Hanzehogeschool Groningen
University of Applied Sciences

FINAL THESIS 2015

A THERMAL COMFORT ANALYSIS OF SUIKERBUURT, GRONINGEN, THE NETHERLANDS

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Executive summary

Man has always tried to create a thermally comfortable environment. This is reflected in buildings traditions all around the world, from ancient history to nowadays. Today, creating a thermally comfortable environment is still one an important parameters to be considered when designing buildings and public spaces.

But, what do we mean by the Thermal Comfort? The term is defined in the ISO 7730 standard as being "*That condition of mind which expresses satisfaction with the environment*" British Standard BS EN ISO 7730 *(HSE _ Health and Safety Executive)*. Most people agree about this explanation, but this definition is not easily converted into physical parameters. It is very hard to evaluate the thermal comfort. A person making some sport on the mountain is as thermally comfortable as a person who is sitting in a house having some lunch. Even though, they are in completely different thermal environments. What I mean is that the thermal comfort is a topic where many physical parameters are involved, not just air temperature. Other factors need to be considered, factors such as humidity of the air, wind speed and mean radiant temperature as main involved parameters on the thermal comfort analysis.

Within this project the thermal comfort is going to be measured on a specific area in Hoogkerk (Groningen), using two different ways to involve people sensation and weather measurements. On one hand some measurements with a weather station called VP2 (Davis Instruments) are going to be done in this specific area to get information about air temperature, humidity, wind speed, radiation and mean radiant temperature. On the other hand, some questionnaires are going to be provided to some Suikerbuurt's neighbours to know about their thermal sensation. The aim for doing both experiments is to compare results (on a warm day) and get answers about where people is feeling thermally comfortable and why.

Actions needs to be taken in urban design for public spaces; that's why this research is carried out. With the analysis of the results a new concept design will be proposed. This study proved that green areas are becoming more necessary to help urban areas to reached lower temperatures during warm days. Therefore, some neighborhood improvements are going to be described and budgeted. These improvements are such as replacement of the asphalt from the parking lot where heat is really high, for a sustainable pavement which helps to keep cool the soil; installation of green roofs instead of the metal existing one; a new fountain within the Suikerbuurt neighborhood to improve environment sensation, rain garden in green areas from the district; planting more trees to decrease temperatures and other solutions which are going to be described in detail within this report.

The main goal of the research is to study how thermal comfort is related to urban development. It is needed to prove before how thermal comfort is affecting the Netherlands due to the fact that the research is going to take place in this country. It is needed to demonstrate these climate problems. Hence, I used a heat map, a land use map and a surfaces map from the Suikerbuurt neighborhood to show where problems are focused on. It is important to increase the awareness from the people about this current problem which will still being a problem in the future. To decrease urban temperatures it is indispensable

to avoid urban island phenomenon by increasing thermal comfort in urban areas. A new concept design will be proposed for this area to achieve the aim of the research: **integrate thermal comfort design solutions into a typical urban development project in the Netherlands.**

Chapter I

INTRODUCTION AND DESCRIPTION OF THE PROJECT

1. Introduction: the Final Thesis

All students are required to complete a graduation project as the last part of their graduation requirements. In my case, it is required by the Academy of Architecture, Built Environment and Civil Engineering of Hanzehogeschool of Groningen to accomplish my bachelor degree.

The purpose of the graduation project is to provide students an opportunity to engage an activity that will allow them to demonstrate their own ability to apply knowledge and skills they have gained throughout their years in the education system. At the end of the bachelor I must be able to apply, analyse and evaluate information and to communicate all the knowledge possible.

This graduation project will take place during five months, from February to June 2015. The report must be finished in June and the Final Presentation will be on the 15th of this month.

The client that allowed me to perform the final thesis is the "Kenniscentrum Noorderruimte", located in Zernikeplein 11, Groningen.

Four years ago, I started my bachelor in Valencia, Spain. I was spending there all the degree and I decided to go abroad to prepare my Final Thesis. The idea was to improve and to practice English whilst discovering other working methodologies and other problems related with my bachelor. I chose The Netherlands for several reasons. One of them was that I heard it is an advanced and ecological country that could help me to get more information about how the world should be managed to be more ecological and sustainable.

As we are going to see, this final thesis is focused on a big problem which may be known for all the earth's inhabitants: the climate change. The Netherlands is a country that has fought with several natural problems within all their history, problems such as the sea level. There is a saying: "*God made the world and Dutch made The Netherlands".* This is not a lie if we see the almost 34.000 m^2 of artificial area that make up the country and the fact that a third part of the land is below the sea level and protected by an effective old dikes systems (*Netherlands facts, information. Encyclopedia. 2007)*

What I pretend to explain with this is how this country is aware of the natural problems that could destroy their land and their lives. They are cautious and they use preventive systems against natural disasters, they encourage innovation and create sustainable solutions to avoid environmental problems. Climate change is nowadays unavoidable, all we need to know is which problems are affecting the cities and which kind of solutions should be implanted right now to begin taking measures to stop global warming.

In this Final Thesis we are going to study one of climate change's major factors: thermal comfort. The aim is to create a better place to live for the inhabitants and to improve climate comfort. We need to prove where the problem is and where people usually feel better, to create more spaces and more solutions helping people to find everyday an appropriate thermal comfort in their lives.

2. Description of the project

2.1. Background

My research proposal is about thermal comfort and climate adjustment in the Netherlands. First, I am going to investigate what problem is found regarding thermal comfort in the Netherlands and how it affects the planning and design of its cities. My aim is to try to find appropriate solutions to the problem, and therefore contribute to make a more sustainable city. The main theme of my report will be to investigate how climate adjustment can be linked to urban development, focussing on thermal comfort and how solutions to this problem can be integrated into a city's planning, design and engineering.

For this research, I will use a case study located in Groningen: The Suikerbuurt (Sugar Neighborhood), in the village of Hoogkerk (west of Groningen). Sugar neighbourhood owes its name to the Sugar Factory, which built houses for its workers in 1920. Some years later, the houses of this district received the status of municipal monument, and were renovated in 1992 because many residents were suffering from moisture and mold problem in their homes. The area is currently being investigated by the municipality as there are many problems such as high groundwater, poverty, pollution industry, poor housing, etc. The fact is that these problems are at the moment being worked on by various architects, engineers and planners makers, so this area is an interesting project to study in more detail as a case study.

