass auch die Ergebnisse aus diesem Raum stammen werden. Der erste Schritt wird ein System sein, das die Person durch diverse Faktoren, wie Aufgaben oder Ranglisten motiviert, jeden Tag einen umweltfreundlicheren Lebensstil zu führen. Dazu gehört eine Vielzahl von unterstützten Aktivitäten in mehreren Kategorien wie zum Beispiel Wohnen und Essen, die unserer Umwelt helfen, aber nur solche, die auch gemessen werden können. Die User erhalten Ziele, die sie erreichen können, indem Sie umweltfreundliche Dinge erledigen, z. B. öffentliche Verkehrsmittel benutzen, anstatt mit dem eigenen Auto zu fahren, oder weniger Fleisch essen. Sie werden dann in der Lage sein, den Fortschritt und die Auswirkungen, die Sie auf unseren Planeten haben, zu sehen.

Die Applikation baut auf dem Prinzip der Serious Games auf, welche versuchen dem Nutzer spielerisch wichtige Inhalte zu vermitteln. In diesem Fall handelt es sich um den Klimawandel, was heißt, dass der Nutzer erfahren wird wie sich seine Emissionen zusammensetzen und wie er diese reduzieren kann. Ein weiterer Aspekt wird sein, dass man sich mit anderen Menschen verbinden und sich mit ihnen vergleichen kann. Die App wird über Ranglisten und verschiedene andere Dinge verfügen, die den Nutzer motivieren sollen und um diese Anwendung zu ermöglichen, muss eine enorme Menge an Daten importiert und so aufbereitet werden, dass diese nutzbar sind. Die User werden sehen, welche Auswirkungen bestimmte tägliche Aktivitäten haben und welche Folgen sie für die Zukunft haben. Die Applikation wird Aktivitäten unterstützen welche der User tagtäglich erledigen muss, wie zum Beispiel sich durch die Stadt fortbewegen oder einfach nur Essen, wobei sich diese Aktivitäten sowohl positiv als auch negativ auf die Umwelt auswirken können.

Zusammenfassend lässt sich sagen, dass die Anwendung einerseits einen Anreiz für den Nutzer bietet, sich um unsere Umwelt zu kümmern und uns im Kampf gegen den Klimawandel zu unterstützen, und andererseits ein Instrument darstellt, mit dem man sich über die Auswirkungen bestimmter Aktivitäten auf unseren Planeten in der Zukunft informieren kann. Der Nutzer wird täglich durch die App mit Anreizen und Bestenlisten motiviert, seinen Lebensstil zu verbessern und unserem Planeten zu helfen.

Die Resultate der Arbeit waren ausreichend um die Forschungsfragen dieser Arbeit zu beantworten und im Zuge dessen auch eine Reduzierung von 5.8% der Emissionen der Nutzer mit sich gebracht hat. Gefragt wurde in welcher Form eine Reduzierung der Emissionen möglich ist beziehungsweise die Motivation und das Engagement der Nutzer gesteigert werden können. Durch eine abschließende Umfrage hat sich gezeigt, dass die Nutzer motivierter und interessierter am Thema Klimawandel waren. Natürlich hatte die Applikation auch einige Limitierungen, die es unter anderem nicht möglich gemacht haben zu kontrollieren ob der Nutzer seine abgeschlossenen Aufgaben auch wirklich im echten Leben absolviert hat. Aufgrund der großen Menge an Daten, die genau das Verhalten eines jeden Users beschreiben, war es jedoch möglich die Daten auf Plausibilität zu prüfen.

Abstract

The goal of the work is to measure the impact of a mobile application on users in terms of their activities that are harmful to the environment. The core of the new approach will be a mobile application that helps a person of the target group of this paper, that is interested in the environment to do something for our environment. Specifically, the app will be used in Austria, in the Vienna area, which means that the results will also come from this area. The first step will be a system that motivates the person to lead a more environmentally friendly lifestyle every day through various factors, such as tasks or leaderboards. This will include a variety of supported activities in different categories such as living and eating that help our environment, but only those that can be measured. Users will be given goals that they can achieve by doing environmentally friendly things, such as using public transportation instead of driving their own car, or eating less meat. They can then see the progress and impact they are having on the planet.

The application is based on the principle of serious games, which try to convey important content to the user in a playful way. In this case it is about climate change, which means that the user will learn how his emissions are composed and how he can reduce them. Another aspect will be that the user can connect with other people and compare yourself with them. The app will have leaderboards and various other things to motivate the user, and in order to make this application work, an enormous amount of data will have to be imported and processed in a way that makes it usable. Users will be able to see the impact of certain daily activities and what their consequences will be in the future. The application will support activities that the user has to do on a daily basis, such as moving around the city or simply eating, and these activities can have both positive and negative effects on the environment.

To sum up, on the one hand, the application provides an incentive for the user to take care of our environment and help us fight climate change, and

on the other hand, it is a tool to learn about the impact of certain activities on our planet in the future. The user is motivated daily by the app with incentives and leaderboards to improve their lifestyle and help our planet.

The results of the work were sufficient to answer the research questions of this thesis and in the course of this also brought a reduction of 5.8% of the user's emissions. The question was asked in which form a reduction of emissions is possible or the motivation and commitment of the users can be increased. A final survey showed that the users were more motivated and interested in the topic of climate change. Of course, the application also had some limitations that, among other things, did not make it possible to control whether the user actually completed his completed tasks in real life. Due to the large amount of data describing exactly the behavior of each user, it was possible to check the data for plausibility.

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CHAPTER 1

Introduction

The first chapter will introduce the problem this paper is about and show that the climate change needs to be addressed as soon as possible. After pointing out the problems that lead to climate change and the current solutions in place, the paper proposes its own research of an approach to see how much impact it could have. It is about a mobile application with the concept of Serious Games, which has the goal of showing how much emission reduction is possible and how much the users can get motivated in engaging more with the climate change problem.
It is important to understand the current situation regarding climate change and what the current problems are. Understanding these problems will make it easier to find approaches that try to solve them. While creating the application the researched climate problems and their proposed solutions will build the foundation for the features of the mobile app.

1.1 Climate and their Challenges

In the present time the need to look after our environment is rising dramatically. It is becoming very important to take action against climate change and several other environmental problems. Unfortunately, the average person in Europe, which is described in more detail later, is not doing enough [34] to improve this problem. Only 5% of EU households have a lifestyle which emissions are within climate targets, which plan to keep carbon emissions below 2.5 tons of CO_2 per year. Modern industrial society, as humanity has built it over the last 150 years, is inherently destructive to the planet.[44] The average lifestyle of people living in Europe is designed to make their life

easier, safer and more comfortable, but this does often disregard the emissions end negative effects for the environment coming with it. [34] The food, the infrastructure, the clothes, the appliances that are used, the transportation the people use and the comfortable temperature that artificially create around them, are only some of the many examples how humanity steadily increases the global temperature of the earth.

1.1.1 Emissions Versus Poverty

Researching the problems leading to climate change in the different income classes will lead to a better understanding where to apply new approaches. This paper is about the research of the approach of a mobile application for the middle-income group of people in Austria, which makes the understanding of the dynamics in this group regarding the environment invaluable.

There is a correlation between a nation's wealth and its carbon emissions.[51] In other words, the richer people are, the more emissions they produce. So the key to solving climate change is simply for the world's richest to cut back on their extravagant lifestyles. That would help, but it would not eradicate the problem. That is because 63% of global emissions come from low- to middle-income countries. [51] Countries where most people are not living extravagantly, but trying to escape poverty at worst and achieve a comfortable lifestyle at best. The unfortunate reality is that escaping poverty and moving up into the middle class is currently causing unavoidable emissions. So asking developing countries to reduce emissions just looks like an attempt to keep them down. It is very hard to argue that a region should protect its virgin forests and spend money on solar panels instead of burning wood when it cannot meet the basic needs of a large part of its population. So saving money is not a popular demand, especially when the countries making these demands have become rich in the past by damaging the environment. So for billions of people, more emissions are personally a good thing. When looking at concrete, which is essential for building networks of streets, it shows that 8% of CO_2 emissions are released by the concrete manufacturing industry. [1] This shows why it is so hard to find solutions on a global level.

Even rich countries are not immune to arguments over quick fixes for climate change. The ban on coal, gas and oil as energy sources is being held back by heated discussions about what should replace them. Citizens may be adamantly opposed to nuclear power, but also to wind or solar in their backyards. Most people agree that something needs to be done about climate

change. They understand that it helps to build fields of solar panels, huge wind turbines, and even nuclear reactors to reduce carbon emissions. But few people want to live near these plants or even have to see them. They worry about how it would affect them personally, such as a loss of property value or inconvenience, and that takes precedence over the vague benefits against climate change. [43]

1.1.2 Food

Soon the world's population will reach 10 billion people [61] and producing enough food without emitting greenhouse gases is currently a problem for the planet. Because of the nature of modern food production, which requires fertilizers or manure, it is impossible to produce food without emissions. Rice alone emits so much methane each year that it is virtually equivalent to the emissions from all air travel in the world. 57% percent of food emissions come from animal sources, even though they provide only 18% of the world's calories and 37% of its protein and the richer people in the world get, the more meat they want.[27] Most cultures traditionally ate a primarily plant-based diet, with a little meat on top, but with the advent of industrial style meat production and factory farming, meat has become a staple. Today, 41% [27] of the world's habitable land area is used in some form of meat production, which is the size of North and South America combined. This is land on which there would otherwise the opportunity to regrow ecosystems like the forests in the Amazon, and extract carbon from the atmosphere, but instead most of it is used to feed animals.
This is the reason why the application will support a category of activities involving food. By showing the users how much emissions they have in that category and proposing buying only regional and seasonal products the app will try lower their emissions in that area.

1.1.3 Solutions Are Not Cheap

In principle, a technology already exists: direct capture of CO_2e from the air involves taking carbon dioxide out of the air to store it underground or convert it into products, but the problem is that it is not possible to deploy these devices everywhere[30]. This is because with the technology that is currently used, it would cost about ten trillion dollars a year[36], which is half the GDP of the United States. That money has to come from somewhere, and currently no one is offering it. If these costs were simply imposed on the big polluters like steel mills and coal-fired power plants, the cost of their products would double, leaving these industries, which operate on very low

profit margins, bankrupt. Making the government pay for it seems logical, but many government funds are used for the opposite, such as subsidizing oil and gas.[12] This seems counter intuitive, but it follows clear incentives. By keeping fuel prices artificially low, transportation and everyday goods are also kept artificially cheap. This has a significant social impact on billions of people around the world.

This creates political lobbies and incentives that perpetuate this cycle that makes it so hard to end fossil fuel production. In the meantime, very costly solutions to a distant problem like carbon capture seem to be able to wait, since technically no one benefits from them right now. Some argue that a move away from capitalism is the only solution to this mess, others insist that markets should be even freer, without interventions like subsidies. Still others suggest that so-called "degrowth", which means that humanity as a species has to cut back, is needed, but the truth is that, at least for now, no political system is truly sustainable, nor has it been in the past. [22]

This is another area where this paper and the mobile app try to research solutions. After completing a small setup, the users will see how much emissions they produce and what they can do to reduce them. The app also encourages them to research about climate change and try to be active on a larger scale, involving going to demonstrations or voting for politicians that care about the environment. This should help to brig attention to politicians and hopefully convince them to put more laws into place, that maybe cost money but are popular in the population which leads to more votes for them.

1.2 Current Contributions against Climate Change

It is important to analyze what is currently done against climate change and which of these contributions is working. After determining what is missing and why certain proposed solutions are not working like they should, then these findings can be used to create specific solutions. Furthermore it is important to research what is already working and use these approaches in the application.

1.2.1 US National Climate Task Force

Joe Biden, as of writing this thesis the current president of the United States of America, is tackling the climate change with the urgency the scientists

demand. He created the National Climate Task Force [29], which has several main goals:

- Reducing U.S. greenhouse gas emissions 50-52% below 2005 levels in 2030
- Reaching 100% carbon pollution-free electricity by 2035
- Achieving a net-zero emissions economy by 2050
- Delivering 40% of the benefits from federal investments in climate and clean energy to disadvantaged communities

In August 2022, the Inflation Reduction Act, a very important legislation against the climate crisis was created and plans to lower energy costs for households, saving most families a lot of money per year. Apart from that the USA try to switch to more green energy, which also brings a lot of new workplaces with it. So they not only take big steps against the climate change itself, but they also manage to do that with positive side effects for the people living in the country.

1.2.2 Europe's Plans Against Climate Change

The European Union does have several plans, like the "2030 Climate Target Plan" [20], in place as well, that try to keep emission down as much as possible, but unfortunately the improvements happen very slowly. The goal of this plan is to encourage international partners to increase their ambition to limit the rise in global temperature to 1.5°C and avoid the most severe consequences of climate change. For example, in 2019 several leaders of the EU's states agreed in the Paris Agreement [47] to achieve climate-neutrality by 2050, which is positive, but that is also a long timespan until then. This agreement states that the EU will reduce their emissions by at least 40% by 2030 compared to 1990 and find ways to compensate for unavoidable emissions to reach net zero carbon emissions. Net zero in this case means, that they will try to avoid as much emissions as they are producing.

They also agreed on a goal that is not so far in the future, because another goal is to reduce emissions by 55% by 2030. This is also a step in the right direction since the goal before was a reduction of 40%. To achieve this goals the EU leaders proposed several approaches:

- Improving green finance standards
- Strengthening the EU emission trading system
- Spurring climate-friendly innovation
- Ensuring fairness and cost-effectiveness

In the past all countries in the EU had agreements and deals to lower emissions, but many did not meet their goals. The EU now tries to change that by making laws out of this goals, which legally obliges the countries to reach their goals. These goals are not easily met, because it requires an enormous investment and that is not something the leaders of countries want to do. This is the reason why the EU plans to use the budget for 2021-2027 only for climate related projects. To name numbers, 30% of the total EU budget will be used for projects that help against climate change and lower emissions.

1.2.3 Carbon Footprint

Ironically the idea about reducing your carbon emissions comes from the idea of footprint calculators, which shows how much emissions can be created just by living your life. This footprint calculator was first used by British Petroleum (BP) [52], which tried to hide how much emissions the company really emitted by moving the attention to the average person. They invented this calculator and showed just how bad your lifestyle is for the environment by asking the right questions and were at the same time hiding the fact the the company itself is far worse than any single person could ever be. The big companies are indeed a big problem, since the top 3 companies emitting the most carbon emissions emit 11.3% of the total emissions on the planet. Saudi Arabian Oil Company (Aramco) with 4.8%, Gazprom OAO with 4.2% and National Iranian Oil with 2.3%. [25] Without them reducing their emissions massively it does not really matter what the average person does, but the earth is at a point where it is important that everybody works together on this matter, which means that applications like shown in this paper could be a big help against climate change.
Even if the biggest companies and the richest people on the planet have the highest amount of carbon emission [24] it is still important to reduce your own emissions. As stated earlier the UN Environment Program [48] predicts that it is important to reduce the CO_2e emission per capita to 2.3 tons of CO_2e per year. After comparing that to the average emission of a user in the application with 18.14 tons CO_2e per year it is obvious that there needs to be

a large reduction of CO_2e emissions to reach that goal, which could be easier by using a mobile application like the on presented in this paper.

1.3 The Mobile Application

The introduction until now showed, that it is important to find ways against climate change and research possible solutions. This paper will introduce a self-created mobile application, that tries to lower their users emissions and motivate them to live a greener lifestyle. The concept of Serious Games will be used, which is described as any form of interactive computer-based game software for one or multiple users. First of all it is important to specify the target group of this paper and the application, which is the "average person" described in the following section.

1.3.1 Target Group of the Application

This thesis will often talk about the term "average person", which is described as a adult, that is in the middle-income class and lives their lives working a regular 9-to-5-job with hobbies in their free time. The target group of this paper is the average person living in or around Vienna and is open in helping against climate change. The change in people's lifestyle is conspicuous, especially young people like to commit time helping our planet or at least try to raise the issue. [13] Some eat food that is better for the environment when looking at its production and others just try to use more public transportation than cars. There are several small things every person can do to lower their emissions and by that help the environment. Recently initiatives, like the "Fridays For Future" movement, emerged that started the battle against climate change, where the main goal is to convince the general population but especially the politicians to advocate measures for a better environment. A person of the richest 1% of the worlds population emits 70 tons CO_2e per year on average. [24] This shows that there needs to be changes on a large scale, which requires politicians that act on the climate change.

1.3.2 Serious games

After looking for solutions to motivate people in serious matters, it showed that there is the concept of Serious Games, which educate their users on topics that are normally not easy to understand or to learn. These games also motivate their players, which is another very important factor when looking at the goal of this paper. Since the paper researches the impact of the mobile application in the daily life of a person it is important that the users have

a very easy access to the app. This is the reason why the app is a mobile application and not implemented for a PC.
Since almost all of the people of the target group of this paper have a mobile phone on them most of the day, it is the perfect tool to use in this study. The application supports their users in their daily activities and shows them what they can do to reduce their emissions. By creating an application for their mobile phone they have access to the app almost all the time, which means that they can work on their emissions whenever they want and can even look at their current emissions to see in which areas they have to improve the most.

In the recent years the serious games market is growing every year [50], since they provide a way to educate a person about a serious matter, while having fun gaming. The term serious games can be translated as "games with a serious (learning) objective". In other words, they are games that are created to teach specific content or competencies in a targeted manner, especially in contexts where playing and learning are often understood as opposites.[50] This is a very promising concept and is the foundation of the mobile application.

Serious games represent a didactic paradigm shift in many areas of learning, especially in the field of vocational and corporate training. Instead of sending employees to monotonous training courses, they are now supposed to play games and have fun while doing so. From the perspective of the people playing, serious games initially have very simple goals: to have fun playing and to win. But the trick is not only that, the players have to keep learning and prove their newly acquired knowledge through play. Above all, the change in motivation is also a big deal, because with serious games, no attempt is made to motivate or even force employees to learn through external pressure. This approach is notoriously unsuccessful. Instead, they rely on the intrinsic motivation and the natural joy of learning and playing of the employees. Learning thus takes place of its own accord within the framework of a game. At the same time, however, this means that serious games have to be really well made if they are to grab players and bring the desired success. [11]

The introduction showed the current problems and some solutions regarding the climate change. As already described, it is hard to motivate people to live a greener lifestyle, which is why this paper researches how effective one approach is. This approach is a mobile application, which has two goals. First it tries to lower the carbon emissions of its users and secondly the users should

get more involved with this topic and hopefully find ways to help the climate outside of just reducing emissions. This involves going to demonstrations, voting for the right politicians and support companies that look after the environment. By gathering a large amount of data from the usage of the application together with the survey at the end of the trial, this paper will draw conclusions how effective a mobile application can be in this regard.

Serious games can be a powerful tool in helping people learn and motivate them to do so at the same time, which is the reason for this paper. In the next chapters the paper will have an introduction on climate change and the current state of it around the world and especially in Austria. The remaining chapters, which are the main part of this paper, will revolve about the research question and what methodology got used to answer with the results and conclusion in the end.

CHAPTER 2

Background Information and Related Work

This chapter shows exactly how urgent this matter is and how much the environment suffers for every day that goes by without any action. There is a need to find solutions as fast as possible and this study will research the viability of one possible approach. New ways to reach the goal of keeping the global warming to a maximum of 1.5°C have to be found, which is seen as a hard task after reading the following chapter. This background information is important for this paper and the mobile application to understand where the emissions come from, how they impact the earth and what the people can do against them.

2.1 Cause of Climate Change

The main cause of climate change is the greenhouse effect. [38] This effect describes that the heat coming from the sun is trapped in our atmosphere because of the mostly human made greenhouse gases. This greenhouse effect is very important and essential to life on earth, else it would get too cold, but it has come to the point where this effect is stronger than needed and heats the planet to the point where is getting dangerous for humanity.

There are four major gases that contribute to the greenhouse effect [38]:

- **Carbon Dioxide(CO_2e):** A very important component of the atmosphere. It is released thorough natural processes, like volcanic eruptions

and human activities, like burning fossil fuels. Because of human activities CO_2e is rising sharply and since it is the biggest climate change driver that should be changed.

- **Methane:** This is the gas that gets released from animals digestion or fossil fuel production. Methane as a gas is a far more effective greenhouse gas than CO_2e, but it is also much less common. Since pre-industrial times the amount of methane in our atmosphere has doubled.

- **Nitrous Oxide:** During organic fertilizer production and use this gas gets released. It has increased by 18% in the last 100 years.

- **Chlorofluorocarbons (CFCs):** Other than the other gases this chemical compound comes entirely from the industry. The Montreal Protocol [60] regulate the CFCs because they damage the planets ozone layer. One should think that this protocol helps in keeping the CFCs low, but due to violations this is not the case. Only in 2018 the amount started dropping after the world leaders called for immediate actions.

Coal and oil burning processes combine carbon with oxygen to make CO_2e, this is the main source of carbon emission [32]. Clearing land for agriculture, industry and other human activities have increased greenhouse gases as well, but to a lesser extent. Since 1750 the atmospheric carbon dioxide increased by almost 50%, which mostly comes from human activities [38].

In the past the sun played a big role in climate changes, for example the Little Ice Age which came from volcanic activity and solar activity, but since 1750 the average amount of energy from the sun has remained constant. There are also climate models that try to reproduce the global warming from solar irradiance, but they are not able to reproduce the increasing temperature numbers. This means that the climate change comes entirely from humans and it lies in our power to find solutions to it.[28]

2.2 Sixth Assessment Report by IPCC

In 2021/2022 the Intergovernmental Panel on Climate Change (IPCC) released their sixth assessment report (AR6), which is one of a series of such reports. They assess scientific, technical, and socio-economic information concerning climate change. There are three working groups [31] contributing to the AR6.

The report had several findings, which will be elaborated in the following section, that show how much impact the climate change has on many different areas on earth. The IPCC has a system to evaluate how much impact the climate change has and how certain they are that it really stems from the change of the climate. The following section will show their findings so that it can be seen how important a change to a greener lifestyle is. The findings written in the report can be found here [32] & [44]. They show what can happen if global warming and climate change is not stopped very soon.

2.2.1 Impacts of Temporary Overshoot

The AR6 describes the concept of overshooting, which means, that the global warming exceeds their 1.5°C breakpoint only temporary and then returns to this point or goes even lower. This means, that even if the human races manages to keep the global warming low in the long run, overshooting the breakpoint may cause irreversible damage to certain aspects of our planet. This means that lowering carbon emissions is essential and this paper is helping in that regarding since it researches ways to lower emissions of the people. The proposed approaches in this paper and the data about them will show how much reduction of CO_2e is possible, which in turn can reduce the overshoot of the global temperature and the impacts of that.

Unlike many other scenarios already shown, there are no models for the impact of overshooting, but the IPCC team has a good understanding of the global warming dynamics to conclude some problems of it, many of them with high confidence. For example a higher temperature only for a short duration of time can lead to glacier melting and a sea-level rise. There will also arise risks to human systems including our infrastructure and livelihoods. The longer the duration of an overshoot the more severe are the impacts of it, which can mean a higher mortality rate, increased wildfires and permafrost, only to name a few.

2.2.2 Adaptation Measures and Enabling Conditions

One of the problems is, that the IPCC thinks that the actions humanity does against climate change are not enough. Many companies and world leaders do just enough to look good to the public, but often times that is not enough. The are many implementations that try to fight climate change, but it depends in the capacity of governance and other important factors. This is the first introduction to one of the research questions of this paper, because ways to motivate people to live a greener lifestyle have to be researched. At

the same time politicians need to get convinced, anti climate change plans and laws are needed. This paper will propose a method to motivate people and research how much impact the method has on their engagement with climate change.

Current Adaptation and its Benefits

Adaptation implementation has increased all across the world, which also includes the public and political awareness. At least 170 countries and many additional cities have installed policies to battle climate change or are in the process of planning them. Additionally there are many projects and experiments ongoing, which hopefully results in optimized climate processes

Most of the implemented adaptations are only effective in helping with current problems or those that will arise in the near-term, but when looking at reducing long-term risks it can be seen that measures against emissions are needed. Another problem is, that many resources get used to create plans against global warming but not so much on implementation. There is a disparity between certain regions regarding adaptation. While the higher income population is on the case and puts many resources into solving the problem, low income population is lacking behind. These two income groups are equally important and it should be a priority to close that gap and battle climate change together. As mentioned above, the risks of global warming are decreasing agricultural productivity and well-being of the people, and this hits lower income population even harder and will lead to many deaths, when there is no immediate action taken.

Limits to Adaptation

There are already some soft limits in place, which can be overcome by addressing a range of constraints. Some of them are inequity and poverty, but also a lack of climate literacy. Climate literacy means how aware the people are of climate change with its causes and implications. Another constraint would be the financial part, because that puts a limit to adaptation in all regions. Since the last report of the IPCC, the AR5, an increasing amount money flows to help against global warming, including private and public sectors, but especially developing countries have their problem with keeping up when trying to implement some adaptations the first world uses. Another problem is, that is is expected that the climate change will lead to financial losses, for example in the agriculture sectors, which makes the financial limit even worse.

Natural systems are getting closer to their hard limits as well and some of them even reached them. When looking at certain ecosystems, for example coral reefs, it shows that some of them have been destroyed beyond repair, but also rainforests and mountain systems are at risk. Human systems like coastal settlements also face limits, because the sea level rises to a level where some regions need to be evacuated soon. The glacier and snow-melt reaches a level where the missing ice poses a risk to freshwater resources, that gets even worse when a average temperature of 2°C more than before industrialization is reached.

Since there are already some soft and hard limits it is expected that even the best adaptations will result in a loss. At this stage it will not be possible to protect every part of the planet, which means sacrifices have to be made and hopefully every human on the planet will realize the danger of climate change early enough.

Avoiding Maladaptation

Maladaptation is a term that describes actions that lead to increased risk of adverse climate-related outcomes, including more emissions, increased vulnerability to climate change and many others. This almost always happens as an unintended consequence of certain adaptations. The working groups have a high confidence, that the perpetrator of maladaptation is focus on the wrong sectors. It is not advised to look for actions that only address certain sectors or short-term goals, instead adaptations that lead to a long-term gain and benefit as much regions and ecosystems as possible have to be put in place. These shortsighted actions, like seawalls for example, can lead risks that are irreversible or very expensive to change. These seawalls reduce the impacts of flooding in the short-term but can also lead to lock-ins and because of that even more exposure to climate change.

Protecting biodiversity and ecosystems is no easy task, since doing that could lead to other problems. When walls or levees to help against flooding get build, it is constraining the nature when it tries to heal it self, by reducing its natural space. It is important to look after certain groups of people like indigenous people or ethnic minorities since they often fall victim to certain adaptations. adaptations have different outcomes for different groups of people and that has to be put into consideration when planning new solutions, that is where indigenous knowledge, local knowledge and scientific knowledge come into play.

To minimize maladaptation it is important to have as much groups and ecosystems in mind and also have adaptations that can be altered to maximize their benefit. That also means, that it needs planning that accounts for the time it takes to adapt and the potentially adverse consequences of adaptation actions if something goes wrong.

2.2.3 Climate Resilient Development

"Climate resilient development integrates adaptation measures and their enabling conditions with mitigation to advance sustainable development for all" [32], that is the definition of the IPCC working groups. It is a solutions framework that combines strategies to adapt climate change with actions to reduce greenhouse gas emissions to support sustainable development for everyone. It was already stated, that there are no easy solutions for climate change and many adaptations can lead to unexpected effects and turn into maladaptations. To achieve climate resilient development it is crucial to reduce exposure and vulnerability to climate hazards and cutting back emissions, while also conserving biodiversity and as many ecosystems as possible.

Conditions for Climate Resilient Development

It is reported that the window of opportunity for climate resilient development is closing rapidly, which comes from the fact that the average temperature is rising, and with it reduces the potential for development. Particularly at a an increase of 1.5°C social and economic inequalities will rise and the balance between adaptation and mitigation needs to be addressed. There are many simulated pathways described in the IPCC report, ranging from an temperature increase of 5°C to under 1.5°C, that are possible in the future, but if the increased temperature is kept under 1.5°C the life on earth will be much more comfortable.

Not all regions across the globe will have the opportunity to apply climate resilient development, because climate impacts and risks exacerbate vulnerability and social and economic inequities, especially in developing regions or particularly exposed sites including coasts and small islands. Unfortunately this also means, that the current efforts in vulnerable and marginalized communities could be not very effective. Dynamic trade-offs between mitigation, adaptation and development exist therefore system-oriented solutions based on equity and social justice enable climate resilient development.

Enabling Climate Resilient Development

To enable climate resilient development diverse knowledge about climate risk and the impacts of certain adaptations are needed. By carefully designing and implementing policy and process interventions that also address inequities in gender, ethnicity, disability, age and location when can reduce structural vulnerabilities. This also includes approaches that focus on meaningful participation of the most vulnerable groups and their access to key resources. Climate resilient development processes link many different forms of knowledge and are more effective and sustainable because they lead to more effective actions.

Inclusive processes are very important since they strengthen the ability of governments to consider rate of change and uncertainties. This also means, that governance for climate resilient development is most effective when supported by institutions, that are aligned across various sectors and regions. Institutions are rules and norms that constrain or enable human behaviour and are most often responsive to emergent risks.

Achieving Climate Resilient Development

At the current rate of global warming levels climate resilient development will be very hard and will be even harder when the average temperature rises by 1.5°C. This development will not be possible in some regions and sub-regions after reaching a breakpoint of 2°C. Regions that already struggle with climate change will have an even harder time and climate resilient development might not be possible there, this includes small islands, deserts, mountains and polar regions. Regions with poverty or food and water insecurity face many non-climate challenges, which hinder climate resilient development even more.

The experience of the IPCC working groups show, that climate resilient development processes are timely, anticipatory, integrative and action focused and common goals and social learning build the foundation for these processes. Adaptation and mitigation should get implemented together, because that leads to many benefits and synergies for human well-being as well as the health of the whole planet. As already explained, knowledge plays a big factor, which is why international cooperation and knowledge sharing is so important, apart from financial cooperation of course. Climate change is a thread to human well-being and planetary health and any further delay in adaptations will miss a rapidly closing window of opportunity.

2.2.4 Biggest Contributors on Global Emissions

It is important that the countries with the highest amount of emissions, which also have the greatest responsibility, take climate change very seriously. Each country's or region's total contribution to global emissions can be seen by looking at the cumulative carbon dioxide produced. The cumulative value is the result of adding up each country's annual CO_2e emission over time.

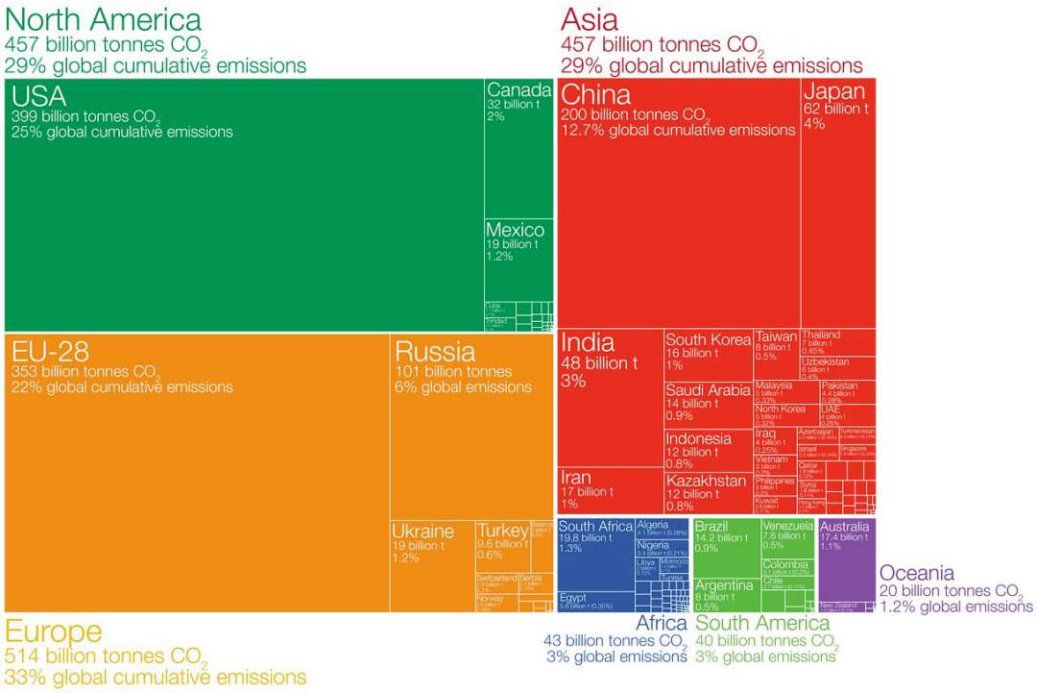

Figure 2.1: This figure shows a treemap, which is often used to compare entities, in this case countries and regions. The countries are presented as rectangles and colored by region, the bigger the rectangle the more emission a country has emitted. This graphic has cumulative data from 1751 until 2017. [41]

Figure 2.1 shows a graphic of regions that emitted most of the cumulative CO_2e in the past years, the data is up until 2021. [42] The United States of America have emitted more CO_2e than any other country to date, which is also twice more than China who are the world's second largest national contributor. Next is the region of the member states of the European Union, which includes 28 countries, with Great Britain still included as well. Even tough the EU tries to have regulations and targets for all their member states they still contribute 22.3% of the global emissions. Keeping in mind

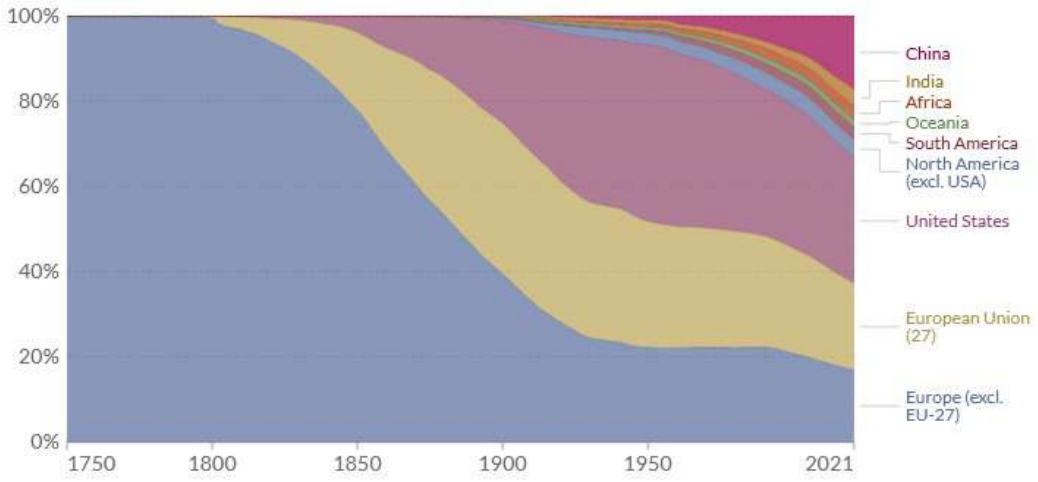

Figure 2.2: Total cumulative production-based emissions of carbon dioxide (CO_2), excluding land-use change, since the first year of data availability, measured in tonnes. This is based on territorial emissions, which do not account for emissions embedded in traded goods. Missing data has been filled with zeros for the purposes of data visualization. [51]

while, countries like India are currently belonging to the biggest emissions contributors worldwide, in the historical context they are not that relevant since most of their cumulative emissions have happened in the recent years. For comparison India contributed 3% of the global emissions from 1751 until 2021, but did contribute 7.3% in 2021.[57]

The fact the the countries of the EU contribute 22% of the global emissions shows that it is important to lower the emission per capita in that area. This will lead to the target group of this paper, which are people living in Austria. This group of people have high emissions and negatively impact the climate change by participating in high carbon emission emitting daily activities. [54]

Figure 2.2 shows that up until 1950 more than half of the historical CO_2e emissions were emitted by Europe and even in Europe the distribution was uneven since the United Kingdom contributed more than half of the world's cumulative emissions until 1882. [51] The USA only started to ramp up their emissions with the industrialization, which led to an steady increase starting in 1850. The discrepancy between the historical emissions and the current emissions also lead to tensions between the countries. Since CO_2e stays in our atmosphere for hundreds of years, countries like USA and China think that the United Kingdom should be doing most to reduce emissions based

on their history, while the UK thinks that the current biggest contributors should do more than anyone.

2.3 State of Climate in Austria

Since the target group of the mobile application are people living in Austria it is important to research about the current situation regarding climate in Austria. By understanding what plans are currently in place and what still needs to be done, this paper can derive approaches that could help.
The following section is based on the latest climate report of the Austrian environment agency from 2022 [68]. 2020 is the year with the latest reviewed data on climate change and emissions. The sum of all greenhouse gases combined for this year was 74 million tons of CO_2 or CO_2e equivalent gases in Austria. 7.7% less than in 2019, but keeping in mind that the year 2020 was shaped by the coronavirus, which meant that less emissions were already expected.