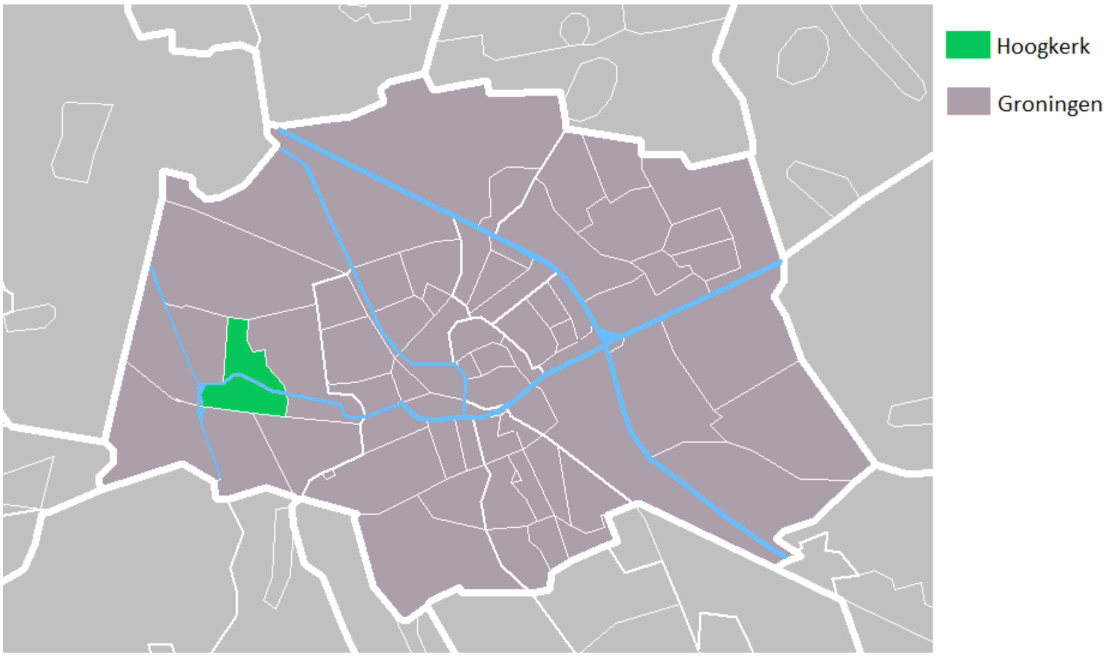


Figure 1 – Hoogkerk location

Groundwater and humidity problems were extremely present until 2012, when 27 residents of Sugar Neighborhood established the action group "*Healthy Hoogkerk*". This group was created by residents of the neighbourhood and Sugar Steelers who decided to work together against the above-mentioned problems. The technical story of the moisture problem created a social issue; and as a result people lost confidence on the corporation. As a renovation of the full neighbourhood could not be economically achieved, Steelers Lande Living (the social housing corporation) fixed an initially demolition and construction in order to solve these problems. Due to the special nature of the area, the residents and the action group decided in early 2014 to draft together a new plan linked to the neighbourhood.

This final thesis project is part of a larger two year research project with the Kenniscentrum Noorderruimte to investigate Climate-Proofing Cities with an emphasis on the problems arising out of thermal comfort. I will collaborate with The Hanze Hogeschool research team but also with other organisations involved in the Suikerbuurt area (Gemeente Groningen, Sugar factory, KAW architects Groningen, Social Housing Company and the community).

A question that many ask is why do we need to investigate thermal comfort heat stress in the Netherlands where the temperatures are not so high. Studies have shown that the problem of thermal comfort is increasing in Europe. Over recent years, the productivity of work has decreased in hot weather and many people have died during extreme heat waves. The aim of the project is to contribute to the improvement of the quality of life and working environment in urban areas locating in the Netherlands, which will be studied according mostly to the Suikerbuurt area.

2.2. Problem analysis

The climate change is a fact that is affecting the whole world. Temperatures are high within the summer and even in the winter. Our earth is increasingly warming with an earth's average temperature raised by 1.4ºF over the past century, and it is projected to rise another 2 to 11.5º over the next hundred years *(EPA. March 2014).* Those changes in the average temperature of the planet can be translated to large and potentially dangerous shifts in climate and in the weather.

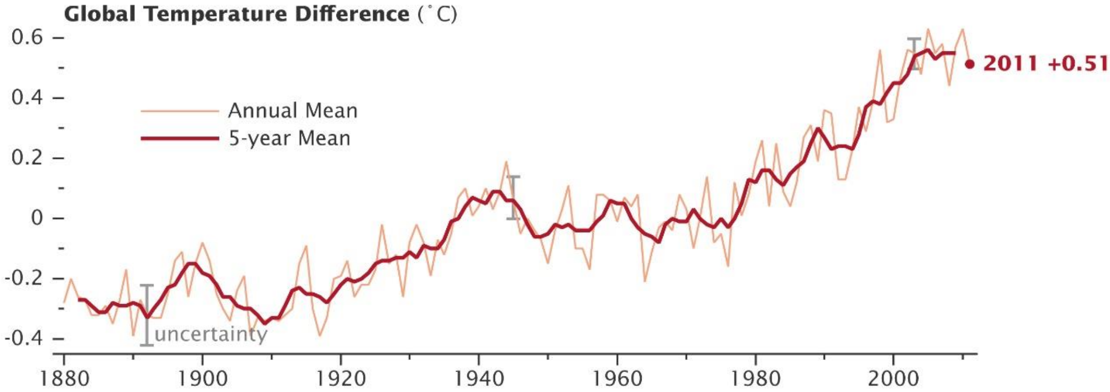


Figure 2 – Course of the Global Temperature since 1880 to 2011

Global temperatures have warmed significantly since 1880, the beginning of what scientists call the "modern record." While average global temperature will still fluctuate from year to year, scientists focus on the decadal trend. Nine of the 10 warmest years since 1880 have occurred since the year 2000, as the Earth has experienced sustained higher temperatures than in any decade during the 20th century. As greenhouse gas emissions from energy production, industry, vehicles and atmospheric carbon dioxide levels continue to rise, temperatures have climbed, most notably since the late 1970s. Scientists expect the long-term temperature increase to continue as well.
(Data source: NASA Goddard Institute for Space Studies. Image credit: NASA Earth Observatory, Robert Simmon).

Many places have seen changes in rainfall, resulting more floods, droughts, or intense rains, as well as a more frequent and severe heat waves. The planet's oceans and glaciers have also experienced big changes such as warming and becoming more acidic. The problems results on ice caps melting and sea level rising. Each decade the changes are more pronounced and they will likely present challenges to our society and to our environment *(EPA. March 2014).*

Who is the responsible for climate change?

Human activities have released an important amount of carbon dioxide and other greenhouse gases into the atmosphere during the past century *(United Stated Environment Protection Agency (EPA). March 2014).* Greenhouse gases come from burning fossil fuels to produce energy, although deforestation, industrial processes and some agricultural practices which also emits gases into the atmosphere.

Greenhouses gases act like a blanket around earth, trapping energy in the atmosphere and causing it to warm: this is called "the greenhouse effect". This phenomenon is natural and necessary to support life on earth. However, this effect is already changing earth's climate and the result of this is very dangerous to human well-being and for the environment survival.

The climate change is affecting everyone because our lives are directly connected to the climate. A warming climate will bring changes that can affect water supplies, agriculture, power and transportation systems, the natural environment and even human's health and safety. Now it's time to change because nowadays they are some changes to the climate that are unavoidable. For example, the carbon dioxide can stay in the atmosphere for approximately a century so, earth will continue to warm at least in the coming decades. This could be translated in more severe changes to the climate and earth's systems. It is difficult to know the exact impacts of the climate change but the only thing that it's clear is that the climate we are accustomed to right now, is not a guide for what we have to expect in the future *(EPA. March 2014).*

The only way is to stop and reduce risks for people coming in the future. We need to make choices that reduces greenhouses gas pollution and preparing for the changes that are already underway. Our good decisions today will help the world tomorrow to achieve a better world and livability in the future. It is time to start creating a better place to live for our children and our grandchildren. In order to achieve this better place to live, there is a problem that needs to be studied and which is a consequence from the climate change: the Heat Island Effect.

This term describes built up areas that are hotter than nearby rural areas. According to EPA *(United States Environment Protection Agency)*, in a publication from 2014, the annual mean air temperature of a city with 1 million people or more, can be 1-3ºC warmer than its surrounding area (rural areas). The metropolitan area is significantly warmer due to human activities, the land surfaces and a decreased amount of vegetation within urban areas. Without vegetation, cities lose the shade, the cooling effects of trees and the expulsion of carbon dioxide. The temperature difference is usually larger at night than during the day due to the fact that, during night time, the short-wave radiation is still within the concrete, asphalt, and buildings that was absorbed during the day, unlike suburban and rural areas. This phenomenon can affects communities by increasing summertime peak energy demand like air conditioning, air pollution and greenhouse emissions; increasing heat-related illness and mortality. I stress the problem which needs to be solve on the basis of this urban heat island effect. Hence, a new concept design of urban areas needs to be ingrained in our society.

2.3. The thermal comfort

2.3.1. The body regulation temperature

Man has a temperature regulatory system which ensures that the body's temperature is kept at approximately 37º but it can be some circumstances than can make body to aim a low or a high temperature. On one hand, when the body is getting cold, the first reaction is for the blood vessels to vasoconstrict (narrowing of the blood vessels that results from contraction of the muscular walls of the vessels), reducing the blood flow through the skin. Then body increases the internal heat production by stimulating the muscles, which causes shivering. On the other hand, when the body becomes too warm, two processes are starting: at first, the blood vessels vasodilate (widening of blood vessels that results from relaxation of the muscular walls of the vessels), increasing the blood flow through the skin and afterward one starts to sweat. This is a cooling tool that the body automatically begins when the energy required for the sweat to evaporate is taken from the skin.