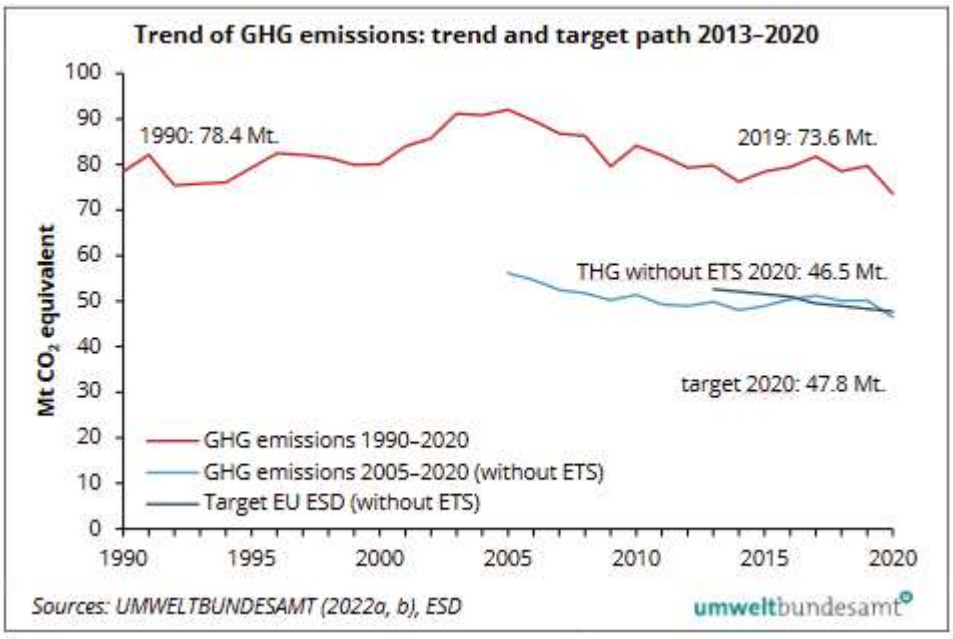

Figure 2.3: History of the greenhouse gases in Austria and how they did in 2020. The goal for 2020 was 47.8 mil. tons and the actual amount was 46.5 mil. tons. [68]

Nevertheless, greenhouse gases were reduced from 2005 to 2014, but starting with 2015 they increased again, which is a result from low cost for fossil

energy and missing climate protection measures. Energy and industry have the highest share (44%) of greenhouse gases in Austria, traffic has a share of 28,2%, buildings have 10,9% and agriculture is for responsible for 10,8% of the greenhouse gases. These sectors combined emit almost 94% of the Austrian emission. Since 1990 the traffic sector increased, while the emission of buildings, and agriculture sectors decreased.

When looking at which gases get emitted the most, it shows that CO_2 is in the lead with a share of 84,3%, methane is at 7,9%, nitrous oxide has a share of 4,8% and CFC gases sum up to 3%. As already stated 2020 was a good year for the climate in Austria, since the CO_2 emissions dropped by 9.2%. As a matter of fact methane had a reduction of 42%, which stems from the fact that dumping of untreated waste with high organic content was banned. Nitrous oxide emission has reduced as well, since the measures in the chemical industry and declining livestock numbers lead to a reduction of 22,5% in comparison to 1990. Since the year 1990, emissions of fluoridated gases have increased by 35.1%. This is mainly due to the increased use of fluoridated hydrocarbons as refrigerants and cooling agents.

2.3.1 Climate Neutrality by 2040 in Austria

The climate protection act(CPA) from 2011 was the first act that included norms to protect the environment. In this context, part of the greenhouse gases emitted in Austria are regulated by the Emission Allowance Act 2011, the other part by the Climate Protection Act. The 2020-2024 government program provides for a comprehensive revision of the Climate Protection Act, which is currently in preparation. Major changes are to include the reorganization of the bodies, the setting of targets for the period from period from 2021 onwards, as well as the legal anchoring of climate neutrality by 2040.

A key component of the law is sectoral ceilings. These were supplemented by an amendment to the CPA for the period 2013-2020. Based on this legal basis, Austria is obliged to achieve the target of -16% compared to 2005 for sectors outside of the emissions trading and this is in line with the requirements of EU's Effort-Sharing-Decision.

2.3.2 Measures

The Climate Protection Act aims to ensure consistent and coordinated implementation of measures through clear target agreements, responsibilities

and binding regulations in the event of non-achievement of targets. The aim is to achieve the mandatory emission reductions by 2020 through domestic measures and not through the purchase of emission rights via flexible mechanisms.

To reduce the emissions cap to a maximum of 47,8 mil. tons of CO_2 and CO_2 equivalent gases, the CPA established procedures for sectoral negotiating groups to develop measures to comply with the cap, including in the following areas:

- Increase of energy efficiency
- Increase in the share of renewable energy sources
- Increasing the overall energy efficiency in the building sector
- Mobility management
- Waste prevention
- Protection and expansion of natural carbon sinks

In a first step, a package of measures for 2013 and 2014 was agreed between federal and state governments in 2013. Additional measures for the period 2015 to 2018 were agreed upon by the federal government and the states and adopted in the Council of Ministers.

2.3.3 National Energy and Climate Plan 2021-2030

To reach the goals the EU set for 2030 [20], which included to limit global warming to a maximum of 1.5°C of temperature increase, all EU members had to create a national plan for 2021 to 2030 where they had to describe how they are going to fulfill these goals. Every member had to submit their plan by 2019, which Austria did.
By knowing the plans against climate change in Austria the suggested approaches in this paper will be tuned for the goals of these plans. This is important to quantify the results from the study and show if the increased engagement of the users and their reduced emissions are enough to reach these goals.

The main goal of the national plans is to see how the member states plan to work together and on their own to reach the set goals until 2030. Under the Effort Sharing Regulation, Austria is obliged to reduce its greenhouse gas emissions by 36% by 2030 compared to 2005. This represents a decrease of 27% compared to 2019 levels. Here are some the most important measures planned by the EU:

- Expansion of renewable energy
- Strengthening and expanding public transport
- E-mobility in individual transport
- Preserving the carbon pool in forestry, increasing wood growth and the material use of domestic wood
- Avoiding methane and CO_2e emissions in waste management
- Tax exemption of sustainable biogas, hydrogen and bio-liquefied natural aas

After successfully implementing all these points by all EU member states it is expected, that the greenhouse gases will see a reduction of 27% until 2030 in comparison to 2005. The goal is to reach a reduction of 36%, which could be done by introducing a green tax, by extending emissions trading to additional sectors or to use auction proceeds from emissions trading for climate and energy-related projects.

2.4 Serious Games

The introduction already talked about serious games and this section will deepen the understanding of them and their goals. Since the mobile application written for this thesis will be a serious game as well, it is important to know what these games are exactly and why they are no important for many people, especially young ones.

2.4.1 Success Factors in Serious Games Design and Development

After conducting an investigation [66] the authors could identify properties that make a serious game successful. One of these properties was music

that got integrated into the game, which helps most of the players to stay motivated playing the game. Another important factor is the guidance that the game provides, which avoids that the player gets demotivated or that he feels lost soon after starting the game. The next big point is the outcome of a players action. The majority of these outcomes should be positive or neutral since a negative outcome is another chance for the player to lose motivation, especially when confronted with it regularly from the beginning.

A study [14] compared the performance of participants who had a certain display on their phones about a serious game and those participants that had no such display. People with such a display got information about the game, which helped to keep them engaged, while those without a display had a steady decrease in performance and engagement. This shows, that keeping the user engaged is very important and regularly reminding the user about the game increases the motivation to play the game immensely. It is also believed that multiplayer games are more motivating than single-player games, because they help the player feel more immersed in the game. [67] The study only showed this effect for collaborative games instead of competitive games, which could mean that a person gets more motivated by helping others instead of playing against them.

Another study tried to find the links between successful commercial games and good accepted pedagogical theory. [5] Games that educate the player should follow certain guidelines, that take into consideration instructional models that are also used in other successful games. There is a certain instruction model that promises success which contains nine events of instruction:

1. Gain attention
2. Inform learners of the objective
3. Stimulate recall of prior learning
4. Present stimulus material
5. Provide learning guidance
6. Elicit performance
7. Provide feedback
8. Assess performance
9. Enhance retention and transfer

2.4.2 The Climate Adaptation Game

Since the mobile application in this paper resembles a serious game it is important to look at existing solutions to see which serious games regarding the climate change already exist and what makes them successful, if they are successful in the first place. The Swedish National Knowledge Center for Climate Change Adaptation collaborated with the Linköping University and national high school teachers to develop a game called "The Climate Adaptation Game", where the player has to find ways to cope with the changing climate. The main goal while implementing this game was to provide a tool that can help teachers while teaching about climate related matters, which are often very boring for the children or young adults. The game is about the needs and opportunities for climate adaptation by providing a background to increase the understanding of the climate change and what humanity can do about it. The interface in figure 2.4 provides valuable advice on how to structure a game like this and helps to find the right elements for the application presented in this paper.

Two versions of this game were developed, where one of them is just a modification for Minecraft while the other is a standalone web application. The reason for this two versions are the different playstyles and their different impact on the player. While the Minecraft version offers a first-person experience of exploring space, the web application has a more static and two-dimensional design, which helps when a person with less experience in gaming has to orient themself. As the last chapters already elaborated, it is very important to offer an intuitive user interface to keep the user and motivated. That is why the game have big graphics that show a tooltip when hovering over them. When starting the game the user has to choose a specific mission that he wants to do, after that a window opens where he is offered different tactics to solve that mission. These tactics are based on different climate adaptation, which all offer degrees of costs and consequences for the sustainability of the city the game is about. Every gaming session has a different result since the course of the game is largely based on the players actions. He has to choose from many solutions and also apply them at the right time. If he fails to do that or even chooses to do nothing climatic events like heat waves and floods can occur that lower the score of the player.

The score is not only based on the allowed climatic events, but also on the city's economy and other development goals like health, water and sanitation. This is because the game tries to represent the real world and solving climate change is a very complex matter where so many things need need to be taken into account, because helping our planet is never easy to do. This is also the

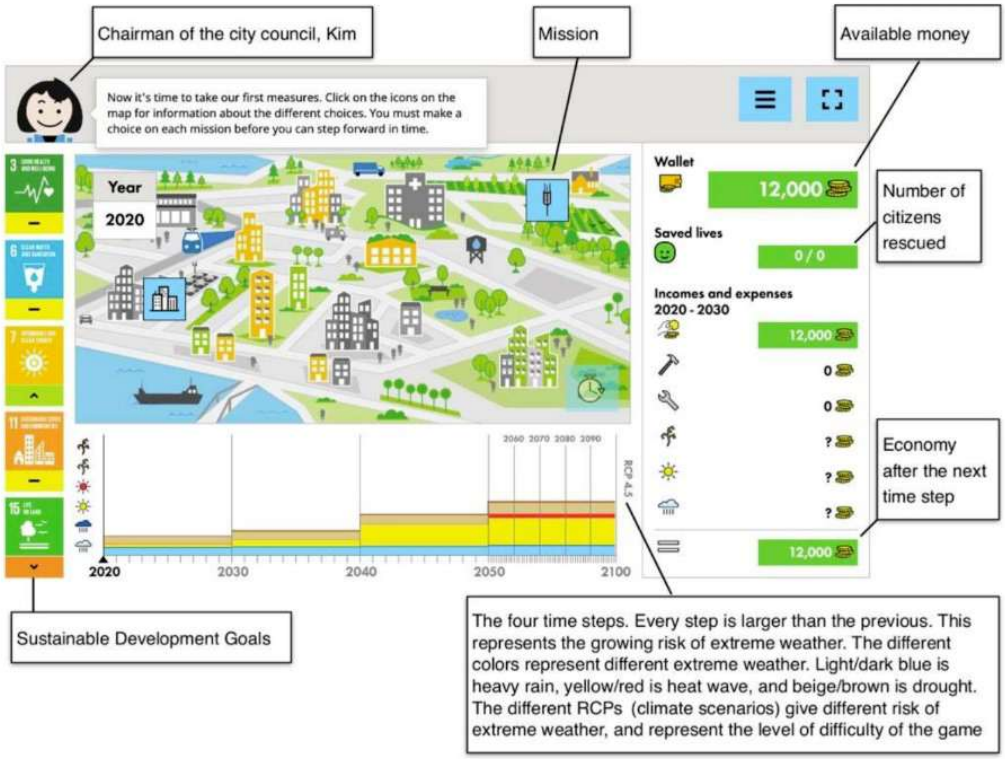

Figure 2.4: This is a screenshot of the user interface of the Climate Adoption Game, where the user has to find ways to support society in coping with the climate change. [39]

main motivation to develop such a game, because the complexity of climate change is often overlooked when trying to solve it and the Climate Adaptation Game tries to bring this complexity closer to the player, which are often students in schools. The real life costs and the selection of best measures are very dependent on the local conditions of this fictional city, which means that this game offers only examples rather the optimal solutions for the whole planet. The game is mostly played alone, but also has a mode for role playing where there are different groups of roles the users get assigned to. Then they simulate a local council meeting, to see the different conflicts of interests and willingness or unwillingness certain groups to different solutions.

After letting Swedish high school students of different schools play the game, the results speak for the game. 79% of the subjects said that they learned about the climate adaptation by playing the game and 81% agreed with the question whether the game motivated them to learn more about the climate

adaptation.

2.5 Social Dynamics

The following section provides valuable information into the mind of a human regarding their choice of activities in their free time. The implemented mobile application should convince and motivate their users to live a greener lifestyle and to know why the people are not doing it without help should be taken into account when brainstorming about the features of the app.
The features of the mobile application will have the goal of motivating its users to live a greener lifestyle. By researching social dynamics in the topic of climate change the features can be planned according to solutions that already work and put the different working approaches together in the mobile application, which will hopefully lead to better results regarding reduced emissions and increased engagement of the users.

2.5.1 Social Dynamics When Moving to a Greener Lifestyle

It is now important to know how it is possible to change people's lives and make them live a greener lifestyle. This is a complex problem with many factors coming into play, which makes finding solutions a hard task. Some people are missing the time to devote themselves to a greener lifestyle and some people have enough time but miss the needed financial resources. Some people really want to help the environment and do everything they can, while others know that the climate change is a problem but are not motivated enough to. So there is a need to look at all the different groups of people and what could potentially motivate them. The EU created the GLAMURS program that ran from 2014 to 2016, which among other things published a study on the social dynamics in connection to a greener lifestyle.[16] This topic is important since it shows how the people think about climate change and which social dynamics could be taken advantage of when creating a mobile application to help the people be more motivated regarding pro-climate activities.

2.5.2 Time Affluence

Time affluence means that someone has to subjective believe, that he has time to do the activities that are important to him. Time for yourself is very important and brings happiness, which material affluence does not. It is also

reported, that if a person does not have enough time to do the activities they like their physical health and family involvement will be negatively effected. [15] This is important knowledge for the development of the application, since it is crucial to know why people refrain to take action in matters they care about.
This is one of the reasons that the approach used in this paper is a mobile application. The people will not be motivated if they have the feeling that they do not have enough free time, but by using an application on their mobile phone the time required to use the app is minimal

The quality of the time a person spends on a day is highly subjective, but it has a high impact on their well-being. If a person is not happy with their time spent they will try to fit in something to do that makes them happy, which often times means he is not trying to live a greener lifestyle since that would be a hard step to take and feels like work at some times. Time scarcity and the lack of a proper work-life balance can be obstacles when trying to change your lifestyle. An additional problem could be that some people feel the need to comply with social norms, which could come from their surroundings, their believes or their religion. Apart from missing time some persons might feel a conflict with their work or family duties when thinking about a greener lifestyle. Many people would have to neglect some aspects of their life, for example using public transportation could mean a worse punctuality or installing solar panels brings a big pile of bureaucratic obstacles with it. On the other hand time affluence and being in control of your time have a positive impact on a persons life and can enhance to ability to change their lifestyle. [35]

European citizens normally work between 30 to 40 hours per week, so they have more than enough time apart from that to live their life as they wish, but not many people are in the position to have personal control over their time. They have to go shopping, cook, eat, do body hygiene tasks and many other mandatory things. So even if they have potential free time it does not feel like it for them, which means that the average European person does not need more time, but an increase in personal control over the organization of their time. Having autonomy to choose how to spend ones free time is very important in most regions and the subjective perception of more free time increases with more control of their free time and not more time per se.[16]

The topic of food plays a big role in living a greener lifestyle and and even bigger role when look at it keeping time affluence in mind. For most people

food is very important, this includes eating but also shopping and cooking. Eating in groups or preparing it together could lead to a more sustainable lifestyle since the people are spending the time with their friends, which is time good spent and while doing that they can look for ingredients that are not bad for the environment or even take care of community gardens. So it shows that doing sustainable activities that are fun will make the change to a green lifestyle easier. [16]

Another big point is the matter of transportation. People generally like taking public transportation over their own car since it feels like they have time for themselves while travelling, in contrary to the car where they should not be distracted while driving. Although trains and buses are a well received alternative to the car, the problem is that they often drain more time and as discussed before, time affluence is important. That means that cities as well as rural regions should invest in public transportation to make it as comprehensive as possible, and get as much people as possible to take the bus. [16]

2.5.3 Determinants of Sustainable Lifestyle Choices

Research about why people make sustainable lifestyle choices show how the mobile application should work and which mechanisms the app should take advantage of. The survey results of the paper from the GLAMURS program [16] show that people who identify as pro-environmental or environmental self-efficacy or have personal aspirations are more likely to make sustainable choices.

A person who is pro-environmental is someone who cares for the environment. This person often performs behaviours that are sustainable, which strengthens this characteristic and in turn lead to a even more sustainable lifestyle. Self-efficacy is a person's belief in their ability to succeed in a particular situation, which is important because it plays a role in how they feel about themselves and whether or not they successfully achieve their goals in life. There is a statistical correlation between people the have a strong sense of self-efficacy and people who lead a sustainable lifestyle. Aspirations are a set of of goals that motivate certain behaviour, among them are 4 categories, which are intrinsic, extrinsic, self-enhancing and self-transcendent. While intrinsic and self-transcendence aspirations support sustainable lifestyle choices, extrinsic ones such as financial success are related to unsustainable choices. If self-enhancing aspirations lead to a greener lifestyle is determined by associations that are culturally and socially encouraged for particular lifestyles.

Another key influence on well-being is the neighborhood quality, since being satisfied with one's place of living leads to to cognitively construed perception of overall satisfaction. This information can also be used to change some people lifestyle into more sustainable ones. When a person is happy at home and in their neighborhood overall, their desire to stay at that place increases. This desire can lead to more social engagement and closer communities which in turn leads to social cohesion. Dependent on the neighborhood this can lead to activities that favour the environment, but a more important point is that people who are happy at home tend to stay there and avoid environmental harmful activities like travelling long distance.