This explanation is simple but actually, the control system which regulates the body temperature is not yet entirely understood. To understand this complexity of the human body, we just need to know that the two most important set of sensors for the control system are located in the skin and in the hypothalamus (within the brain). This last term is a heat sensor which starts the body's cooling function when the body's temperature exceeds 37º; and the skin sensors are cold sensors which start the body's arms against cooling down when the skin temperature falls below 34º. *(Innova AirTech Instruments. 1997)*

2.3.2. The thermal comfort and the project

This project would try to prove why it is important to take into account the thermal comfort in urban development plan. As I explained above (2.2. Problem Analysis), temperatures are going to continue to increase. Heat waves can lead to heat stroke and dehydration, and are the most common cause of weather-related deaths (*Harlan S.L., et al., 2006)*. Excessive heat is more likely to impact populations in northern latitudes where people are less prepared to cope with excessive temperatures. The more vulnerable people for heat-related illness use to be young children, older adults, people with medical conditions and the poor. Notable recent events include the heat waves of 2003, which killed an estimated 35.000 Europeans in two weeks and more than 1.900 people in India (*Harlan S.L., et al., 2006)*. Deaths and illness from air pollutants and infectious diseases also increase during extremely warm weather. Climate change will likely lead to more frequent, severe and longer heat waves during the summer period as well as less severe cold spells in the winter.

Urban areas are typically warmer than their rural surroundings. Climate change could lead to even warmer temperatures in cities. This would increase the demand for electricity in the summer to run air conditioning, which in turn would increase air pollution and greenhouse gas emissions from power plants. The impacts of future heat waves could be especially severe in large metropolitan areas. It is therefore necessary to make every effort to plan and design urban environments to reduce the effects of this heat increase. This is the main theme of the research.

The thermal comfort is the main term of this project. The aim is to measure it based on the four main concepts that defined it: humidity, radiation, air temperature and wind speed. In order to get this, I am going to use a specific measurement tool that is going to be described in the third chapter of this report: **Methodological Framework**. The thermal comfort gives us an idea about the state of mind of a person and how is he/she feeling in a specific place and on a specific moment. The person can feel or too cold, too hot or neutral. It is an ambiguous term to define exactly because there is not an accurate result for this and it needs to be studied by different ways. In this research I am going to use two of those ways to achieve the thermal comfort: Measurement with a weather station and questionnaires to interview people living or being in the Suikerbuurt neighborhood.

3. Research objectives

My work will be focused in The Netherlands (Groningen) and therefore my research will include an investigation into the changes of temperature in the region and find what the predicted future temperatures are likely to be. This is needed to demonstrate the effect of climate change on urban areas.

3.1. Goals and benefits

3.1.1. Goals

The main goal of this research is to know exactly what is the thermal comfort and how it could be measured in a specific environment. The aim is to investigate the thermal comfort in the Suikerbuurt area (Hoogkerk); so what is need to be done it's to measure the temperature in several places of this neighbourhood, such as gardens, grass parking, shopping area, streets houses… on a warm day. Whilst measurements are done, what is important to recollect is some data from the neighbours living or being there. I need to know how they feel in warm days and what they used to do or go on those kind of days. It is important to know this because the place where they used to go when they feel warm is the place where their thermal comfort is.

I will analyse the results of this study and give suggestions of how the area could be redeveloped to improve the thermal comfort and therefore quality of life for the residents and workers.

These goals of a sustainability work are:

- Make a city more sustainable
- Create green spaces and more water places
- Raise awareness of the people
- Improve quality of life
- Improve quality of work
- Improve productivity
- Improve quality of the planet

The main goals of this final thesis are:

- To estimate the temperature of several places within the Suikerbuurt area
- To know how are feeling people living there
- To compare data from measurements and questionnaires and make conclusions
- To find solutions for a better thermal comfort in the future
- Improve the quality of life of people living in this neighborhood and prove that the thermal comfort is an important fact that needs to be investigated due to the climate change.

3.1.2. Benefits

The thesis have also several benefits that needs to be mentioned:

- The advantage for the neighborhood is the acquisition of knowledge that is needed to improve their livability and to cope extreme weather.
- To make a city more sustainable, proving how to improve the thermal comfort of the inhabitants of the Suikerbuurt and minimise resource uses.

- For myself, this research will help me to be more aware about the current situation about the earth's climate change. Nowadays, my country (Spain) is more affected than the Netherlands because of heat waves, so all the information that would be learned during the processes would help me to understand more how cities need to be built in the future to make them more livable and heat resilient.

3.2. Contents of the Report

- Chapter I, **Introduction and Description of the project**

Within this chapter, it would be explained all the background information, the problem analysis and the objectives of this research, including all the questions overview as a summary about what we need to do and to look for within the research.

- Chapter II, **Literature Review and Hypothesis Development**

This chapter will explain all the parameters and terms of this project and all about the related literature used to carry out the research. All the instruments used to get the results are going to be described within this chapter.

- Chapter III, **Methodological Framework**

The third chapter will include all the methodology used to get the thermal comfort in this research. All the steps are going to be explained about how to use each tool and what should be done for the final measurements and questionnaires.

- Chapter IV, **Data analysis and Results**

The chapter four is to show all the measurements and questionnaires results, with the calculations results, the charts and an analyses of the final results together with a discussion.

- Chapter V, **New Concept Design**

The chapter VI is intended to make an estimation cost about a new concept design described to solve the area's main problems. These new solutions are proposed based on the data analysis of chapter IV, intended to improve the neighborhood thermal comfort.

- Chapter VI, **Conclusion and Remarks**

This final and conclusive chapter of the report is made to conclude the research and to make some remarks for future and similar researches. The main research question is going to be answered as conclusion of the report.

- Chapter VII, **Bibliography**

- Appendix

4. Questions overview

Main Question:

How can thermal comfort design solutions be integrated into a typical urban development project in the Netherlands?

To get the final answer to the main question, there are some steps that are needed to be followed. These steps are other questions (sub-questions) that can help us to have a guide and not forget anything important to being mentioned.

There exists a case study of Suikerbuurt on Groningen.

Sub- questions:

The Netherlands:

- **What is thermal comfort and how is it related to urban development?**
  - What is exactly the definition of thermal comfort?
  - Which factors are involved with this?
- **Is thermal comfort a problem in The Netherlands?**
  - Why is this a problem?
  - What are the consequences of this problem?
  - Why should it be solve as a priority?

Suikerbuurt neighbourhood:

3. **What are climate and land use conditions in Suikerbuurt?**
   - What parameters are we going to measure?
   - What are the current climate conditions in Suikerbuurt?
   - What are land use conditions (black asphalt, light grey concrete, grass (10cm-20cm), etc.) in the area?
4. **What are the current problems in the area (engineering, social and economic)?**
   - Engineering problems?
   - Social problems?
   - Economic problems?
5. **Is thermal comfort a problem now or in the future? What ways can thermal comfort be reduced in the area?**
   - Is there some different ways to reduce thermal comfort? Which ones?
   - Which of those ways would be better to use in the area? Why?
6. **What is best method to design for thermal comfort?**
   - What are different methods to design for thermal comfort?
   - Which is the best one to be used for this case study?
7. **How can a concept design be made that includes a cost/benefit analysis?**
   - Make a concept design
   - What are the cost/benefit of this method?

Chapter II

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

5. Literature Review

The theoretical review is an important aspect of the report. Within this chapter all the parameters to be considered in this research are going to be explained. The aim is to describe all the important terms that are necessary to understand the project as a whole. Each parameter is going to be described by the previous related research as well as the theory found in the literature review.

5.1. Literature used

When you are about to start a research study, it is important to read a lot about the subject you are interested to investigate. When I chose the theme of the Final Thesis, I didn't know exactly how extend this area was. I realized after many researches that there are a lot of information that needs to be studied in detail. The first articles read help me to select the most important data to use in this project.