As already mentioned it was discovered that less time at work does not necessarily lead to a more sustainable lifestyle, since the subjective perception that one can control their free time as they wish is the key factor. This results in interventions that target higher autonomy in work and out of work activities as well as higher levels of personal control over their organization of time being more effective than giving people just more time. Another point why the choice to use the mobile phones of the people as the device for this paper should lead to better results.

Unfortunately there is a discrepancy between the desired lifestyle changes and the actual ones. The desired lifestyle changes go in a sustainable direction, but the problem is, that the current economic models tend to encourage work cycles and not time affluent lifestyles. For most people the motivation comes from intrinsic or self-transcending aspiration, which means that the focus should lie on activities that lead to a more sustainable lifestyle but also promote a better well-being.

The study also showed that sustainable initiatives lead to environmental friendly behaviors and have a positive impact on people that join these activities. This means that European policies hold great potential for promoting a greener lifestyle with a strong emphasis on personal well-being. These changes could be done by supporting the expansion of such initiatives with opportunities to interconnect and collaborate.

2.5.4 The Role of Sustainability Initiatives in the Adoption of Sustainable Lifestyles

The paper by GLAMURS [16] looked at 14 initiatives in Europe and advanced their understanding in how they have a positive impact on people's lifestyles

and the environment as a whole. These initiatives are very different, while some of them are only for small local communities others are very big and aim to grow even bigger. The initiatives cover the 6 most important lifestyle domains that are relevant fur sustainability: work-leisure balance, housing, food consumption, mobility, energy use, and the consumption of manufactured products.

Since the members of such programs report that they are happy with their life and partially link that happiness to the membership of their initiatives, it seems that they are well received. Some factors for that happiness are social and personal, such as experiencing personal growth, getting to know like-minded people. But these initiatives do not only bring joy with them. Some people experience frustration due to the fact that their actions seem unimportant on a global scale, but if some of them started with negative feelings about the project most of the people ended up with a better well being than before starting with it.

People that participate in such initiatives sometimes do not do that because of their pro-environmental motivations, but also because of social and well being motivations. People find themselves more important and useful when looking after the environment and becoming engaged in sustainability initiatives is just one step on their path to a greener lifestyle. Put most citizens find the perceived barriers an easy way out when arguing against changing their lifestyle. It is important for policy-makers and founder of green initiatives to find these barriers and learn how they can be overcome. The GLAMURS paper categorized some of the most important hurdles in a list based on a specific study.

- **Mobility:** As for many barriers the hindering factor convenience plays a big role. When trying to use car sharing most often the person is bound to have someone who shares the car, which could be a problem when there are important appointments to attend, like visiting at a doctor.
- **Energy:** Apart from the fact, that it often takes time to see the results when investing in renewable energy, it is not easy to get support and resources to change your energy production.
- **Food:** Many people want to eat healthier and greener. They look for sustainable choices such as meat-free alternatives but when looking for

these choices it shows their high prices as well, which pushes most people away of this idea.

- **Housing:** There are options to live in ecovillages, which brings many sustainable living benefits with it, but also some downsides such as inefficient heating systems or less comfortable facilities. It also means that this person would need to move away from their friends, which could have the appearance that they are trying to isolate yourself from others.

By being involved in these initiatives people develop or cement identities that care about the environment. They recognize caring about the environment as an integral part of their self-definition, which in turn leads them to making even more sustainable choices. This loop is very good for a person when keeping the environment in mind, because through this loop they will care more about the planet. The problem is, that these kind of people are still in minority and make a very small part of the population, this means that the government should think about ways to encourage people to enter the just mentioned loop.

This is where the initiatives come into play. Many of them cater to the already sustainable living person, but others try to convince new people to live a greener lifestyle. To make this vision reality a connecting link between sustainability initiative members and policy makers is needed, for example local agenda representatives of regional development agencies.

2.6 "Multiplication saves the day"

The author Bill McKibben wrote a column [37] for the Orion magazine which talked about how only talking about changing the world for better can make a big impact. He is assuming that only 5 percent of the American population care about the climate change. Care so much, that they use solar panels wherever possible, do not use cars, let their clothes air dry and cut their air travel time among many other things. These 5 percent give it all they have to save the planet, but the real impact of them on the global emission is almost zero.

That is a problem, since 5 percent of the American people are many in an absolute number, but still they have almost no impact on emissions. After researching he came to the conclusion, that this could not be further from

the truth. The people are thinking that a person can only reduce CO_2e by reducing their own CO_2e, but since they are living in a democracy these 5 percent can change very much. Imagine if these 5 percent only vote for parties that make it their mission to reduce emissions, then these parties have a 5 percent head start over the others in every single election.

Even without voting, these 5 percent of people can change so much, since actively participating in actions to make people aware of the problem can lead to even more people wanting to help. When looking at the civil rights movement, it only took one quarter of a percent of the American population going out on the streets and protesting to make big changes with this movement.

So what is needed are these 5 percent persuading other American people, congressmen, senators or even presidents. There are many websites, rallies and other chances for symbolic political action to change the world for better. This concept also sparked the idea for the application. The results will show, that 64 people used the app, keeping in mind that the app was only given to 24 people. The app was just shown to some friends, colleagues and relatives and they liked the app, which is why they started talking to other people and the app started to distribute itself just by people talking about it.

This concept will also the used in this paper while distributing the application and in certain features. The app will be given to certain people, which are also allowed to give the application to others. This will show how fast the application can spread and how much the users talk about climate change in their free time.

CHAPTER 3

Methodology

This chapter comprehensively describes all the methodological choices in this study. It elaborates on the approach that was taken, who data was collected from, how this data got collected. Furthermore it will be described in further detail than before as to why the decision was made to create a mobile application.

The main goal of this paper is to research how much impact the mobile application has on the motivation and emissions of their users and to answer the two research questions, which also try to show how much it is possible to motivate people to engage in pro-climate activities, that reduce their yearly emissions by using a mobile application.
The goal is not to solve climate change, but to provide more insights and show an approach that can help to better the environment. Of course since the paper is about climate change the suggested approaches of this paper will also show how effective they are in reducing carbon emissions. While writing this paper a mobile application will be implemented, that will help to find out how much the the target group of this paper can be motivated to engage in CO_2e reducing measures. Apart from reducing emissions the study will answer how much it is possible to motivate and engage people with this mobile application and also find out how fast the application spreads when people talk about it.

The test subjects will receive the application and are allowed to give the app to anyone who asked for it. One reason for this approach is, that this way the initial test subjects will not feel the need to find new subjects and by that

do not give the application to people that are not even interested in using it. The goal was, that the test subjects talk about the app in their free time, just because they are interested in it and by that find persons that are also interested in this topic and the mobile application. This simulates the real life example of a new application which spreads by word of their users.
Every person can use the app for exactly two weeks, where the user input will be logged and evaluated after the trial period ends. Furthermore a survey will take place for every user, which tries to find out how they liked the app, if it motivated them and other important insights to answer the research questions.

The reason a mobile application was used as the tool to get the data is that in the current day most people have their mobile phones with them almost all the time, which means that they also have access the the application most of the day. The app will have a questionnaire where the users input how their current lifestyle is regarding carbon emissions and then give them suggestions to lower them. Since the goal is to lower their emitted CO_2e in their daily lives it makes sense to use a tool they will access to most of the time in their daily life.
The application will have several features that motivate the user to lower their emissions and think about how much carbon emissions certain tasks produce. This will not only lead to less CO_2e per user per year, but also engage the user in the topic of climate change.
After collecting all the data from the user inputs in the application and from the survey this data will be analyzed to answer the research questions and show how successful the trial was. The user should have had fun when using the application and most importantly get motivated to reduce their emissions. Since the app will be given to a group of people who can share it with others the results will have two groups of people. First the group of known users and secondly the group of random people. This will enable the analysis of the results to find correlations between these two groups to give as much insight in the data that got collected and answer the research questions as in depth as possible.

3.1 Research Questions

It is clear that the climate change is happening right now and that humanity needs to act as soon as possible. The problem is, that even if everybody knows the problem there are very few people that actually care and actively try to help against the climate change. Some people just try to minimize

their CO_2e emissions as much as possible and others go on the streets and join demonstration or try to convince businesses and politicians to increase their engagement with the environment.

Even if a person cares about the environment there is still a long way until they are engaging themselves in helping the climate, because they claim that they do not have enough time or no motivation. This is were this study comes into play, in that it is trying to research approaches that can potentially help against these problems. The first and main problem this paper is trying to find new approaches for is the missing motivation, which means it is important find activities that help the environment, which are fun for people that are willing to help against the climate change. This leads to the first research question.

3.1.1 How Much Can Mobile Applications Reduce the Carbon Emissions of Their Users?

To motivate as much people as possible a mobile application for Android and iOS will be created. Everybody has their phone on them almost all the time, which means the device could help and remind them to do good for the environment on a regular basis. To give a short overview of the application: The user will start the application with a welcome screen with different questions about their lifestyle regarding the CO_2e emissions of their actions. The answers to these question will determine the users CO_2e score. The goal will be to lower this score, which will be achieved by completing tasks that the application is going to offer to the users. The tasks will be for the areas where they perform the worst, which means where they have the highest CO_2e emissions.

After every completed task the users score will go lower and lower, which is hopefully a motivating aspect because they can look at their starting result and their current result to see how much the user improved already. One of the limitations was, that it cannot be made sure that the user really did complete the tasks or just pressed the "Complete"-button in the application, but with the large amount of logged data, which showed exactly what the user did in the application and when he completed the tasks it was possible to do plausibility checks for every users data. The tasks are the first motivating aspect, while the second one will be the leaderboard. In the application there will be a leaderboard showing the current score of every user. No names will be used and every user will be anonymous, but the experience of climbing up

the leaderboard by lowering their score as much as possible, should be the second motivating factor.
The motivation to use the application comes from the fact, that the target group of this paper already consists of people that want to change to a greener lifestyle and the motivating features of the application increase their motivation even further.

Apart from the features the application itself has, it will also be interesting how the application can be distributed to as much users as possible. Every user that gets the application will have the permission to give it to people that are also interested in it. So nobody should go out of their way and promote the application, but this way it could be simulated how the app would spread in the real world. This has two aspects to it. On the one hand the more people use the application the more people will live a greener lifestyle, if they get motivated by the app. On the other hand, it gets tested how much people talk about helping the environment and how hard or easy it is to convince others, that taking action against climate change and change the way the people are living is of importance.

3.1.2 How Much Can Mobile Applications Motivate their Users to Learn About and Engage More in the Battle Against Climate Change?

The second research question this paper tries to answer is how much it is possible with this mobile application to make the application's users to engage more with the climate change and find ways to help against it on their own. Unfortunately not every person is motivated to take action against climate change, which means that they need to be convinced to change their lifestyle as well. Especially politicians should get motivated to put laws into place that help against climate change. While the first research question just looks at how much emission can be reduced, this question answers how much the people can be motivated to engage in actions against climate change, that do not only involve reducing their emissions, but also talk about the problem, convince others and attend demonstrations or other initiatives.

The first and most important step if of course the reduction of carbon emissions, but to achieve as much reduction as possible the users do not only have to look at their own amount of CO_2e emitted, but also bring others to do the same. The best case would be if these people manage to convince their politicians to put effort in the fight against climate change. Another way

to achieve a large amount of carbon emission reduction is to only support companies that look after the environment. In the recent years it became more popular for companies to engage in climate change reducing actions, because it is well received in the general population.

3.2 Gathering Results

To answer the two research questions, the trial of this paper together with the mobile application will gather a large amount of data. Firstly every action of the users in the application will be tracked and gathered in a report at the end. It will be known how often the users opened the application, when and which tasks they did complete and in which category that happened. Furthermore a extensive survey will be given to every person after using the application for two weeks which will also be the end of the trial for the user. The survey will answer how much fun the user had, how motivated it got and how much he engaged in the climate change matter after using the application. Together with the data of the completed tasks, which will reveal the reduction of emissions per user the data will be able two answer both research questions.

3.3 Activities

Since one of the research question asks how much it is possible to reduce the carbon emissions of the users in their daily life it is essential to support the right daily activities. The most important activities will be researched, their emissions will be researched and then they will be categorized, which enables the application to show the user in which category there is the most need to improvement. Of course it is important to first decide which activities should be supported. Since the app will accompany the users in their daily life the supported activities should mostly consist of action in the daily life of the users. Fortunately there exists a study about the everyday activities in Austria [54], which show the most important activities to support and how much impact certain group of activities have on a person's emissions. Especially eating, cooking, personal care and housing are areas that have a big impact on the yearly CO_2e amount of a person in Austria. Derived from this paper four categories got created that try to cover the most important aspects of the daily life, which are housing, food, consumption and transportation.

3.3.1 Survey of Activities

The first and most important step is to find emissions for each of the supported activities. One of the problems is that energy gets consumed to do certain things, like watching TV or cooking a meal and this energy gets produced differently in every country. For example, the percent of renewable energy in Austria is 78% of the total energy production [46], while Hungary only has 11% [46]. That means that a person can use more energy in Austria than in Hungary and still be greener regarding our planet, but only if that energy comes from renewable sources. To make it as simple as possible the source of the energy will be disregarded for now and the focus will lie on the produced emissions.

Most people calculate their emission in CO_2e, which will be done in this paper as well. As officially defined by Eurostat, CO_2e is a metric measure that is used to compare emissions from various greenhouse gases by converting amounts of other gases to the equivalent amount ofCO_2e. Some people also compare the CO_2e amount to the equivalent of kilometers driven by car to grasp how much their emission really is. Firstly it will be researched, how much emissions certain activities produce and state them inCO_2e. The paper may sometimes compares the activities to their equivalent in car kilometers, but for the most part concentrates on the CO_2e, which is more important.

To keep some structure, activities that belong to the different categories will be looked up, which the app is going to support (housing, food, transportation, consumption), together with their produced CO_2e emission. This means that the user has a better overview of his emissions and can focus on some categories instead of trying to better himself on various unconnected activities. This is the list of categories, that will be supported in the application. At the end of this chapter is an exhaustive list of activities that are supported.

- **Housing:** Activities that involve your own place and how your lifestyle looks like at home.
- **Transportation:** Activities that involve transportation, including public transportation, cars, flights, ...
- **Food:** What a person eats also impacts their emissions, since buying season or regional products is less bad for the environment than products coming from a different continent.

- **Consumption:** It is important which products and how often they are bought. If a person is buying clothes that emit a high amount of emissions in production and then throw them away after some months to buy new ones it will result in a high amount of carbon emissions.

For every group there are activities in the list at the end of the chapter and also proposed solutions associated with that activities, to keep the CO_2e of a specific group as low as possible.

As presented the application tries to cover various fields of a person's daily activities. The user should be able to track their life with regards to the environment regardless of if it helps or destroys the planet.

Even if only 2% to 4% of the global population flew internationally in 2018 most if that comes from wealthy countries like in Europe or the USA [26]. This means that it is also important to include flying per plane in the activities. For example, commuting per car is around 140g CO_2e per km [53], which is quite high when compared to other tasks. The alternatives are not better so it will be bad for the environment if a person does not live near their workplace regardless of their choice. Flying is on another level with 1100g CO_2e per km [40], which shows how bad it really is. Many people prefer flying over taking the train even if both are viable options, which is attributed to the higher cost of money and time. Of course it makes sense to take the cheaper option, but this would mean that the politicians have to think about the pricing of the different transportation alternatives.

Another part is the cleaning, which must be done every day as well. Whether it is the cleaning of your home or of yourself, both have high CO_2e emissions. The problem in this area is the missing alternatives of more environmentally friendly activities. People have to clean their home and also have to clean themselves, but they can try less water which could go a long way. A misconception is handwashing the dishes in favor of putting them in the dishwasher is more environmental friendly, but as shown in the list washing per hand is far worse than the machine.

Sitting on the computer or using your mobile phone can increase your emission as well. Even if it's just sending an email or a selfie, when doing that multiple times a day it can pile up.

Looking at the numbers for cooking it is clear that this is a problem for the daily emission numbers of an average person. With 9600g CO_2e per meal, which is the equivalent of a car drive of 69km, since the average passenger car has an emission of 140g/km [53]. People who try to live environmentally friendly and try to take public transportation, still "drive" 80km every day, just by cooking their meal. Of course, there are meals that have less emission, which means they have to use ingredients that produce less CO_2e in production and then also use less energy while cooking.

Now it needs to be decided which of these activities should be supported in the mobile app, which means that is also important to choose the activities that are most present in everyday life. Points like travelling by bus or train are very important, but other activities like sending a selfie are a drop in the bucket and could be unimportant to many groups of people. There are also things like showering or cooking that are very important and could be a big part of ones recorded activities.

To generate a profile for a user he will be able to input his lifestyle choices to see how good he is doing among our users. A part of this will be his housing and especially the heating option he chose. The following list shows how much emission a kWh "costs": [63]

- Natural gas: 0.22kg CO_2e/kWh
- Liquefied petroleum gas (LPG): 0.24kg CO_2e/kWh
- Heating oil (gas oil): 0.30kg CO_2e/kWh
- House coal: 0.39kg CO_2e/kWh
- Electricity (2017 generation mix): 0.23kg CO_2e/kWh

3.3.2 Prioritizing Activities

In order to keep the application in a size that is appropriate for a master's thesis the activities need to get prioritized and sorted based on how important they are for the app. To start of the sorting the little activities like sending a mail or sending a selfie to the bottom of the list. Things like travel by bus are important for everyone and should be on the top.

Supporting daily activities is important for two reasons. First the more activities are supported the more effective is the application. On the other hand, the user could be more motivated to help the environment if he sees how much emission he produces daily. That is the reason that the application tries to support as many activities as possible regardless of their impact to show the user that he can make a difference.

For every activity there will be, if possible, an alternative to help the users to reduce his emission. Hopefully they will replace their high CO_2e emitting activities with better ones, which leads to better emission statistics for them thereby motivating them to replace one environment unfriendly action after another. Sometimes it is not possible to provide a better alternative, which will mostly happen for less significant tasks. The solution then would be to just stop doing that specific task on a daily basis.

When starting the application for the first time the user is greeted with a little setup screen to tell how his lifestyle impacts the environment at that moment. He will state how he lives, what he eats, how he moves around, and which daily tasks impact our planet the most. After this setup he will get suggestions to better his lifestyle and reduce his CO_2e emission. These suggestions will be very important, because they are the first steps to reduce the emissions which paves the way to a healthier environment.

This leads to the most important activities, which are the suggestions against the activities emitting the most emission. These activities will have the biggest impact and are the most important ones, which means they will have the highest priority. A subset of these activities will be the transportation, eating habits and the usage of water at home.