First, I was planning to make a large study about the heat stress in The Netherlands but I didn't know exactly the main points of the methodological research. So I started reading articles about the heat stress and I realized that this term was using more frequently referring to the thermal comfort on a workplace, I mean in indoor environment. What I needed to understand at this moment was that there are different parameters to determine the thermal comfort indoor and outdoor. With the article wrote by Höppe P. in 2002 about "*Different aspects of assessing indoor and outdoor thermal comfort",* the author explains that this subject was discussed and investigate by *Potter J. and De Dear R. (2000),* when they asked themselves *"*Why do holiday makers deliberately seek out thermal environments, that would rate 'off the scale' if they were encountered indoors?". It was a very good question because it's true that people use to go for holiday where the weather is warm and higher than the according estimate temperature for the indoor thermal comfort in precedent studies. So Potter and Dear decided to investigate outdoor scenarios experimentally and they found that the outside temperature where people used to feel thermally comfortable was higher (27ºC) than the predicted thermal neutrality for indoor spaces (24,1º). So they concluded that the thermal sensation outdoors was perceived differently from that of indoors and even postulated, that "indoor thermal comfort standards are not applicable to the outdoor settings".

Therefore, the next step was to know which were the factors involved in outdoors thermal comfort and how to measure them. In order to do that I used several articles such as the one about the *"Psychological and physical impact of urban green spaces on outdoor thermal comfort during summertime in The Netherlands",* wrote by Klemm W. et al., in 2014, where the information gave was about how green infrastructure could improve thermal comfort in outdoor urban spaces. In this article we could read some indication about how the thermal comfort could be investigated through "some meteorological variables and human-biometeorological indices". It is a good article because it is focused in the Netherlands, where the study case of this research is focused on, so the data are going to be more helpful for it. This article helps to understand better the relationship between green spaces and thermal comfort. Basically, the article gives information about the helping green areas against heat waves problems stated a "decrease of the air temperature with an increase of size of parks". The article talk about human perceptions, with the interaction of physical, physiological, psychological and behavioural factors.

When the new concept design would be designed, this article should be taken into account due to the repetitive suggestions about how green spaces improve perception of places and perceived thermal comfort. The article is subdivided in two main questions: How people perceive green places within urban environments and what are the physical thermal comfort conditions in urban green areas; after that it introduce several ways, methods and materials to study and answer the main question mentioned just above (Study 1: Interviews; study 2: Measurements)

Now the main ways to measure the thermal comfort was introduced in my research: making questionnaires and measurements; the next step was to study which were the best method to make those studies to achieve the thermal comfort of the Suikerbuurt area. The article of *"Instruments and methods in outdoor thermal comfort studies – The need for standardization"* wrote by Johansson E., Thorsson S. et al. in 2013 was very useful to know the different ways to perform a good measurement and the better questionnaire. The data gave on this article were a "review of the instruments and methods used to assess outdoor thermal comfort and subjective thermal perception in 26 studies during the last decade". The article explains all the different terms and parameters needed to solve the thermal comfort. Within them, we can find the mean radian temperature (Tmrt), a factor that needs to be calculated from some other factors data that need to be measured with a weather station. In the following paragraphs each of those terms are going to be described and defined according to this article and another's articles such one called "*The effects of solar radiation on thermal comfort",* wrote by Hodder S.G. and Parsons K. in 2007. This article explain the term of the radiation and is based on other studies as the one made by Nielsen et al. in 1988 and others latest such as the one from Narita et al. made in 2001.

The article of the instruments and methods is very clear and I used it as a guide to know about each term, about the weather station complements (the globe thermometer), about the formula needed to get the mean radiant temperature and about which are the main questions that need to be done to the subjects to know about their thermal sensation and their thermal comfort. For this reason this articles is going to be mentioned in the following points and chapters, where all the terms are going to be defined and all the instruments and methods are going to be described.

"*Neighborhood microclimates and vulnerability to heat stress"* wrote by Harlan S.L. et al. in 2006, is another helpful article for this research. This thesis is about the thermal comfort in a specific area: the Suikerbuurt neighborhood. This article is useful because it is explaining how the heat stress or thermal comfort affects some neighbourhoods and gives solution to improve the life's quality of people living there. For example, something interesting that I read in this article was that "neighborhoods with stronger ties had better social support and lower mortality rates during Chicago's 1995 heat wave". It gives solutions to help people to fight with high temperatures and shows differences between neighborhoods which have cooling systems such as swimming pool or reflectivity of roofing material for a sample of detached houses. Is an interesting article which can help me (and other people) to perform a research about matter and to improve the inhabitants' life using sustainable solutions.

Those articles are the main articles that I am going to use, but there are some other sources that can be mentioned in other points too. For example, in the Appendix 5, there will be information about the weather station characteristics that will be described in the chapter III, **Methodological Framework.** In the next following passages all the mains terms will be described.

5.2. The thermal comfort

The thermal comfort is defined in British Standard BS EN ISO 7730 *(HSE _ Health and Safety Executive)* as "that condition of mind which expresses satisfaction with the thermal environment". What it is explained with this short definition of the concept "thermal comfort" is the description of a person's psychological state of mind, i.e. if someone is feeling too hot or too cold. The term is very difficult to define because there is not an exact answer for the thermal comfort. It depends of each person, of the environment and what makes people feel comfortable. What is needed to be found in this project is a thermal environment that satisfies the majority of people in the same workplace. "*HSE* considers 80% of occupants as a reasonable limit for the minimum number of people who should be thermally comfortable in an environment."

People make the mistake in thinking that the thermal comfort is measured by air temperature, but this is a wrong concept. The thermal comfort is a combination of different factors including temperature, humidity, wind and radiation. It is particular important to know the thermal comfort of a workplace. People working in uncomfortable hot and cold environment are more likely to behave unsafely because their ability to make decisions and/or perform manual tasks deteriorates.

How to measure the thermal comfort?

A specific way to determine thermal comfort is to measure at a certain location the temperature, humidity, wind speed, radiation and mean radiant temperature (Tmrt). There are some meteorological instruments suitable for measurements in urban areas. It is more usual to found indoor tools for these measurements, because it was more usual to measure the thermal comfort on a workplace. But our goal is to measure thermal comfort in outdoors spaces. For this, we need to have an extra consideration to exposure of instruments, the measurements of wind speed and of mean radiant temperature *(Johansson, 2014).*In this research, the thermal comfort is going to be measured by two different ways.

On one hand, a weather station is going to be used to get data from all the different factors I mentioned above (temperatures, wind speed, humidity and radiation), that are needed to achieve the thermal comfort. This first way requires a warm day and a lot of time due to the fact that each measurement needs to take at least 20 minutes and it is necessary to make many measurements to compare results at the end. In this experiment, I made several measurements with this weather station on a different locations around different environment. What I mean is that in the same Suikerbuurt area, I will make some measurements in places with different surfaces such as grass, asphalt, sidewalk, tennis field, etc. (See appendix 1 and 2: Land use and Surfaces of the Suikerbburt area). Some of these measurements will take place in the shade, some others will take place in a sunny place, some others will be near a water environment (near the waterway), other in the asphalt parking lot and other one in a green area, with and without trees. After measurements, results need to be analyzed by making some calculations and graphs.

On the other hand, questionnaires are going to be provided to people living or being in the Suikerbuurt area on the same warm day as measurements are taking place. Questionnaires need to be done on the same specific place and at the same specific time that the weather station is being used. The aim is to link measured thermal conditions (temperatures, humidity, wind speed and radiation) with people's subjective thermal perception. It is crucial that measurements are conducted near the subjects interviewed if the goal is to analyse how people perceive the thermal comfort.

On the following paragraphs, all the terms needed to achieve the thermal comfort, are going to be explained.

5.2.1. Air temperature and humidity

Temperature and humidity sensors may be heated by radiation sources such as the sun and warm urban surfaces. There are many factors that need to be considered when measuring air temperature and humidity. We need to take care to a temperature probe exposed to solar radiation which can produce overestimate data from air temperature by several degrees Celsius.

When the measurement are going to take place, it is important to letting a time of 11/2 times the response time of the sensor elapse measurements can take place, to account for instrument thermal inertia *(Johansson E. et al., 2014)*. According to this article, it is important to state if the probes were shielded or not and it a forced ventilation of the temperature probe was using for the measurements so (page 13 of the article), so I need to specify that the probes were shielded and they had a fan to keep the air moving.

5.2.2. Wind speed

The wind speed is caused by air moving from high pressure to low pressure, usually due to changes in the temperature and can affects weather forecasting. The wind speed was measured in all studies, confirming the importance of this measurement for the research. Those kind of measurements were performed using a **cup anemometer.** This is a simple type of anemometer invented in 1846 by Dr. John Thomas Rommey Robinson. This kind of anemometer consists of four hemispherical cups each mounted on one end of four horizontal arms which in turn were mounted at equal angles to each other on a vertical shaft. The air flow past the cups in any horizontal direction turned the cups in a manner that was proportional to the wind speed. Therefore, counting the turns of the cups over a set time period produced the average wind speed for a wide range of speeds. The following picture shows a cup anemometer.

Figure 3 - Cup anemometer from the weather station

For this research, it is important to consider the speed and the direction of the wind due to the fact that it can affects to the temperature measurements. Wind speed and direction needs to be strongly taking into account in outdoor environment, and especially in urban areas. The following aspects needs to be considered as well:

- ✓ Making 3 dimensional measurements: horizontal and vertical wind speed
- ✓ Instruments need to have a quick response time and sufficient accuracy
- ✓ Measurement interval should be sufficiently large (15 minutes more or less) to be able to measure both low and high speeds, at least in places where high speeds are common

5.2.3. Solar radiation

The solar radiation cross the atmosphere and is divided in three ranges: ultraviolet (UV), visible and infrared (IR) which is subdivided into sections. Just a small section containing 45% of the energy emitted is visible to the human eye. There are evidences found in studies from *Blazejezyk et al., (1993)*, from *Moran et al. (1995)* and from *Shapiro et al., (1995)* proving that radiation (or radiant component) its more effective in humans rather than as a component within mean radiant temperature (Tmrt).

It is not known neither whether radiation energy will have different effects on human perception of thermal sensation nor whether people are sufficiently sensitive to react physiologically to subtle changes in the spectral sensitive heat *(Hodder. S. and Parsons. K. 2007).* Some studies were made to investigate the effect of the spectral content of solar radiation on thermal sensation of the black of the hand.

In this research we are just measuring some radiation data with the weather station, trying to understand with the results analyses if this can affect to the thermal comfort of the people if the results for a bad thermal comfort match with higher radiation and vice versa.

5.2.4. Mean radiant temperature (Tmrt)

<u>Mean radiant temperature</u>: *"Uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body equals the radiant heat transfer in the actual non-*uniform enclosure" (ASHRAE, 2001).

The mean radiant temperature is the most difficult to measure accurately. This is one of the most important variable in assessing the thermal comfort during warm and sunny weather conditions. The mean radiant temperature can be determined using several methods, however a simple method to give a good approximation has been developed (See equation (1)).

The method involves using a test equipment as a tool to measure some factors of the weather, such as the air temperature, the wind speed and the globe temperature. This globe thermometer consists of a flat grey tennis ball (40 mm of diameter) and a Pt 100 temperature probe *(Thorsson et al., 2007)*. The measurements data from a globe thermometer can be used in following equation to give Mean Radian Temperature (Tmrt). According to *ISO 7726 (1998)* and *ASHRAE Handbook of Fundamentals (2001)*, it is recommended a medium grey colour for the ball because measurements are going to take place outside. If measurements were made inside, the globe should be black. The grey colour is because the globe is going to be exposed to solar radiation and like this it would have a better agree with outer surface. So the grey tone is important. To achieve sufficiently short response time, the globe should be of small size (table tennis ball) and have a small heat capacity. *ISO 7726 (1998)* and ASHRAE (2001) said that the shape of the globe influences the measurements of the Tmrt. According to *Olesen et al., (1989),* an ellipsoid-shaped sensor would probably give a more accurate estimation of the Tmrt of a standing person. The spherical shape has proven to work well enough, at least in –to high – latitude climates *(Thorsson et al., 2007)*, as our case study is in Suikerbuurt area.

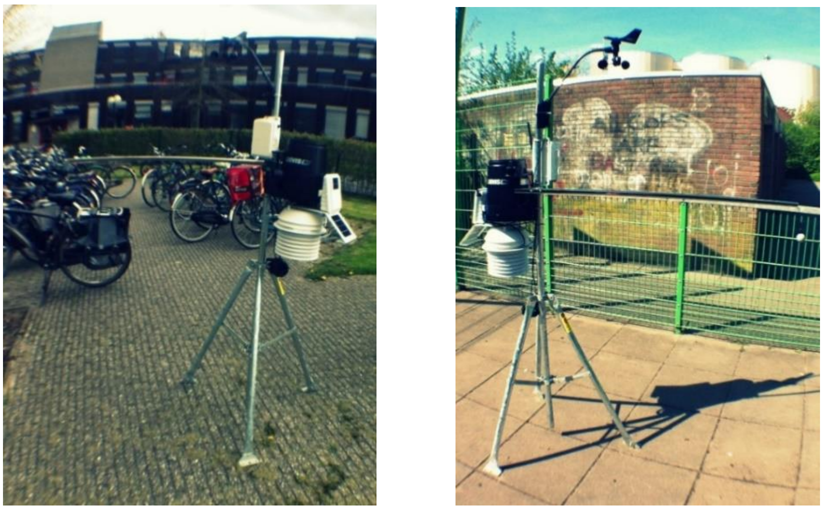


Figure 4 - The weather station

There are models such as Rayan *(Matzarakis et al., 2010)*, *SOLWEIG (Lindberg et al., 2008)* and ENVI-met *(Bruse, 2011)* to estimate the Tmrt, but this is not the way I am going to use to achieve the thermal comfort.

To put all in a nutshell, what we are going to use to calculate the thermal comfort is an instrument which includes a grey table tennis ball, as a globe thermometer, that is going to give us data about the air temperature, the globe temperature, the wind speed, the solar radiation and the humidity. To get the mean radiant temperature the humidity and the solar radiation are not necessary but there are thermal comfort factors that needs to be considered.

The equation (1) to achieve the mean radiant temperature is the following one:

$$T_{mrt} = \left[(T_g + 273.15)^4 + \frac{1.335\ x\ 10^8 Va^{0.71}}{\mathcal{E} D^{0.4}} (T_g - T_a)\right]^{1/4} - 273.15$$

Where:

- T_g is the globe temperature (°C)
- V_a is the wind speed (ms^{-1})
- T_a is the air temperature (°C)
- D is the globe diameter (m)
- $\mathcal{E}$ is the globe emissivity

There are some data that are going to be stable such as the globe diameter (D) (0,04 m, table tennis ball) and the emissivity of the globe (0,95). I had some doubts about how to get the globe emissivity ($\mathcal{E}$), so I asked to Lisette Klok (researcher on climate resilient cities at the University of Applied Sciences in Amsterdam), who asked to Fredrik Lindberg (they are making some urban development plan using the emissivity data) and they told me that they were using 0,95 for their own study. They've got this data from *Nikolopoulou (1999).* As they explained to me, the emissivity is a material characteristic. It is the ability to absorb (and emit) radiation. An emissivity of 0,95 means that the surface absorbs 95% of the radiation that is receives. The other 5% is reflected. An emissivity of 0,95 also means that it emits 95% of the energy compared to a black body.