3.3.3 Supporting a Subset of Most Effective Activities, Leverage Social Dynamics

As already mentioned in the last chapter, the most important and most effective activities are the ones with the highest emissions and suggestions that battle them. This will also be the most effective approach for the users, since they can clearly see how much impact they can have by changing their activities in the daily life.

Furthermore, the application will have a leaderboard to compare yourself to other users. By using activities that have the biggest impact will motivate the

users the most, since they can see how good they are doing and be "better" than others. Not only will they be able to be on top of the leaderboard, but they will also see how much good they are doing by chasing the first place.

Leveraging social dynamics will be very important, because many people are not against changing their lifestyle in favor of the environment, but people are lazy and need a push until they start doing something. This push could be our application, since it motivates them on many different levels and shows them how easy it can be to change for the better.

3.3.4 List of Activities

Here is the list of activities that were considered for the application. Every one of these activities can be input of the users daily actions, which will determine their daily CO_2e emissions. The activities where chosen accordingly to the target group of this paper to, which enables the data collection to get the results needed for this paper. This list could be endless but it was only important to get several activities per category, which were food, housing, consumption and transport. When the user starts the application he will get asked about these categories and their areas, this is why it is important to have the emission data about all of them.

- Cooking a meal: Average 9639g CO_2e [18]
- Scrolling on Instagram for one hour: 93g CO_2e [8]
- Watching Netflix for one hour: 36g CO_2e [7]
- Sending a selfie: 50g CO_2e [17]
- Load one web page: 1,76g CO_2e [65]
- Card payment: 4g CO_2e [6]
- Tap water running per year: 157000g CO_2e [4]
- 15 minutes shower: 1700g CO_2e [55]
- Using dishwasher at 65C: 990g CO_2e [55]
- Washing dishes per Hand: 8000g CO_2e [55]
- Using Computer for 8 hours: 777g CO_2e [19]

- One Google search: 0,2g CO_2e [23]
- Train travel per km: 49g CO_2e [9]
- Bus travel per km: 60g CO_2e [10]
- Commute per km: 141g CO_2e [53]
- Average virtual Meeting on Zoom: 160g CO_2e [59]
- Streaming music per hour: 55g CO_2e [45]
- Sending an email: 4g CO_2e [3]
- Strawberries in Winter: 3400g CO_2e per kg fruit [56]
- Emission of cheese: 5700g CO_2e per kg cheese [58]
- Making a tea or coffee: 53g CO_2e [55]
- Having a bath: 1100g CO_2e [55]
- Commercial flight for one km: 11000g CO_2e [40]
- Emission of eggs: 3000g CO_2e per kg eggs [58]
- Produce one pair of jeans: 33000g CO_2e [2]
- Production and sale of a T-shirt: 7000g CO_2e [49]
- Lifecycle of 1kg wool: 46000g CO_2e [64]
- Lifecycle of 1kg Polyester: 21000g CO_2e [64]

Apart from the activities on their own, groups of activities will be supported as well, which means that if a user has a particular high CO_2e value in a specific group they will be offered solutions to lower their emissions in this area. These are only some of the activities that would help to reduce emission:

- **Housing:**
  - Purchase energy-efficient appliances
  - Unplug electronics when they are not being used
  - Grow your own vegetables
  - Switch to LED lightbulbs

  - Conserve water

- **Transportation:**
  - Use public transportation when possible
  - Reduce air travel
  - Alternative to public transportation use bike or walk

- **Food:**
  - Stop throwing food away
  - Eat less meat
  - Try plant-based protein
  - Cut back on dairy

- **Consumption:**
  - Buy clothes that need low emission in production
  - Recycle clothes
  - Do not buy unnecessary goods

- **Small daily activities:** As there are many small activities a person can have on an average day it is not possible to have general solutions for all of them, which means that there will be emission values associated with certain activities, which are show to the user. That should show the user how much he could lower his emission score by avoiding these small activities.

3.4 Expected Results

Obviously it will not be possible for this paper to solve climate change, but by researching aspects about this topic approaches could be found that have not been thought about until now. Humanity needs to work together on this topic, which is why ways to motivate people to look after the environment are needed. In the course of this paper the created mobile application tries to reduce the average carbon emission per user by showing them the first steps in the right direction. In completing the initial setup they will see their current emissions and can lower them by completing tasks, this together with the leaderboard should motivate the user to live a greener lifestyle.

Apart from reducing emissions, this study wants to find out if the users also engage more in the topic of climate change and talk about it more often. When the point is reached, where the majority of people want to see actions against climate change it is very likely that politicians have to act as well. Not only does the emission per capita have to get reduced below a certain point, but even that is not enough if the largest companies on the planet do not care about the environment, which does need a actions of politicians. Because of that engagement in the topic of climate change is essential, to raise the issue as much as possible.

The target group of this paper is the average person, which got described in further detail in the introduction and to emphasize again, this paper and the mobile application will be no solution against climate change but only help to find what solutions could work.
As for the results, the paper will show how much the average emission of the user got reduced over the course of the trial. Apart from that there will be data about the task system, where it is shown how much tasks got completed per user, when the users did these tasks, which category got the most completed tasks and many more. Furthermore the extensive survey will show how the users think about the application. There will be questions about how much they were motivated by using the app, how much fun they had, how much more they are engaging in anti climate change activities because of the app and other questions.

CHAPTER 4

Implementation

This chapter elaborates how the mobile application was implemented and what the thought process behind the decisions were, while implementing the application. First of all, about the decision on which platform the app was going to be released. Since there are only two big operating systems for mobile phones (Android and iOS) the application should work for at least one of them. Luckily some tools and frameworks exist, that help implementing a mobile application for both operating systems. Apart from that as much daily activities as possible that effect the CO_2e emissions of a average human in his daily lives had to get researched, which was going to be supported in the app. After creating the list of these activities, which was described in detail in the chapter above, the exact emissions associated with them had to be researched.

4.1 The Application

The mobile application was written for iOS and Android to reach as much users as possible. Since writing two separate applications would take too long the flutter framework was used together with a java backend and a PostgreSQL database to save data of all the users. This database also had all the data about the logged user actions, which made the evaluation of that data for the results easier.

After choosing which activities the application is going to support a initial setup was created, where the user had to answer several questions about their lifestyle to determine their starting emissions. The questions come in 4

Figure 4.1: This is a screenshot of the initial setup, where the user has to answer questions in 4 categories.

categories (food, transportation, housing, consumption) which were explained above and will have to be answered when starting the application for the first time.

Some more example questions:

- How often do you eat dishes that contain meat or fish?
- How many kilometers do you travel annually by car or motorcycle?
- On average, how many hours have you traveled privately by air in the last five years?

- How many degrees do you heat your home to?
- At what temperature do you wash your laundry?

Each question has various answers, and each of these answers has a certain CO_2e value. After the setup all CO_2e values from each answer gets added up to get a score. There is a overall score and a score for each of the four categories. The source of the CO_2e value of these answer can be found in activity section above. All of the questions had to be answered and it was not possible to skip a question. Every category had between 7 and 9 questions.

After answering all the questions the user had complete to process by confirming his answers and was greeted with an overview about his results after that. The overview showed your own results and the result of an average person in Central Europe. The result screen showed the users overall CO_2e value in ton per year and also the CO_2e emissions in the four categories.

4.1.1 Motivating the Users

Without users it would be impossible to get data for this study. This leads to the fact that the application has to have several motivating features, that keep the users engaged with the app. The timespan where the users can use the application is only two weeks, but it should be avoided that they lose interest in days.

Tasks

This is arguably the most important part of the application. One of the goals of the app was to lower the yearly CO_2e emissions of its user. Some users may be motivated on their own and try to better their score, but many others are lazy, which meant there had to be mechanism that motivated every user.

A task system, that offers users several tasks to complete, tries to tackle this problem. These tasks try to bring down the emission of their worst categories. If a user has a high CO_2e emission coming from their living conditions at home the app gives them the task to lower their temperature at home to save emissions by not using the heating or asks them to let their washed clothes air dry instead of putting them in the dryer. These are small actions on their own, but can have a huge impact when applied to every part of the users daily life.

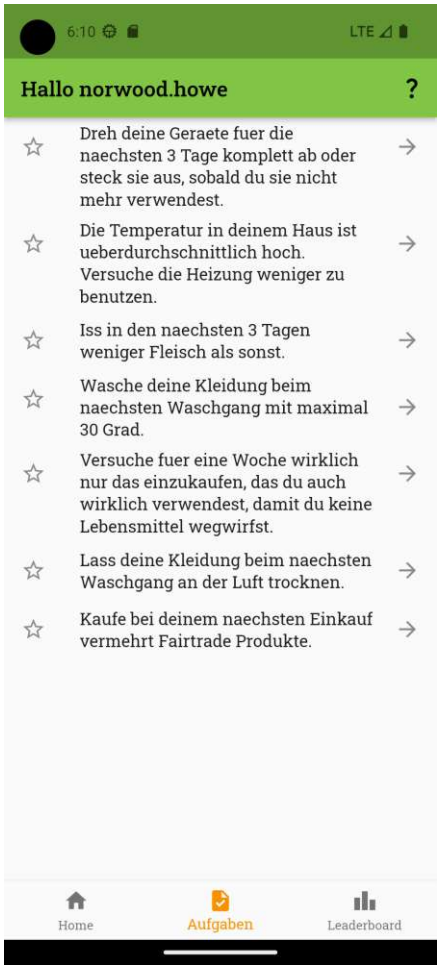

Figure 4.2: This is a screenshot of the tasks that are offered for the user, which are personalized based on his result from the setup.

The tasks will be offered for the users categories with the highest CO_2e emission. After doing these tasks their score will get lower and they will receive tasks from the next worst categories. That theoretically goes on until there are no "bad" categories anymore, but that did not happen for any user in the time span of the study. Since you can only do so much to avoid emissions after completing all tasks, the users should just keep avoiding the bad activities and keep their emissions low. Of course it is not possible to reduce their emissions to zero, but when they are on a level that is hard to improve they would have to look at other ways to help the environment, which could include voting the right politicians or draw attention to the problem in other ways.

So they get the list of their personalized tasks and can do the tasks however they like to. When clicking on a task a info windows opens where the user can see a description of the task, why he gets the task and what impact doing the task has. Of course only doing the task once has no big impact, so the goal would be to do the task for the first time and then keep on living like your doing your task every day or week depending on what the task description was.

The interface with a list of tasks can be seen in figure 4.2. This list only shows the tasks for the areas the users performs the worst at regarding carbon emissions. Of course there are many other tasks for each of the areas and here are some more examples of the tasks a user could get:

- Wash your clothes on the next wash cycle with a maximum of 30C degrees.
- Buy more seasonal foods the next time you go shopping.
- Take the bike or public transportation the next time, for a way that is otherwise covered by your car.
- Try to buy only what you really use for a week, so you do not throw food away.
- Buy more Fairtrade products in your next shopping.
- Eat less meat than usual for the next 3 days.
- Drink less milk than usual in the next 3 days.
- Air dry your clothes after the next wash cycle.

Most of these tasks try to tackle specific problems in the daily life of an average person and try to bring down the personal CO_2e emissions down on a personal level, which is the main area the application tries to better.

As can be seen in figure 4.3 the task details also show how much impact doing a task has on the CO_2e emissions over a year. After completing the task the user can immediately see the impact on his emissions when looking at the home screen where there is a list of their overall emissions and the emission per category. That itself should be motivating, since it should be fun to make your own results better and better.

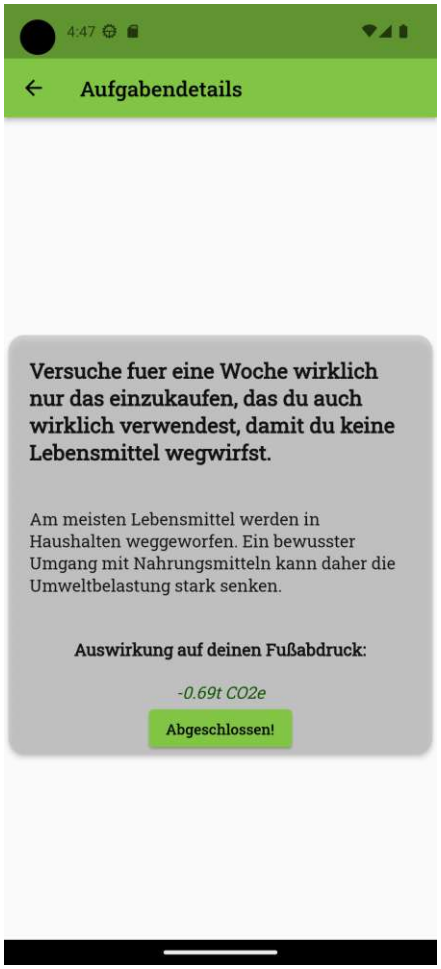

Figure 4.3: This is a screenshot of the task details, where there is a description of what the user has to do and how completing the task impacts his CO_2e emissions.

Leaderboard

The next big point is the leaderboard which shows a list of all the users that did the initial setup and only shows the current CO_2e score. As already mentioned, by doing tasks the users can bring down their emission score and in that help the environment. The leaderboard should show how their emissions stand in comparison with other users, that are also trying to better themselves. This is also shown in figure 4.4.

This should be the next big motivation for users since they can compare their score with others in real time and climbing the leaderboard up by doing as

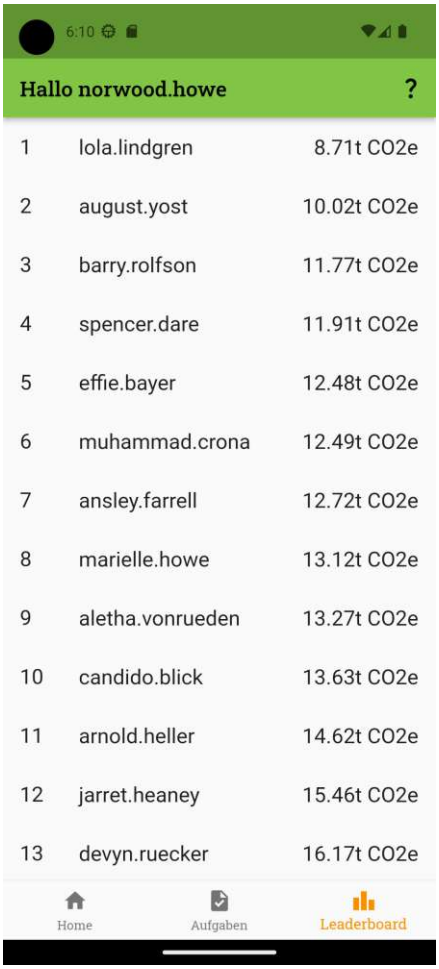

Figure 4.4: This is a screenshot of the leaderboard, where the users can see how they currently stand against the emission score of other users.

much tasks as possible is good for the user and of course for our environment. The most important part of the application, when trying to find ways against the climate change, is that the users are doing their tasks and by showing them their own score, the score of others and the possible improvement after completing a task should motivate the user more than enough.

Many people want to help in the fight against climate change [21], but do not really know how. The application should guide them on their first steps and show them where the potential for carbon emission reduction is the highest.

Just to show everything the application has to offer, figure 4.5 shows a little help screen, where every page gets described and how to use the application.

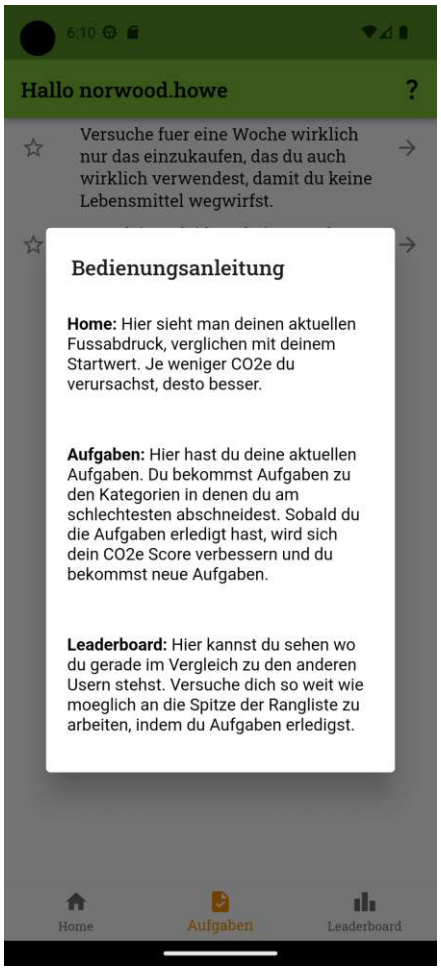

Figure 4.5: This screenshot shows the help screen, which can be opened at all times and describes how the application exactly work.

CHAPTER 5

Evaluation

After the the trial concluded a big amount of data was gathered. This data was analyzed and brought into a easily readable format to show the findings of using the application for two weeks. Of course it will also be shown how the data got collected and who it was collected from.

5.1 Test Subjects

In the end 64 persons used the application, with nearly half being female and the others being male, but this and the following facts about the users are only known for the known group of users. Most of the users are living in Vienna a big city, which has to be considered when looking at the results. Users not living in Vienna lived in Austria nevertheless, which also plays a role since other countries have more or less green energy than Austria, which can have a big impact on a persons CO_2e score. The average age of the subjects was 31 years old, ranging from 20 to 65 years.

Every user had a timeframe of 14 days, with some of the users using the application one day more or less, where they should use the app as much as they liked. They got told that it would also be no problem if they did the initial setup and then never used the application again. This was because the study should simulate how the application would perform in the real world and if the application would be available for everyone in the Appstore, it could be that many people would download the app and then never look at it again. So by putting no pressure on the users, they used the app when they wanted to and even if every single user just opened the app once and

then never again the results would then just show, that the application is not engaging enough. Meaning that the app would be a failure and the answer to the research question would be that it is not possible to motivate people into changing their daily habits into more sustainable activities with the application used in this study.

After evaluating the results they showed that the users indeed like the application and used it quite often. Of course the usage frequency between the users differed, but all of them were motivated and often enthusiastically talked to me about how they got better in the leaderboard or how they already improved their score.

It should be noted that I as the author of this paper and creator of the application know the first 24 persons the application got distributed to. This means, that the basic facts about these 24 persons were known, but all the other users were completely anonymous. Of course every user provided the same data by using the application and filling out the survey. It is known where they live, how old they were and other little facts that could be relevant. The other persons were strangers without these additional facts, which meant there are two groups of people in the results. The following report of results will include the data of the whole group of 64 persons, but since there are two subgroups they will also be compared and if there is a big difference in data it will get mentioned. One group will be called the "known group" and the other one will be the "group of strangers"

5.2 Data collection

To get as much data as possible and to ensure validity of data every input the user could make was logged. This meant that the initial setup was logged, as well as the tasks where the logs showed which user completed which tasks at which time. The logging generally logged every input possible by the user, of course the data was anonymous.
When the user starts the application for the first time they have to answer several questions about their emissions in their daily life. The result of the questions and the time this setup was done is logged and saved. This showed when the user has started using the application, which also marked the beginning of their trial period.
After the setup is completed the user can start working on their tasks. Every time a user completes a task the timestamp of this completion and which task got completed was logged. This meant the results did show if a user just

randomly completed tasks as he liked or if the time difference between the completed tasks was high enough to make it plausible that he really did the tasks in real life. Of course some tasks could be competed in a short amount of time, but since every single task completion of every user was logged, it was possible to recognize patterns. It was also logged when and how often the users opened the application to see the engagement with the application.