5.2.5. Questionnaires

Another way to measure and estimate the thermal comfort is doing some questionnaires to people and, if the percentage of people dissatisfies with the thermal environment is above certain level, it would be needed to change something in the environment. There are some factors that could be a risk for people: air temperature, radiant temperature, humidity, air movement, metabolic rate and clothing. It is important to include in the questionnaire what people are thinking about the thermal comfort. It is important as well to measure temperature in the same place as the questionnaires are going to be done, to know exactly within which temperature people use to feel in thermal comfort and where people doesn't feel to be in (See appendix 7). The questionnaires will include the following questions (with open answer or multiple choice):

1. **General Information**

a) Time
b) Location (Coordinates, in the shade/sun)
c) Name interviewer

2. **Personal Information**

a) Age
10-20, 20-30, 30-40, 40-50, 50-60, 60-70, +70
b) Gender
M / F
c) Clothing
Jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d) Activity level
Sitting, standing, walking, running
e) Home country/How long have you been in The Netherlands?
f) Thermal history
i.) For how long are you at this specific location?
ii.) Where did you come from?
iii.) Were you outdoors 5 minutes ago?

3. **Thermal Perception**

a) How do you feel now?
Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b) What do you think of the sun at this moment?
I prefer more/OK/Too much sun
c) What do you think of the wind at this moment?
Stale/Little wind/OK/windy/too much wind
d) What do you think of the humidity at this moment?
Damp/OK/Dry

4. **Thermal comfort**

a) Do you find this environment thermally comfortable?
Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable

5. **Thermal preference**

a) How would you prefer it to be now?
Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

6. Hypothesis Development

What it is expected to achieve with this research is to demonstrate how urban well-designed spaces, in particular green areas, improve thermal comfort in physical as well as in psychological terms. The aim of questionnaires is to prove the hypothesis that people generally perceive green urban places more positive for warm days. The measurements are made to demonstrate this.

I am going to make several measurements in different places with different environments, changing materials around and weather conditions (shade, sun and wind). The idea of choosing several environments is to get different results for both measurement and answers in each location. The places chosen vary from a shopping area inside an urban area to a green area within the Suikerbuurt neighborhood. Of course, the expected results are those which can demonstrate that people feel thermally comfortable in those locations where the main elements are the shadow or the green spaces.

Performing this measurements I pretend to find how warm could be places such as the parking lot situated beside the Albert Heijn store, where the floor is making with asphalt and where there is any element producing shade. In this place, if we take a look to the Heat Map extract on the right (see the full map in the Appendix 3 and its explanation in the Appendix 4), we can realize that the heat is extremely high (**A**). By contrast, there are other places as the green area within the Suikerbuurt neighborhood where there is not any trail of heat (**B**). Those differences are the ones that are needed to be demonstrated to start changing our environment. We need to be aware about the increasing problem about the high temperatures in urban areas, and the goal is to get results proving this.

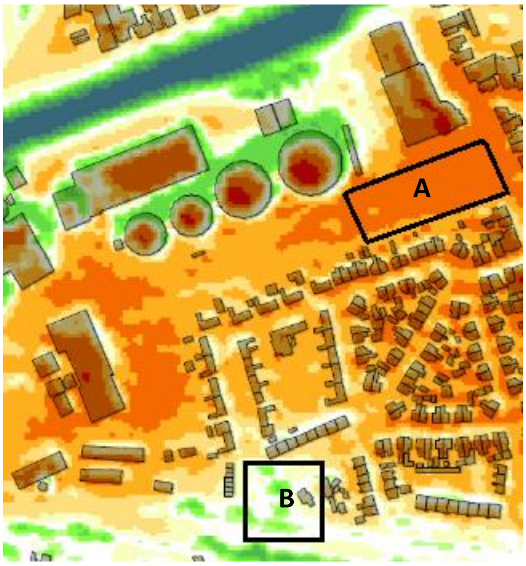


Figure 5 - Extract of the Suikerbuurt Heat Map

To put all in a nutshell, with this research I expect to find coherent results showing how big can be the weather conditions differences between some sustainable places (including green spaces and water environment) and other urban areas.

Chapter III

METHODOLOGICAL FRAMEWORK

7. The measurements

7.1. Instruments to measure

7.1.1. The weather station

The weather station that it was used for measurements in Suikerbuurt area is called “Wireless Vantage Pro2 Plus Stations” or Davis instruments. This tool is able to measure barometric pressure, temperature, humidity, rainfall and wind speed and direction. It gets highs and lows data, as well as averages, for the past 24 days, months, or years. A noteworthy thing is that you don’t need any computer to make that. So it is an easy tool to be manage and transporting. But I need to make a subsection here; for our research we used the computer to move all the data from the console for being analysed with tables and graphs.
The instrument is composed by two main components: The Integrated Sensor Suite (ISS), which houses and manages the external sensor array, and the Console which provides the user interface, data display, and calculations (See Appendix 5: The weather station).

Figure 7 - The integrated Sensor Suite

Figure 6 - The Console

To use correctly the ISS is important to include tripod that helps to keep quiet and stable the instrument.
Even if the console can be used with any cables when the measurements are taking place, the panel may be powered by batteries before each use. This console operates within a temperature range from +32º to +140ºF (0º to +60ºC), and some important data to be mentioned about this equipment are:

- ❖ The historical data includes the past 24 values listed
- ❖ The earliest time of occurrence of highs and lows (period starts and ends at 12h00 am)
- ❖ If data are collected for a month, the period begins and ends at 12h00 am on the first of the month
- ❖ If data are collected for a year, the period begins and ends at 12h00 am on the first of January
- ❖ The use can select the graph time interval. This interval can be 1 minute, 10 minutes, 15 minutes, 1 hour, 1 day, 1 month and 1 year.

As we already it is explained in other chapters, for our research it is necessary to make some measurements to get factors constituting the thermal comfort. The weather station can bring directly information about the humidity, the temperature, solar radiation and the wind speed.

We need to take care because the weather station bring us information about the **humidity** from the console (inside relative humidity) and from the ISS (outside relative humidity). We decided to take the last one because all the data that are took are from the exactly place where the ISS (with the tripod) is being situated. So we need to get data from Outside humidity. The units for this measures is 1%, and it works within a range from 1% to 100% RH. The accuracy is + /- 3 % (0 to 90 RH), +/- 4 % (90 to 100 RH).

For the **temperature**, the unit used is 1ºC or 1ºF, it depends of the user selection. The range of outside temperature is from -40ºC to +65ºC and the sensor accuracy is +/- 0,5ºC above 7ºC, +/- 1ºC under -7ºC. The update interval is from 10 to 12 seconds.

To get the **solar radiation**, the station requires for a solar radiation sensor. The units used are 1W/ m^2 and the accuracy is +/- 5% of full scale. The update interval is from 50 seconds to 1 minute, except in the dark, where the update interval turns to 5 minutes.

Finally, the **wind speed** could be measure in several units, but as the equation that we need to use needs to have the wind speed data in 1 m/s, it is this one that is going to be used. The weather stations works on a range from 0,5 to 89 m/s and the update interval is 2,5 to 3 seconds. The accuracy is 1m/s or +/- 5% (whichever is greater). To measure the wind speed, it is used the following sensor:

- Wind Speed Sensor . . . . Solid state magnetic sensor
- Wind Direction Sensor . . . . .Wind vane with potentiometer
- Cup anemometer (see explanation in Chapter II, **Literature Review and Hypothesis Development**, point 5.2.2 Wind Speed)

All those data are explained in more detail in the Appendix 4. Here I've just mentioned the most important information of each parameter that is going to be used to achieve the thermal comfort.

7.1.2. The globe thermometer

To determine the Mean Radian Temperature (Tmrt), there is several instruments and methods. The most common method to determine the Tmrt, used in 46% of the studies was by using a globe thermometer combined with measurements of air temperature and wind speed *(Erik Johansson et al., 2013).* The types of globe thermometer varied greatly respecting size, colour and material of the globe. The shape of the globe thermometer may influence the measured Tmrt, especially in our case: outdoor environment. The shape of the globe could be ellipsoid or round, the choice of one of them depends on the latitude where measurements are taking place. In Hoogkerk, the latitude is 53º and, according to *Thorsson et al. (2007)*, a good correlation was found between a spherical globe and standing persons in Göteborg, Sweden, where the latitude is 57º. At lower latitudes, the Tmrt might be overestimated by round instead of ellipsoid globe. Even if there is not too much difference between Hoogkerk latitude and Göteborg latitude, we decided to use a round ball due to the fact that it is easier to use and to find. There is a simple explanation about why the globe thermometer method is used. It is a simple method and the instruments are easily to move from a place to another. The cost is not cheap compared to other instruments *(Bell S. et al., 2015)* but even though, the advantages for reliable results were guaranteed.