Another big part was the conclusive survey, that every user had to do. Fortunately every user did the survey which provided data about how the users liked the app, how much fun they had, if they thought the application was useful, if it changed their lifestyle to a more sustainable one and several other questions. The survey took place after the end of the period were the test persons had to use the application, to ensure that they have the most optimal overview over the application.

As already explained, there were two groups of users, where on of the groups, which contained the initial 24 persons the app got given to, had some known facts about them. These facts were asked in the course of distributing the application to them. The other group of strangers had no information about them, which meant there was the opportunity to compare the known users with the group of random people.
This meant that there were two different types of users with their own data that could be compared. It was possible to find some correlations between the groups and showed how a random person thought about the application and how the the group of known persons used the application.

From using the logged data from the application and the results of the survey every test subject did there was a big amount of data to analyze. It was possible to show how much fun the users had, how much the app motivated them and if they were more engaged in the topic of climate change.

5.3 Results

Since the logging of data covered everything the users could do in the app to get as much data as possible from their involvement, the data showed how often they opened the app, how often they did tasks and when all of that happened. After reviewing this data several metrics, like completed tasks, reduction in emissions and the user engagement were created. As already stated, the study had 64 users, where some of them used the app more and others less. In the end all of them but one answered the setup truthfully and

looked at the application more than one time. Every single user completed at least one task and opened the application several times over the span of two weeks, which shows that there was interest in the application. Unfortunately did the engagement with the application decline over the course of the trial, but that does not mean that the users used the app for two days and then quit. 81% of the users completed a tasks in the last two days of the trial period, which means that most of them used the application until the end.

The first point was to get the average CO_2e emissions per user after doing the initial setup, to see how they started and then after the study was done their current emissions were examined to see how much they were improving. Furthermore the data also showed the best and the worst result a user had. Here are the results, the worst single result was 49.45CO_2e but this user only chose the worst answer to each question. The next worst result was 37.23t CO_2e and it could be argued that the worst result with wrong input should be deleted, but since there was a large amount of users this outlier did not change the result too much the user was left in the results:

- Number of users: 64
- Average emissions per user: 18.64t CO_2e per year
- Average emissions per user after using the app: 17.49t per year CO_2e (-5.796%)
- Best result: 8.71t CO_2e
- Worst result: 49.45t CO_2e

While the worst result is most likely just a user inputting wrong answer, the next worst result with 37.23t was in comparison to the other users quite bad as well, since the third worst result was only 23.68t CO_2e per year. This needs to be considered when looking at the results of the users, because removing these two worst results would give us a value of 16.66t CO_2e per user per year. These two results were of course not deleted, because even with a larger amount of users the average would stay very similar to the actual results of this study.
After the trial period ended for the 64 test subjects, they had an average emissions of 17.29t CO_2e per year, which is a 5.8% decrease from the average starting emissions per user of 18.24t CO_2e. The median of the results after using the application was 16.93t CO_2e per year.

The next point were the tasks, where data about how many tasks got completed and how many tasks the average user did got collected. Furthermore there was data gathered that looked at the categories and how many tasks got done in them, to see in which category the emission score could be improved more easily and which were not so easy to complete. Here are the results for the tasks:

- Amount of tasks completed: 238
- Average tasks per user completed: 3.72
- Most tasks completed in food category
- Least tasks completed in mobility category

The average emissions reduction was almost identical and the average tasks completed per user was a little lower than the overall average with 3.21 tasks completed per user for the known group.
Furthermore there was a discrepancy regarding the completed tasks between the data for the first and the second week for the trial period. The first week had a higher engage rate than the second week, which was expected, but it shows that the users activity in the application is declining, which could potentially be a problem if the app would release to the public. 68% of the completed tasks were done in the first week and with every day the engagement of the user declined a little bit. By week two, the amount of times the average user opened the application decreased by 24% in comparison to the first day, which is to be expected since new apps are always more exciting than the ones they already know.

As for the categories the food category had the most completed tasks with a number of 91, while the worst category namely mobility had the least completed tasks with only 34 tasks. Between these two categories were the housing category with 63 completed tasks and the consumption category with 50. In the beginning the tasks in the housing category were most often completed, which could lead back to the fact that they could be done without going outside. These tasks just asked to user to change up the users activities while being home, which can be done quickly if they are motivated. Over the course of the two week trial period the food category caught up and had by far the most completed tasks in the end.

Another important factor is how fast the mobile application spread. The initial distribution only included 24 persons, who were told to use it however they liked and if someone asked about the application they could give it to them, but it is absolutely not necessary to promote the application. The count of users in the end was 64, which means, that every person gave the application to two others on average in the span of two weeks, which is extraordinary. This shows, that many people like to help the environment and look for ways to accomplish this goal, but do not know where to start and the application gave them suggestions on how to do their first steps. It could very well be, that this does not only work for a mobile application, but also for other easy ways to convince people to live a more sustainable lifestyle.

5.3.1 Survey

After the two weeks per user, all the data was collected and a report was created with the numbers above. Additionally every user had to answer a survey after the two weeks were over, to have a look what they were thinking about the application. In total there were 8 statements, where every statement had 4 possible answers (fully agree, somewhat agree, somewhat disagree, fully disagree).
The first statement in figure 5.1 that was asked was if the users understood the goal of the application, where ~62% fully agreed and 38% somewhat agreed. This was important, to see that the users saw what this paper was trying to accomplish and how the app helped in doing that. The answers were very satisfying in the sense that every single user at least understood a little bit what the goal was. Nevertheless in an optimal case every user should know exactly why the application was made, but the fact that this is not the case is most likely because the application was spread by users as well who may have not explained the purpose of the application very well, which is also backed up by the data which showed, that 91% of the group who only somewhat agreed with this statement was from the group strangers.

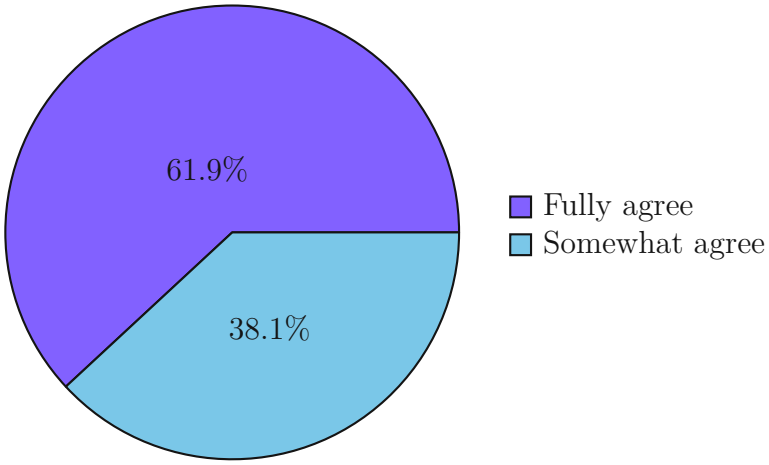

Figure 5.1: This graph shows how the users reacted to the following statement: "I understood the goal of the mobile application".

The next statement shown in figure 5.2 tried to bring into knowledge, if the users were more motivated by using or after using the app. The next crucial factor, which would be positive if it would be agreed on by most of the users, because if the users are more motivated to do more for the environment, they will live greener lifestyles even without using the application. Maybe they are

so motivated that they will try to convince others to do the same of participate in public actions against climate change. The answers were pleasant, because more than 71.5% of the users at least somewhat agreed and said that they were more motivated. Still 28.5% disagreed with the statement which meant that they were not even more motivated to support the environment and almost 10% even fully disagreed. This means that it needs to be looked at in why the application did not motivate all of their users, considering that all of the users where interested in the app to begin with. The data showed, that 71% of the people that disagreed with this statement where of the known group, which could mean that there were people in this group that were either already motivated enough or they just used the application to help get more data.

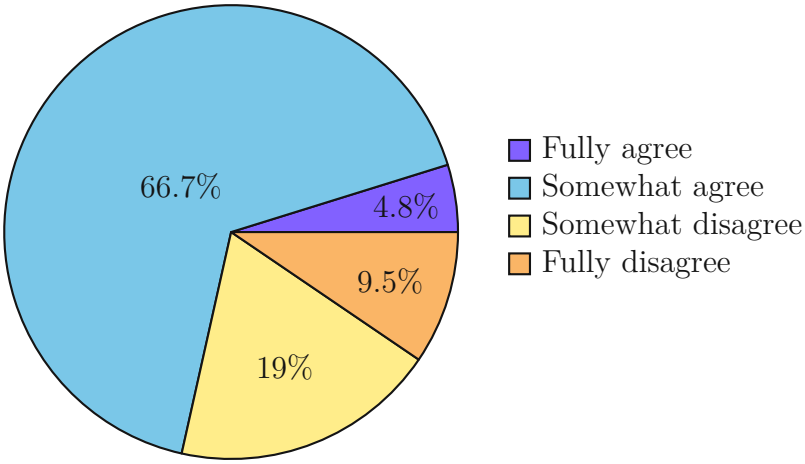

Figure 5.2: This graph shows how the users reacted to the following statement: "The application motivated me to live a greener lifestyle and support the environment"

It was also important, that the users will learn more about the environment, which could help by pushing the user to think more about what their actions can do for or against the climate change. More people than not did not agree with this statement, which meant that they did not really learn anything new about the environment generally. In detail and also shown in figure 5.3, 19% fully agreed and another 19% somewhat agreed, but the rest did at least somewhat disagree with this statement, where 19% fully disagreed. The application was not really designed to teach the user something about the environment, but for most users the realization on how much emissions they really emitted should come after doing the initial setup. One explanation

could be that the users which disagreed with this statement already knew their amount of emitted CO_2e, which meant that the app did not teach them anything. The intention of this study also was that the users of the application get more interested in climate change and research actions against it, which would be another take away the users could have had. This time the results for this question was not different between the two group of users, because the users who agreed contained 55% of the known group. This number is too small to show any correlations.

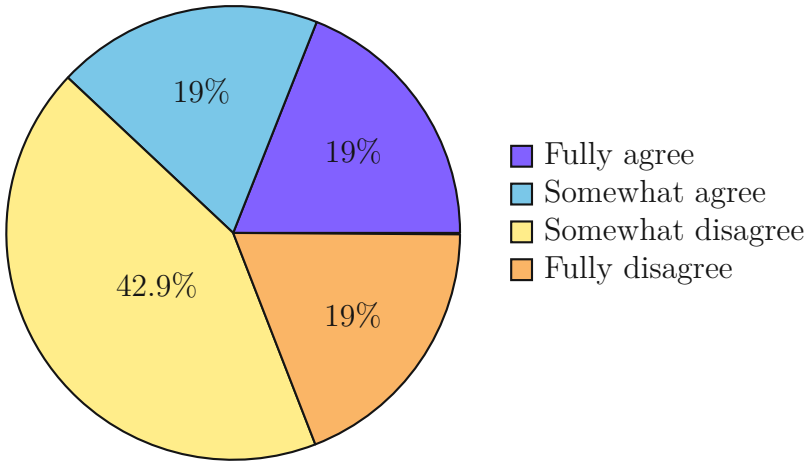

Figure 5.3: This graph shows how the users reacted to the following statement: "I learned something about the environment by using the application"

By knowing what implications a certain daily activity has on the environment they may try to avoid certain actions, which would help a lot. If a person does not know the consequences of their actions they may not even think about it the damage they are doing to our planet, which could have drastic effects on the climate change. Fortunately the majority of people said, that they agreed and did in fact learn something new, which is shown in figure 5.4. While 23.8% fully agreed and 52.4% somewhat agreed, only 14.3% somewhat disagreed and 9.5% fully disagreed. As mentioned above, since every user had to do the initial setup they got to know how much impact they had on global emissions, which means that every users should agree with this statement. In theory they could only disagree if they knew their emissions before using the application, which is of course also a possibility. Of course the data for the different groups of users for this statement is available, which showed that there is no significant difference in answers between these groups. 54% of the known users agreed with the statement, while 46% of the group of strangers

agreed. Vice versa for the people that disagreed of course. This is almost no difference when keeping the sample size of the two different groups of users in mind. (51% of the known users where part of the users that agreed with the statement)

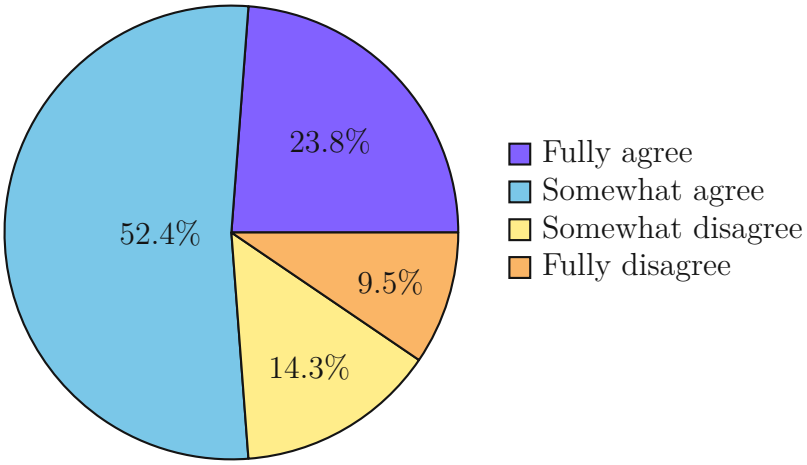

Figure 5.4: This graph shows how the users reacted to the following statement: "By using the application I learned how much my daily actions impacted the environment".

A very important factor with the type these applications if if the user had fun using the app or not. Of course, people are more likely to return to the application if they have positive initial experiences with it. Even the most motivated people regarding helping against the climate change will not use a mobile app for this exact problem if they had no fun doing it and if not even these people will not return, then unmotivated are even less likely to use the app. As shown in figure 5.5 over 76% stated that they agreed with the statement (28.6% fully agreed and 47.6% somewhat agreed), that the app was fun, which is also a very good indicator for a successful performance of the application. Only 14.3% somewhat disagreed and even less people with 9.5% fully disagreed. While this result is not bad, it needs to be noted, that 23.8% at least somewhat disagreed with the statement, which is almost a quarter of the user base. Since the application is considered a serious game having fun is essential for the success of the app, but when almost every fourth user disagrees with this statement then the there need to be changes to the motivating and fun factors. For this statement the results of the survey showed a difference between the different groups of users. 69% of the group of strangers agreed with the statement, while only 31% disagreed, which shows that this group had more fun than the group of known users. This matter

will also be discussed in further detail in the discussion section, but one of the reasons for this could be, that the group of strangers only used the application because they were really interested in the theme of it and what it tried to accomplish. Most of the users of the known group did not really know what they were getting into before agreeing to try the app, apart from the fact that it tried to motivate users to live a greener lifestyle. The group of strangers got told about the application and what the application did, which means that they knew exactly what they were getting into, and people that did not like what they were wold about the application had no interested in using it.

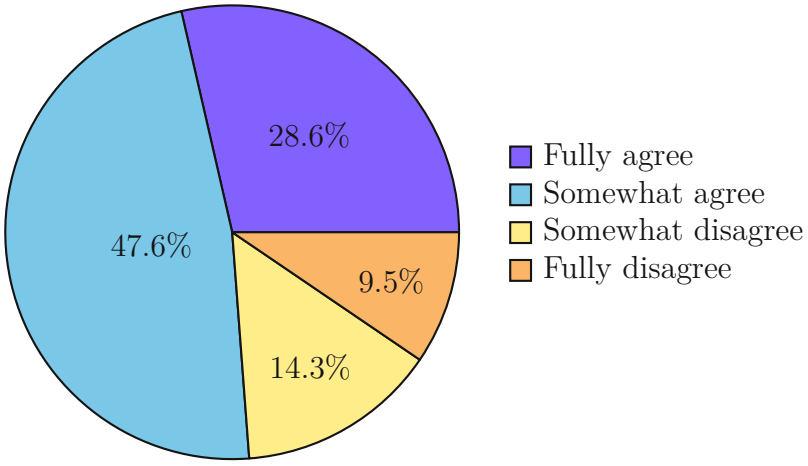

Figure 5.5: This graph shows how the users reacted to the following statement: "I had fun using the application".

As already explained previously, the two main motivating factors while using the app were the tasks and the leaderboard. The users should do their task and get as high as possible in the leaderboard, by decreasing their CO_2e value as much as possible. This mechanism should be fun and and hopefully be a big motivation for the users. Most of them agreed with this statement and only 9.5% fully disagreed, which is very important, since the application managed to motivate the users at least a bit. Figure 5.6 also shows, that the largest group of users with 42.9% somewhat agreed with the statement, that asked if the tasks and the leaderboard motivated them to live a greener lifestyle. On the contrary a large group of 23.8% somewhat disagreed with the statement and the last group of 23.8% fully agreed. This result is not bad, since more than half of the users got motivated by the features of the application, but like the results of the last statement they could be better. With the tasks and leaderboard being the main motivating factors in the application the optimal case would be that every user was at least somewhat

motivated by them, which is not the case here. Since the scope of the app had to be kept small for the purpose of this thesis it could be that these two features were not enough to keep the users motivated or even motivate them in the first place. This shows that there is definitely room for improvement in this area. After looking at the data of the different groups the results show, that the known group of users was a bit less motivated by the app with 56% of them at least somewhat disagreeing on the statement. It shows a small tendency that the group of strangers was easier motivated, which could again lead back to the fact that they used the application because they wanted to. This means that they were already motivated to reduce their emissions with the tasks and leaderboard being an improving factor.