When measurements are indoors, the globe thermometer is black painted with a diameter of 150mm, mde of copper *(ISO 7726, 1998*). However, such globe thermometer may take 20-30 minto reach equilibrium *(Spagnolo and De Dear, 2003; ISO 7726, 1998)* and a globe which is having so large time constant is not suitable to measure Tmrt outdoors where radiative fluxes and wind speed change rapidly. Instead of a black colour, it is recommended to use a medium grey colour globe (*ISO 7726, 1998 and ASHRAE, 2001*). What we used in our study was a 40mm flat grey globe thermometer, made of a grey painted table tennis ball, as it has been used in several outdoor studies (*e.g. Thorsson et al., 2007*). The grey tone is important because according to Thorsson studies (2007), the grey tone gives accurate results, specifically the type of grey used is the RAL 7001 *(Johansson E. et al., 2014).* One fact needs to be mentioned here.

Figure 8 - The grey ball for the globe thermometer

Even if the grey ball is the most appropriate for being used in outdoors studies, it is important to know that the results used slightly overestimates the Tmrt during shady conditions and slightly underestimates it during sunny conditions *(*Thorsson *et al., 2007)*

7.1.3. Other necessary complements for the Thermal Comfort Analyses

7.1.3.1. Fisheye camera

Figure 9 - The Fisheye camera

A fisheye lens is an ultra-wide-angle lens that produces strong visual distortion intended to create a wide panoramic or hemispherical image. Even if nowadays this tool can be used by everyone due to some phone applications that gives to you this effect for free, historically the camera was created in 1920 for use in meteorology to study cloud formation. The fisheye can give an angle of view between 100 and 180 degrees, so it is useful to take photos of the sky at the exactly moment where the measurements take place. The idea is to have information about the weather from several sources such as the weather station, photos from the sky and thermal photos to know the elements temperature around the weather station. With this fisheye camera, the photos showing the weather (sunny or cloudy) confirm the measurements data of a specific moment.

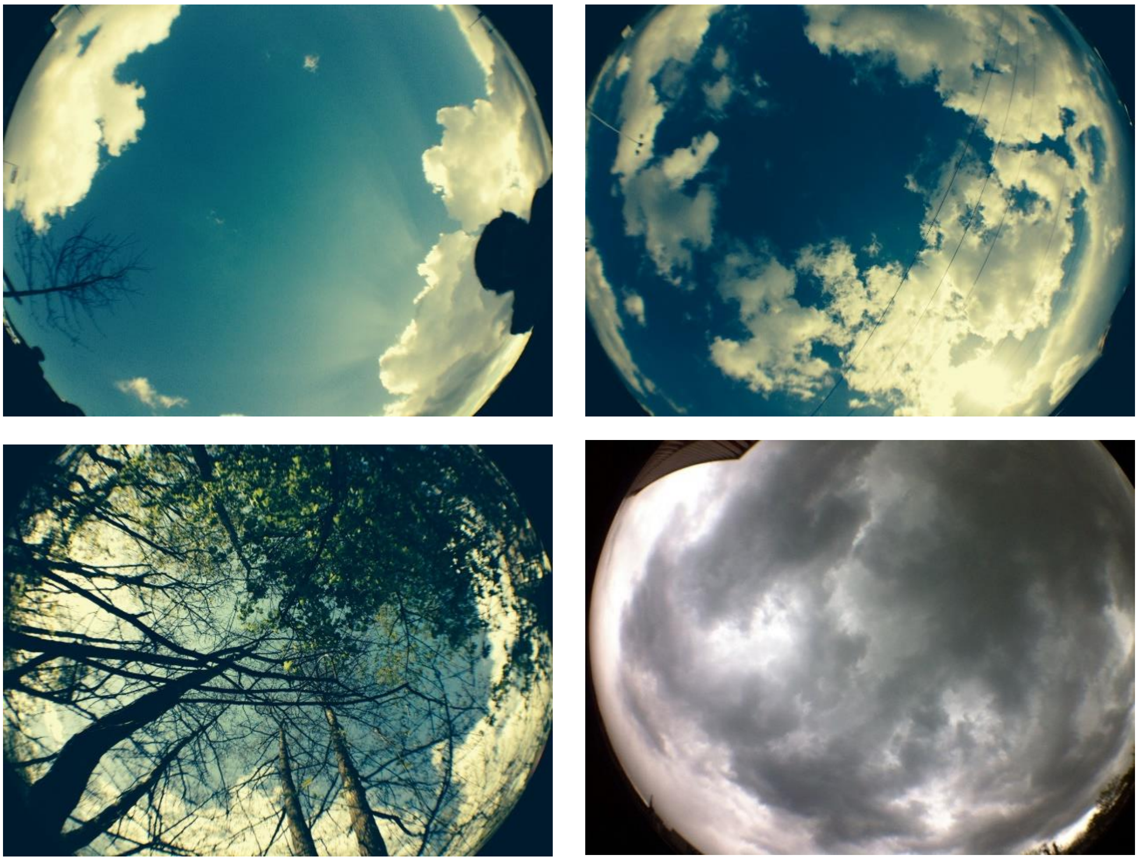


Figure 10 - Examples from the fisheye camera on different weather conditions

Those photos are useful for a model which is valid for applications in urban areas characterized by the complexity of the urban structures and other environments in the micro-scale. The aim of using this model is to get the Mean Radiant Temperature. This can be quantified by use of thermophysiological indices like Predicted Mean Vote (**PMV***), or Physiological Equivalent Temperature (**PET***) or Standard Effective Temperature (**SET***), based on the human energy balance. To use the Rayman model, there are some data required such as the air temperature, the wind speed, the humidity, the vapour pressure and the global radiation. Those data have to be inserted manually in a window of Rayman to get the mean radiant temperature. The photos are used in other window of the program to know how much light is influencing the weather (cloudy, sunny, trees…) and give a lower or the same mean radiant temperature as it was calculated with the data introduced in the first window. For example, if we have a Tmrt result and we introduce the first photo above, the Tmrt is not going to change too much, but if we introduce the last cloudy photo, the Tmrt is going to change to another lower result because of the dim light of the image. *(Matzarakis A. et al., 2002).*

PMV* (Predicted Mean Vote) provides an index to classified thermal (dis-)comfort at various states of activity and clothing insulation, according to Fanger's 1972 study. There are a relation existing between the thermal perception and the physiological stress level for a low activity and for normal indoor clothing. Jendritzky and Nübler added in 1981 a complex outdoor radiation to apply PMV to outdoor conditions. This means that in the environment there are many components changing the human radiant energy perception such as trees, clouds, sun, or buildings.

PET* (Physiological Equivalent Temperature) is an index which takes into account all basic thermoregulatory processes, based on a thermo-physiological heat balance of the human balance model called Munich energy balance model for idividuals (MEMI), created by Höppe between 1984 and 1999). According to Höppe, PET is the equivalent air temperature at which, in a typical indoor condition heat balance of the human body exists.

SET* (Standard Effective Temperature) is the effective temperature (ET) based on human energy balance two-node model. With ET, thermal comfort conditions can be compared to the conditions in a standard room with mean radiant temperature equal to air temperature and constant relative humidity of 50%. SET was the new standard effective temperature proposed by Gagge et al. in 1986 which can be use both as in indoor and outdoor comfort index. Ishii et al. compared in 1988 several thermal comfort indices and demonstrate that SET can be better used for evaluating outdoor comfort. In recent studies (2008), Lien et al. proved the use of SET as an output of Computational Fluid Dynamics (CFD) models.