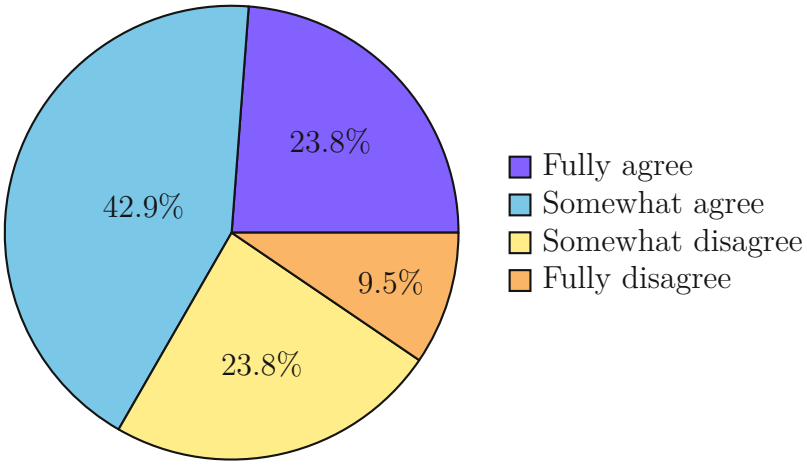

Figure 5.6: This graph shows how the users reacted to the following statement: "The tasks and leaderboard motivated me to live a greener lifestyle".

The next statement was one of the most important ones, since it asked if the users would recommend the application to others. As described above, the column "Multiplication saves the day" is a very important concept and since telling others about the app and by that getting an increasing number of users, the goal to convince and motivate people to live a greener lifestyle would be much easier to achieve. Almost one fourth fully agrees and would definitely recommend the application, and only 5% disagree completely, which means most of the users would tell other people about it and by that spread the application's outreach. Since the application was spread mostly by the users themselves this fact was highly expected. According to the survey and also shown in figure 5.7 23.8% fully agreed with the statement, that they would recommend the app to others, while 38.1% somewhat agreed and

33.3% somewhat disagreed. The fact that ~38% of the users at least somewhat disagreed with the statement shows that even when the application spread to so many people there is still a big part of the group that would not recommend the app. The difference between the two user groups was not existing for this statement, since exactly 50% of the people agreeing/disagreeing were from the known group of users while the other half was from the group of strangers. This shows that there is no correlation between the group of users and the probability with which they would recommend the app to others. With at least 66.7% at least somewhat agreeing, almost exactly 2 out of 3 people would recommend the application, which also showed in the rate the app got distributed to other people than the initial 24 persons.

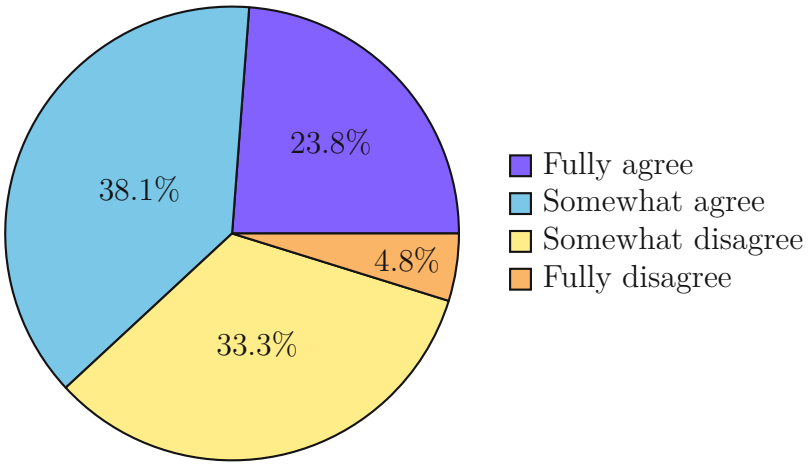

Figure 5.7: This graph shows how the users reacted to the following statement: "I would recommend the application to others".

The last statement asked, if the users think that mobile applications like the one presented in this paper could help in the battle against climate change. If the previous statements about how they liked the app and how much it motivated them would not be answered positively it could be checked, if they do not like apps like that in general or if only this application could not help them. Since most of the users had a positive experience with it, it would be obvious that they would also have a positive experience with similar apps like the one presented in this paper, which is the case since 76% at least somewhat agreed with the statement. The figure in 5.8 shows, that 19% fully agreed with the statement and 57.1% somewhat agreed, while only 14.3% somewhat disagreed and 9.5% of the users fully disagreed. This rounds up the results perfectly, since it shows that a big part of the users has the opinion that a

mobile application could help in reducing the global emissions, which is the main part of the research question of this thesis. Again the results for the different groups of users do not have much to take away from. 57% of the users who at least somewhat agreed to the statement were of the group of strangers, which means, that the remaining 43% came from the known group. While this is of course a difference between the groups it is not enough to look for correlations between the groups and their answers.

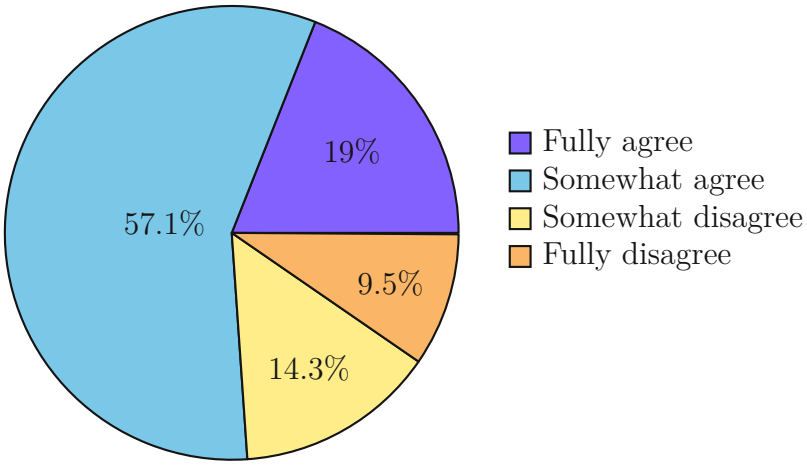

Figure 5.8: This graph shows how the users reacted to the following statement: "I could imagine that applications like this one could have a positive impact on climate change".

CHAPTER 6

Discussion

This is the last chapter which concludes this paper. The first section will be a quick summary about the problems this paper was trying to solve and how successful the proposed solution was. Since there was a big amount of data there will also be sections about the interpretation of certain findings and the limitations of the mobile application.

Summary The most important information is as to why this paper was written and what the purpose was. The environment and climate change are getting worse every year and soon it will be too late to do something against it, which is the reason that every human on our planet has to work together and keep our CO_2e emissions down as much as possible. Many people want to lower their emission, but do not know how or are not motivated enough. Another aspect is that some people do noteven realize how easy it could be to keep their CO_2e down. It is not easy to find solutions to all of these problems but the idea of a mobile application, that shows their users how much emission they have, how they can lower it and at the same time motivate them in helping the environment seemed like a good approach.
The application has a setup process where the user answers questions about his lifestyle and gets their result of CO_2e emissions in various areas as a return. This is the first step, where the user can see their daily activities with the highest emissions and hopefully take action to lower them. After the setup the user will get tasks based on his activities with the worst emissions score and by completing them his result that he started with will get lower depending on which tasks got completed. This will go on until they have improved on every aspect in his lifestyle and hopefully they will keep on living like the application suggests.

Another motivating factor was the leaderboard, which was a list of all users, where they could see how good they were doing in comparison to others, and beat them in the leaderboard by completing tasks and lowering their emissions. The results showed that there was an emission reduction of 5.8% on average and the app distributed itself over the course of the trial, which shows that an applications that tries to motivate its users to help the environment could work. According to the survey most of the users had fun using the app and did more tasks than anticipated. The average CO_2e emission reduction shows, that the application had a positive effect on its users and shows that pursuing a mobile application to motivate people live a greener lifestyle could be viable. Another big success was how fast the application has distributed itself, since every user gave the application to two other persons on average. The duration of the study was only two weeks, so it is not clear how the result would differ with a longer trial period. The most important part of this thesis is of course the answer to the research question, which asked how much it is possible to motivate people to live a greener lifestyle. The results are very promising and show that a tool to help people, who want to do something your our environment, in their daily lives could have a big impact on the climate change. A 5.8% decrease per user in the span of two weeks is promising result. This shows that it is possible to motivate people in this area, which even leads to a reduction of emissions for the application's users.

6.1 Interpretation

The usage frequency stated in the results show, that the users used the application and were motivated to do the tasks until the very end, with 81% of the users completing a task in the last two days. This shows that the application managed to keep their users engaged and seemed to motivate them in lowering their carbon emissions. Some survey questions indicated that some users were not so much motivated by the app and some said they did not really have fun using the application. The fact that the tasks were completed over the course of the whole two weeks until the end shows that the application fulfilled its purpose, which was to gather data to answer the questions raised on the beginning of this paper and lower the users emissions. In conclusions about the usage frequency it is save to say that the users were at least somewhat motivated by the features of the application, but the survey results showed, that there is still room for improvement.
The results of the two worst results were far worse then the rest of the results, with the worst result even being from a user that always chose the worst answer for every question on purpose. One could argue that the data of this

result should be deleted, since the user input was not genuine, but as already explained in the results, the data was kept in since it did not change the overall results in a meaningful way. This way the results reflect the reality without any changes.
Apart from that the results show a reduction of 5.8% on average per user when comparing the initial emission value and the value after the two week trial period ended. This is a good start and shows that the application is working in the sense that it helps to motivate the users and brings them to engage in emission lowering activities. This amount was achieved in only two weeks, which could be more if the usage period would have been longer.
Even with the 5.8% decrease in CO_2e on average, one has to keep in mind, that a reduction of the carbon emissions to 2.3t per capita per year is necessary [48]. It is hard to predict how the users and the application would have performed if the trial period was longer than 14 days. Since the users did their tasks until the last day it could be that the decrease of 5.8% would grow bigger with more time, but is not possible to predict how much the users would reduce their emissions over the course of a whole year using the application. It could be that they decrease their emissions even more, but then get tired of the tasks and the application and fall back to their old habits and emit more carbon emissions again.
Furthermore there could be a discrepancy between what the users think they do and what they actually do. They could be thinking that they are now motivated to live a greener lifestyle, but lose this motivation in the span of a week and emit as much emissions as before.
The result of 5.8% decrease in emissions also has to be taken with caution, since there are several factors that could change this number, which are not present in the data provided for this paper. First of all there is the limitation that it was not possible to make sure that the users really did complete the tasks, but instead plausibility checks had to be done to filter out users that did not take the app serious. Luckily the checks only showed one user who did not use the app like they should have, which means that the number of 5.8% should be fairly accurate, but there could be more users that were not genuine which has the consequence that there must be a small range of fluctuation. How big this fluctuation is not clear with the current data.

As for the categories the results showed that the food category had much more tasks completed as the "best" category, while the mobility category had the least amount of tasks completed. This could be because the tasks in the food category were easier to do, while some tasks in the mobility category could be impossible for some people. tasks in the food category included buying different groceries or eating less of something, which is quite easy to

do if one has enough money (since fair trade or organic products are usually more expensive). Changing your daily transportation could be quite hard for many people since this could have a big impact on their life. Suddenly taking the bus instead of driving with the car could be an unwelcome change for many, even if it would mean a decrease in emissions.
The question stands as to why the different categories performed as they did in terms of completed tasks. As just mentioned, the food and mobility category could have the reasons stated above for performing how they did, but the other two categories namely consumption and housing could have other reasons. One reason could be that these categories require effort and willingness to change the users lifestyle. Tasks in the housing category required the users to turn down their heating or to use shock ventilation instead of opening the windows for a longer period of time. This could bring the people out of their comfort zone which could mean that they are less likely to complete such tasks. The same is true for the consumption category.
Another possible reason for the transportation category performing the worst, is that changing the transportation for people that do not live in the cities is very hard if not impossible. Almost every user of the known group was located in Vienna or in the metropolitan area around Vienna. That means that many of them already used public transportation which is very convenient in Vienna. So on the one hand the users got less tasks for the mobility category, because they had already quite low emissions scores in that area and if users got a mobility tasks they just could not do it, since relying on the bus or train instead of the car is not feasible for many.

The results also showed different results for the two groups of users (known users and group of strangers), where the known users did less tasks than the group of strangers. The group of strangers most likely was more motivated to do the tasks since they only consisted of people that were motivated and really wanted to try the application, while the known group most likely had people in it, that just tired die app and did not like it as much.

Every user agreed with the statement, that they understood what the application was trying to accomplish, but a large part of them answered that they only somewhat agreed with this statement. This leads back to the fact that the the results contained two different user groups. The people who only somewhat agreed almost exclusively come from the group of strangers, which could be because the known group got the app explained before using them, but the group of strangers may just have heard about it from another user and started using it without getting an explanation about what the goal if the app was.

Another statement of the survey asked the users if they agreed that the application motivated them to live a greener lifestyle, where most of them did in fact agree but only 4.8% fully agreed and a big group of 66.7% only somewhat agreed. While it is good to know, that most of the users were motivated by the application it is worrying that only almost 5% fully agreed. It could be that the tasks and the leaderboard as the two main motivating factors were not enough to fully motivate the users, which would be the fault of the application. In contrast it could also be that the users just do not get motivated from a mobile app as much as was hoped. The first case would require more features to keep the user more engaged, which will be discussed in the next chapter.
An interesting fact is, that of the people who disagreed with the statement 71% where from the known group. There are several possibilities for that result. One of them could be that the users were already motivated, so the application could not motivate them further, which is unlikely, because if that were true the probability that the users of the other group also were already motivated is the same as in the known group. That would mean that the difference in answers between the groups would be smaller. Another reason could be, that the known group of users were interested in the application and agreed to use it, but after seeing how the app worked they lost interest and did not want to engage with it as much as the other group of users. The group of strangers only used the application after they got told what it was about and how it worked, so they only downloaded the application when they really thought that it would motivate them to live a greener lifestyle, which was the case according to the results.

The same reasoning can be used for another statement where there was a discrepancy between the two user groups. According to the results of the survey 61% of the group of strangers stated that they had fun using the application and the rest coming from the known group, which meant that the former group had more fun. Again this most likely leads back to the fact, that the known users agreed to use the application before knowing exactly how it worked, while the group of strangers only got the app after getting told everything about it.
Even if the fact that two groups existed is disregarded and just refer to the overall results it shows, that 23.8% of the users at least somewhat disagreed with this statement, which is a bad indicator for the performance of the application. Of course the average emissions decreased and several other performance indicators showed that the application is a step in the right direction, but when almost a quarter of the users does not have fun while using the app it is a problem. Even some users from the group of strangers

knew exactly what the app did, downloaded it because of that and still had no fun using it, which could mean that some people were not convinced of the implementation of certain motivating and fun features.

Most users agreed with the statement, that the application is fun to use, but the duration to use the app was only two weeks and if the goal was, to hold the users as long as possible, the current state of the application would not be enough regarding its features. Of course a bigger application was just not possible in the duration of this master thesis, but to keep the users engaged more features are necessary. This could be a project for future work, to extend the application and have more features that keep the users engaged with the application. The fact that

The mobile app is not controlling the users, since the users choose when they want to open the app and when they want to complete their tasks. There are no push notifications convincing the users to reduce their emissions, but still the people using the application will give the app insight into their daily life, which could be deterrent for some of them. The results show, that the users were happy to input their data and complete tasks, which at the same time shows which activities they have done on this day. While it could be possible that in case the application goes public that some people do not want to share their data, in the study of this paper this claim could not be proven with data.

Since the results showed a decline of completed tasks from the first to the second week it can be assumed, that the users got progressively less motivated over the course of the two weeks. While the users were happy to comply, use the application and share their data it seems that they were less likely to complete a task at the end of the trial in comparison to the start. The survey results showed, that they were more motivated by the application and felt motivated by its features to live a greener lifestyle. This could either mean, that the users learned over the course of the two weeks which activities emit high emissions and which were better for the environment, which would mean that they did not need the application anymore. Or the features did not keep the users engaged over a longer period of time and theory lost interest in using it. If the latter is true, there need to be more features in the application to keep the users motivated.

6.2 Implications

The results showed that a reduction of emissions is possible for its users, but they are not enough to slow down the effects of climate change. The problem with the distribution of the world's emission is, that the richest 1% have on average 70 tons of CO_2e emission per person per year. [24] This group of people will not change their lifestyle with a mobile application and do not belong to the target group of this paper, which is why they are going to be disregarded for now when answering the first research question. This group of people should be impacted by the second research question. If the people are more engaged with climate change and participate in initiatives against it, it could convince politicians to put laws into places that reduce the carbon emission output of the richest 1%.

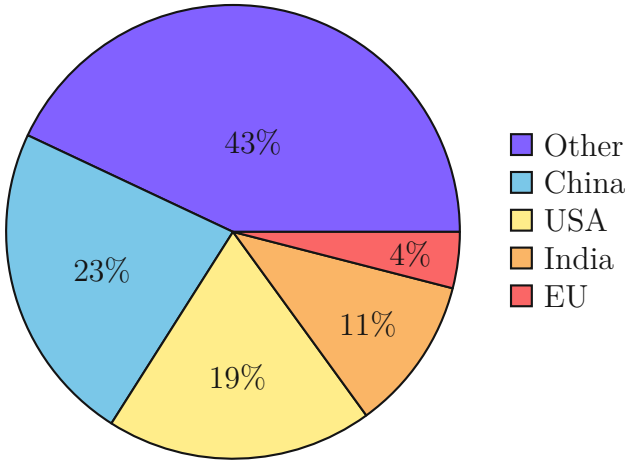

Figure 6.1: Source of emissions disregarding world's richest 1% [24]

For now only people that do not belong to the richest 10% will be included, since they do not belong to the target group of this paper. This includes the middle class and the poorest group of people, where a mobile application could have an impact. In this study all of the participants in the known group are located in the middle class. The results state, that there was a 5.8% decrease in CO_2e emissions in the span of two weeks. That value is a good start, but when looking at how much this group needs to decrease their emissions to reach the 1.5°C goal, which tries to limit the global warming to a maximum of 1.5°C there is further improvement needed. While the poorest 50% are theoretically even allowed to increase their consumption emissions by 233%, the next 40% called the middle class should decrease their emissions by 57% [24]. The application shows that it is possible to reduce people's emissions,

but the changes have to be more significant to reach to most important goals against climate change. The result of 5.8% less emissions over the span of two weeks is promising, but do not forget, that there were limitations with the monitoring of the completed tasks where it was not possible to be 100% sure if the user really did complete a certain task. This leads to the fact that the 5.8% cannot be taken as a fact but should be seen with a possible range of fluctuation. Hopefully some technological inventions will save even more CO_2e and bring us over the edge of holding the global warming to a maximum of 1.5°C.

The point that the application was given to only 24 people and spread to 64 people in a short time is a pleasant surprise for sure, since it shows how willing the average person in the study was to help against the climate change and how motivated they were with the right tools. It is good to know, that the people really want to take action even if it is just buying different groceries. If the people want change to keep the global warming to a minimum, then politicians and businesses need to be convinced as well. These two groups want to please the public, which should mean, that the more the general population cares about the environment, the more they could employ climate friendly measures.

6.3 Limitations

The participants were only located in Vienna or the outskirts of Vienna, which means that the results only count for a very small area in and around a big city. That meant that categories like transportation got very few tasks completed of reasons that were stated before. The age of the users was a small limitation as well, since most of them were around 30 years old. Much younger or much older people might behave differently, especially old people would have a problem using a new mobile application.

The biggest limitation the application had was that the results had to rely on the truthfulness of the input of the users. Every user could just randomly answer the initial questions in the setup and then complete tasks as they liked and nobody could stop them. It was not possible to have a mechanism that checks if a certain task was really completed or not in the scope of this thesis. This is why every input the user did in the application was logged to filter out users that were not using the application the right way and reading the section about the results one could see, that the data showed one user did not take the application serious. Every other user had a plausible behaviour

when using the app, which meant that the validity of the data presented in the results is given. Still, it could be possible that some users just completed tasks without really doing them and without detecting it in the data.
Apart from that there were several texts while using the application for the first time, which should draw attention to the fact that this is a research project and it would appreciated if every input could be genuine, since there would be nothing to gain by faking some results or inputting wrong information.

As already stated in the result chapter there was an outlier that answered every single question with the first answer, which was the worst answer regarding the emission as well. This user obviously did not take the initial setup seriously and just answered through the setup as fast as he could be only choosing the first answer, which meant that his data is not really representative for the average user who uses the application because he wants to. One could argue that this users data should be removed from the results, but it was kept in since the change to the numbers in the results from this user were negligible. If more users chose that approach and input data that was not genuine a solution would be needed. On the one hand keeping those data in the results means that they would represent the reality as close as possible, but on the other hand this study tries to answer if the application manages to motivate its users when they are already interested in helping the environment. When a user does not even take the setup seriously they are likely not the target group of the app.

Another important point is the topic of location, where the implications have to keep in mind, that all of the users were located in Austria. The same study in a different country could bring very different results, since the Austrian people know that the climate change is happening and most of them are open to help [62]. In different countries this experiment most likely has less people trying to help and the application would be less effective, since the USA has of the largest groups of people that do not believe in climate change. [33]

The last limitation was the timeframe of the study. A longer trial would not be possible in the scope of this master's thesis, which meant that the users were only allowed to use the application for two weeks. The results showed a 5.8% decrease of carbon emissions over the trial of two weeks, but it is hard to guess how that number would translate into a timeframe of a year or even longer. The fact that the average tasks completed per day was decreasing over the course of the study shows, that the number of 5.8% will not increase linearly over a year. This limitation only affects the results and

not the outcome of the study, since the goal of the study was to see how a mobile application worked in motivating its users regarding climate change.

CHAPTER 7

Conclusions and Future Work

In summary, this study explored the development and impact of a mobile application aimed at inspiring users to actively participate in environmental protection. The potential of the application to promote positive behavior change regarding their lifestyle and instill a sense of environmental responsibility in users became looked like they did improve after evaluating the results. According to the survey, most of the users were motivated by the application and had fun using it, furthermore the emissions by the users decreased by 5.8% in the span of two weeks.

The results of this study highlight a number of important points. First, the user-friendly interface, motivating features, and gamification elements of the mobile application engaged users and made small environmental changes possible, as can be seen in the results of the average emission reduction and the survey answers. The application allowed users to see the immediate results of their actions, which further strengthened their commitment to environmental causes. Users also gained access to real-time data and personalized progress tracking, by looking at their own progress or the progress of other users in the leaderboard.
Then again the results also showed what could have been done better. Even if the majority of people stated that they had fun using the application, a quarter of the users did in fact not have fun, which shows that the application could have had more motivating and game-like elements to it. Also, the engagement of the users declined over the course of the trial period of two weeks, which means, that the application could not keep the users as engaged until the end of the trial.

The results showed that the mobile app succeeded in encouraging users to live greener lifestyles while using the application. The app encouraged users to develop environmentally friendly lifestyles and habits through personalized tasks and the constant comparison with others. Although the app has shown promise, it is important to consider some shortcomings and potential areas for development. It was difficult to retain users over the long term, so regular updates and new content are needed to keep users interested. In addition, certain populations may be more receptive to the app's approach, so targeted outreach strategies are needed to ensure inclusive and equal participation.

This research provides insightful knowledge about the disciplines of environmental psychology and behavior change that are supported by technology. In order to develop solutions that address today's society and its digitally connected citizens, it emphasizes the importance of merging technology and environmental protection.

The main goal of this paper was two answer the two research questions stated earlier. The first question asked how much a reduction of emissions was possible by using a mobile application as a motivating and helping aspect. The results show a decrease of 5.8% of the average users carbon emissions over the course of two weeks, which indicates the a reduction is very well possible. The reduction itself is a good starting point when keeping the length of the study in mind and could be higher if the users used the application more than two weeks, since the data showed that the users used the application until the last day.
The results also answered if a mobile application can motivate and engage their users to learn more about the climate change. When people learn about the consequences of the climate change they hopefully see, that it is important to act as fast as possible in deploying climate change reducing measures. The results from the survey show, that 75% of the users learned how much their daily actions impacted their emissions, but only 38% agreed with the statement that they learned something about the environment. Even if the second number is not high, the fact that three quarters of the users learned how much impact they have hopefully leads to more awareness regarding the climate change.

The introduction showed that the three companies with the most carbon emissions have combined 11.3% of all emissions on earth. While it is hard for an individual to have an impact on the reduction of global emissions, it is indeed possible to make a change on a larger scale, by voting the environmental

friendly parties or supporting companies, that support the environment, as consumers. Since the results show, that the users got motivated by the application to engage in anti climate change measures it shows that the application could help in that aspect.

In summary, the mobile application considered in this paper represents a promising step in motivating and enabling people to take action for the environment and against climate change. Such applications have the potential to play a critical role in addressing environmental challenges and promoting a sustainable lifestyle for future generations.

One of the limitations of the study was that all of the test subjects came from the same city in middle Europe. In the future one could repeat this study in different locations and not just in Europe but also on different continents like Australia or America. Especially the last one has a big group of people that denies the climate change, which is why the study executed in the USA would be very interesting. One could also just release the app in a global launch, but that comes with other problems as well. Having a global leaderboard could be quite hard, since some continents have much more or much less emissions than others, which means that a comparison just based on CO_2e would not be meaningful. Furthermore, when looking at how the energy gets produced it is important to distinguish between areas that have a high portion of renewable or green energy and others, that still mostly rely on coal to produce energy. Using the same amount of electricity from green energy is not comparable to the same amount of energy coming from a coal plant.

As stated before, the duration of the study was only two weeks long, which means that the application did not require a large amount of features to keep the users engaged over this short time. If the application should succeed on a longer period of time or even permanently, it would be crucial to implement new features. This could include daily or weekly tasks, that the user has to complete, which could give him virtual rewards or maybe a friends leaderboard to see how they are doing compared to people they know. At the moment all of the data is anonymous.

Another big point could be the implementation of a mechanism, that ensures the validity of the user input, especially the completion of the tasks. At the moment it is not clear if it would be at all possible to implement a system that cannot be cheated, but it would be great to have it. Maybe the user has to include a proof that he has indeed completed a certain tasks, which would

be easy for things like grocery shopping, where they could just take a picture of the check, but quite hard when it comes to proofing that he really took the public transport instead of the car. Of course the pictures and their metadata could be checked, but that would be much work when the user count gets too high. In the end it does not seem like it would be possible to create a system that can automatically check the user input without any person monitoring this process.

List of Figures

Bibliography

[1] R. M. Andrew. Global co2 emissions from cement production. *Earth System Science Data*, 10(1):195–217, 2018.

[2] avantilipids.com. Sustainability seconds: Review: Can fashion ever be sustainable? https://avantilipids.com/news/sustainability-seconds-review-can-fashion-ever-be-sustainable. accessed on 08.11.2022.

[3] BBC. Is spotify bad for the environment? https://www.bbc.com/future/article/20200305-why-your-internet-habits-are-not-as-clean-as-you-think. accessed on 08.11.2022.

[4] BBC. The hidden impact of your daily water use. https://www.bbc.com/future/article/20200326-the-hidden-impact-of-your-daily-water-use. accessed on 08.11.2022.

[5] K. Becker. Video game pedagogy: good games = good pedagogy. *Games: Their Purpose and Potential in Education*, 2008.

[6] brc.org.uk. Making checkouts greener: Cutting CO2 and costs. https://brc.org.uk/news/csr/making-checkouts-greener-cutting-co2-and-costs/. accessed on 08.11.2022.

[7] carbonbrief.org. Factcheck: What is the carbon footprint of streaming video on Netflix? https://www.carbonbrief.org/factcheck-what-is-the-carbon-footprint-of-streaming-video-on-netflix/. accessed on 08.11.2022.

[8] carbonfingerprint.io. Make social media climate positive. https://www.carbonfingerprint.io/old-home. accessed on 08.11.2022.

[9] carbonindependent.org. Emissions from train travel. https://www.carbonindependent.org/21.html. accessed on 08.11.2022.

[10] carbonindependent.org. Emissions from train travel. https://www.carbonindependent.org/20.html. accessed on 08.11.2022.

[11] R. E. Clark. Learning from serious games? arguments, evidence, and research suggestions. *Educational Technology*, 47(3):56–59, 2007.

[12] M. D. Coady, I. W. Parry, N.-P. Le, and B. Shang. Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates. IMF Working Papers 2019/089, International Monetary Fund, May 2019.

[13] A. Corner, O. Roberts, S. Chiari, S. Völler, E. Mayrhuber, S. Mandl, and K. Monson. How do young people engage with climate change? the role of knowledge, values, message framing, and trusted communicators. *Wiley Interdisciplinary Reviews: Climate Change*, 6, 09 2015.

[14] S. de Freitas and F. Liarokapis. Serious games: a new paradigm for education? *Serious Games and Edutainment Applications*, 2011.

[15] J. De Graaf. Take back your time: Fighting overwork and time poverty in america, 2003.

[16] A. Dumitru and R. Garcia-Mira. Green Lifestyles, Alternative Models and Upscaling Regional Sustainability (GLAMURS), Dec. 2016.

[17] earth.org. How Social Media Habits are Contributing to Internet Pollution. https://earth.org/how-social-media-habits-are-contributing-to-internet-pollution/. accessed on 08.11.2022.

[18] ecogreenlove.com. CO2e produced when cooking these traditional UK dishes. https://ecogreenlove.com/2020/08/08/co2-ukdishes/. accessed on 08.11.2022.

[19] energuide.be. How much power does a computer use? And how much CO2 does that represent? https://www.energuide.be/en/questions-answers/how-much-power-does-a-computer-use-and-how-much-co2-does-that-represent/54/. accessed on 08.11.2022.

[20] EU. 2030 climate target plan. https://climate.ec.europa.eu/eu-action/european-green-deal/2030-climate-target-plan_en. accessed on 24.08.2023.

[21] U. C. Flynn and E. Yamasum. *The Peoples' Climate Vote*. United Nations Development Programme, 2021.

[22] I. M. Fund. Climate Change | Fossil Fuel Subsidies. https://www.imf.org/en/Topics/climate-change/energy-subsidies#Who%20Benefits%20from%20Energy%20Subsidies. accessed on 07.08.2023.

[23] Google. Powering a Google search . https://googleblog.blogspot.com/2009/01/powering-google-search.html. accessed on 08.11.2022.

[24] T. Gore. Carbon inequality in 2030, Nov. 2021.

[25] A. P. Griffin. The carbon majors database. *CDP Carbon Majors Report 2017*, 2017.

[26] S. Gössling and A. Humpe. The global scale, distribution and growth of aviation: Implications for climate change. *Global Environmental Change*, 65:102194, 2020.

[27] M. R. Hannah Ritchie and P. Rosado. Emissions by sector. *Our World in Data*, 2020. https://ourworldindata.org/emissions-by-sector.

[28] Z. Hausfather, H. F. Drake, T. Abbott, and G. A. Schmidt. Evaluating the performance of past climate model projections. *Geophys. Res. Lett.*, 47(1):e2019GL085378, 2020.

[29] T. W. House. National climate task force. https://www.whitehouse.gov/climate/. accessed on 17.01.2023.

[30] IEA. Direct Air Capture. https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage/direct-air-capture. accessed on 07.08.2023.

[31] IPCC. IPCC Working Groups. https://www.ipcc.ch/working-groups/. accessed on 08.11.2022.

[32] IPCC. Summary for Policymakers. In P. Shukla, J. Skea, R. Slade, A. A. Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, and J. Malley, editors, *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York, NY, USA, 2022.

[33] Ipsos. A new world disorder? https://www.ipsos.com/en/global-trends. accessed on 18.07.23.

[34] D. Ivanova and R. Wood. The unequal distribution of household carbon footprints in europe and its link to sustainability. *Global Sustainability*, 3, 07 2020.

[35] T. Kasser and K. Sheldon. Time affluence as a path toward personal happiness and ethical business practice: Empirical evidence from four studies. *Journal of Business Ethics*, 84:243–255, 02 2009.

[36] Z. B. Katie Lebling, Haley Leslie-Bole and L. Bridgwater. 6 Things to Know About Direct Air Capture. https://www.wri.org/insights/direct-air-capture-resource-considerations-and-costs-carbon-removal. accessed on 07.08.2023.

[37] B. McKibben. Multiplication saves the day. https://orionmagazine.org/article/multiplication-saves-the-day/. accessed on 30.07.2023.

[38] NASA. The causes of climate change. https://climate.nasa.gov/causes. accessed on 11.08.23.

[39] T.-S. Neset, L. Andersson, O. Uhrqvist, and C. Navarra. Serious gaming for climate adaptation—assessing the potential and challenges of a digital serious game for urban climate adaptation. *Sustainability*, 2020.

[40] U. D. of Transportation. Transportation statistics annual report 2020, 2020.

[41] ourworldindata. Biggest contributors to global emission. https://ourworldindata.org/uploads/2019/10/Cumulative-CO2-treemap.png. accessed on 01.01.2023.

[42] ourworldindata. Biggest contributors to global emission. https://ourworldindata.org/contributed-most-global-co2. accessed on 02.01.2023.

[43] S. G. O'Neil. Community obstacles to large scale solar: NIMBY and renewables. *Journal of Environmental Studies and Sciences*, 11(1):85–92, March 2021.

[44] M. Pathak, R. Slade, P. Shukla, J. Skea, R. Pichs-Madruga, and D. Ürge-Vorsatz. Technical Summary. In P. Shukla, J. Skea, R. Slade, A. A. Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, and J. Malley,

editors, *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK and New York, NY, USA, 2022.

[45] E. Peirson-Hagger and K. Swindells. Is Spotify bad for the environment? https://www.newstatesman.com/environment/2021/11/how-environmentally-damaging-is-music-streaming. accessed on 08.11.2022.

[46] B. Petroleum. Bp full report–statistical review of world energy 2021. *British Petroleum (BP): London, UK. Available online: https://www. bp. com/conte nt/dam/bp/busi n esssi tes/en/global/corpo rate/pdfs/energy-econo mics/stati sticalreview/bp-stats-review-2021-full-report. pdf*, 10(12):2022, 2021.

[47] U. N. E. Programme. Paris agreement, 12/12/2015.

[48] U. N. E. Programme. Emissions gap report 2021: The heat is on – a world of climate promises not yet delivered, 2021-10.

[49] S. Rana, S. Pichandi, S. Moorthy, A. Bhattacharyya, S. Parveen, and R. Fangueiro. *Carbon Footprint of Textile and Clothing Products*, pages 141–166. CRC Press, 04 2015.

[50] M. I. Research and Advisory. Serious Games Market Size and Share Analysis - Growth Trends and Forecasts (2023 - 2028). https://www.mordorintelligence.com/industry-reports/serious-games-market. accessed on 07.08.2023.

[51] H. Ritchie, M. Roser, and P. Rosado. Co^2 and greenhouse gas emissions. *Our World in Data*, 2020. https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions.

[52] A. Schendler. Worrying about your carbon footprint is exactly what big oil wants you to do. *New York Times*, 2021.

[53] sme news.co.uk. New survey reveals large regional differences in workers' commuting experience. https://www.sme-news.co.uk/new-survey-reveals-large-regional-differences-in-workers-commuting-experience/. accessed on 08.11.2022.

[54] B. Smetschka, D. Wiedenhofer, C. Egger, E. Haselsteiner, D. Moran, and V. Gaube. Time matters: The carbon footprint of everyday activities in austria. *Ecological Economics*, 164:106357, 2019.

[55] social change.co.uk. Five ways your everyday carbon footprint can be reduced. https://social-change.co.uk/blog/five-ways-your-everyday-carbon-footprint-can-be-reduced. accessed on 08.11.2022.

[56] Statista. Co2-fußabdruck ausgewählter obst- und gemüsesorten in deutschland im jahr 2019. https://de.statista.com/statistik/daten/studie/1197342/umfrage/obst-und-gemuese-co2-fussabdruck/. accessed on 13.07.23.

[57] Statista. Distribution of carbon dioxide emissions worldwide in 2021, by select country. https://www.statista.com/statistics/271748/the-largest-emitters-of-co2-in-the-world/. accessed on 02.01.2023.

[58] Statista. Ökologischer fußabdruck von milchprodukten, eiern und milchersatzprodukten in deutschland im jahr 2019. https://de.statista.com/statistik/daten/studie/1198026/umfrage/co2-fussabdruck-von-milchprodukten-eiern-und-milchalternativen-in-deutschland/. accessed on 13.07.23.

[59] K. Travers. How to reduce the environmental impact of your next virtual meeting. https://news.mit.edu/2021/how-to-reduce-environmental-impact-next-virtual-meeting-0304. accessed on 08.11.2022.

[60] UN. About montreal protocol. https://www.unep.org/ozonaction/who-we-are/about-montreal-protocol. accessed on 17.11.2022.

[61] UN. World population to 2300. *World population to 2300*, pages xi, 240 p. :, 2004. On t.p.: Dept. of Economic and Social Affairs, Population Division.

[62] E. Union. Special eurobarameter 538, 2023.

[63] T. O. University. Heating systems and co2 emissions. https://www.open.edu/openlearn/nature-environment/energy-buildings/content-section-3.5. accessed on 17.11.2022.

[64] J. Wexler. The carbon cost of clothing. https://www.ethicalconsumer.org/fashion-clothing/carbon-cost-clothing. accessed on 08.11.2022.

[65] wired.co.uk. Your website is killing the planet. https://www.wired.co.uk/article/internet-carbon-footprint. accessed on 08.11.2022.

[66] J. Yim and T. C. N. Graham. Using games to increase exercise motivation. *Proceedings of the Conference on Future Play*, 2007.

[67] J. W. H. Yim. Computer-aided exercise. Queen's University, 2008.

[68] A. Zechmeister. *Klimaschutzbericht*. Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2022.