(Tsuyoshi Honjo. 2009)

7.1.3.2. Thermal camera

A thermographic camera is a device that forms an image using infrared radiation, similar to a common camera that forms an image using visible light. Instead of the 450–750 nanometer range of the visible light camera, infrared cameras operate in wavelengths as long as 14,000 nm (14 µm). Their use is called thermography.

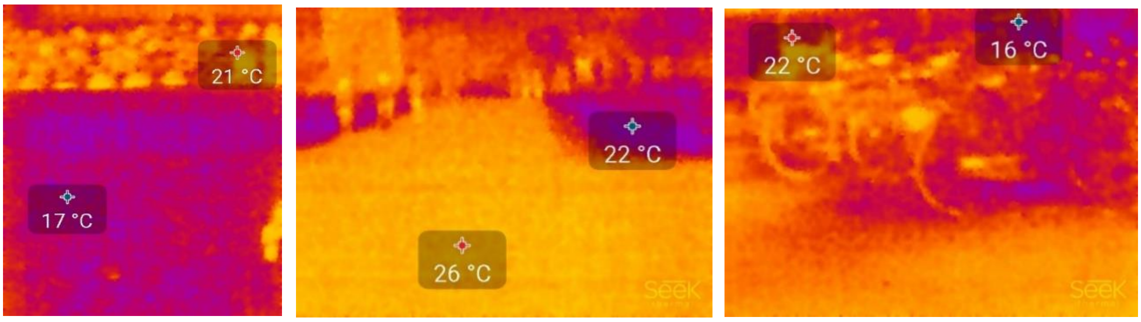


Figure 11- Examples from the Thermal Camera

The thermal camera gives information about the difference between temperatures from several elements of a picture. As we can see in the photos above, in the first one we can see a difference between the grass temperature (17ºC) and the cars of the parking lot temperature (21ºC). In the second one, the trees have a temperature of 22ºC and the floor is about 26ºC. In the third one the difference is between a bike's parking (22ºC) and a tree (16º).

With this instrument we can see where, in a reduced space, the temperature is higher or lower depending of the materials. For example, the bikes, cars and even the asphalt are warm elements because of their material's components (metal, bitumen) thus gives a higher temperature. The lower temperature is brought by trees and grass, due to the fact that green areas can make temperatures drop up to 3 degrees.

7.1.4. Davis instruments compared with other instruments

The instrument used for this research is the one described just above. However there are other tools which could be also used to measure the thermal comfort. In the Department of Computer Science from the University of Aston (Birmingham) a study was made to know which instruments were the most appropriate to use for those researches *(Bell S. et al., 2015)*. The compared ones were the Davis Vantage Pro2 (VP2), the Oregon Scientific WMR200, Davis Vantage Vue, La Crosse WS2350 and the Fine Offset WH1080. The following table is exported from this study and it was compared prices, software used to download observations, the temporal resolution (in min), the memory time (in days) and the rainfall increment (in mm).

Station	Station manufacturer	Station model	Price[a] (approximate)	Software used to download observations	Temporal resolution (min)	Time until memory full at this temporal resolution (days)	Rainfall increment (mm)
VP2(1)	Davis Instruments	Vantage Pro2 FARS[b]	£890	WeatherLink	10	18	0.2
VP2(2)[c]	Davis Instruments	Vantage Pro2 FARS	£890	WeatherLink	10	18	0.2
Vue(1)	Davis Instruments	Vantage Vue	£390	WeatherLink	10	18	0.2
Vue(2)	Davis Instruments	Vantage Vue	£390	WeatherLink	10	18	0.2
WMR200	Oregon Scientific	WMR200	£350	Virtual Weather Station	10	291	1.016
WS2350	La Crosse	WS2350	£100	Heavy Weather	60	7	0.518
WH1080	Fine Offset[d]	WH1080	£70	EasyWeather	10	30	0.3

[a]Prices include accompanying software, but not mounting accessories such as tripods. Only the WMR200 comes with a mounting pole as standard. Prices include VAT.

[b]FARS stands for fan aspirated radiation shield.

[c]The VP2(2) had been in the field for approximately 1 year before installation at Winterbourne No. 2. All other stations were brand new.

[d]Fine Offset manufacture this station but it is frequently sold under many different brand names including Maplin, Watson, and Ambient Weather.

Picture 12- Summary of the seven CWS tested as part of this field study.

The tool used here is the first of the table, i.e. Davis Vantage Pro2. The selection was because of many reasons. To see more details see the article wrote by Simon Bell, Dan Cornford and Lucy Bastin in 2015 about a study made in Birmingham.

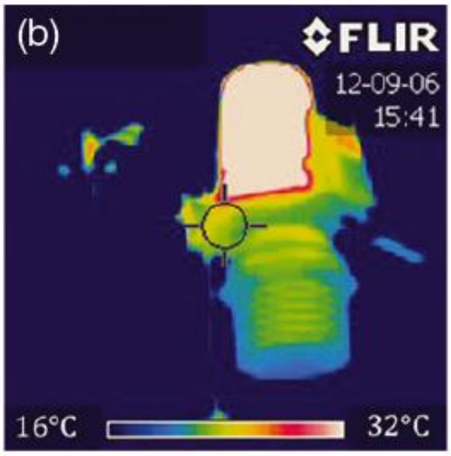


Figure 13 - Thermal image took from the southwest by a thermal camera on a sunny summer afternoon. Royal Methodological Society.

The figure on the left shows the Davis Instrument, the same as we used in this research, but this picture was taken during the Birmingham study. The colour-scale is consistent. The white (hot) part of the VP2 station evident is its black rain gauge. The image shows coolest colours compared with the other weather stations from the study (see Figure 12). This is justified by that it is the only tested model to include a fan-aspirated radiation shield which is solar powered. Consequently, under a sunny and calm conditions the aspirated VP2 station would probably provide better estimate results for the air temperature than other models.

We should underline that, as I said in the Introduction, this research is part of a larger project started 2 years ago in Amsterdam so, to make it more effective, the aim should be to compare results of both studies. Therefore, as Davis Instrument was used in Amsterdam research, it could be useful to use the same tool for the currently study. Besides, according to the Birmingham's research and comparing several instruments, Davis is the one who gives the most accurate results. It's simple to use and to understand results. Even though, there is one thing that needs to be mentioned as it is the most expensive instruments between the seven compared in the table above.

7.2. Zernike equipment testing

7.2.1. Measurements

Firstly and before making the final measurements in the area of our case study (Suikerbuurt area), we decided to make some measurements in Zernike to know how all the tools are working and to know if there is some problems with the final measurements results from this day. This first experiment was made the 30th April 2015. It was not a warm day as it is supposed to be for the final measurements in the Suikerbuurt neighbourhood but we needed to make it to have enough time to correct all the possible mistakes or problems that may arise. What we wanted with this is to know approximately how much time was needed for each measurement in the different places. In Zernike we were waiting between 10 and 15 minutes to change the emplacement of the weather station. It was a good experiment because after seeing results, we realized that we were taking too less time for each measurement.

We made several measurements in different places to have different results about temperature, humidity and wind speed. We took two measurements near water environment (the fountain and a channel), then we took two more measurements between two buildings to reduce the wind speed results, two measurements on a green areas, beside the "Architecture, Built environment and Civil Engineering" school parking, and two last measurements near bikes parking and on the asphalt. The aim was to see differences on the results between each area and get some conclusions about mistakes made on those first measurements to improve the final measurements on the Suikerbuurt area.

When we saw the results we realized that it was not time enough for the grey ball to get an stabilized temperature, so we decide to increase the time of measurement at least about 20 minutes. We decided to take 20 minutes because on the data we realized that it was just the first 5 minutes (more or less) that were needed for the globe to get a stable temperature.

We could also saw that after the measurements near the water environments, the humidity wasn't lower. The explanation of this fact was that after making those measurements near the fountain or the channel, it was necessary to dry the weather station to get the right results on the following measurements. There is some examples of the measurements that we made:

<u>Measurement 1</u>:

- Green area
  From 10h54 to 11h08

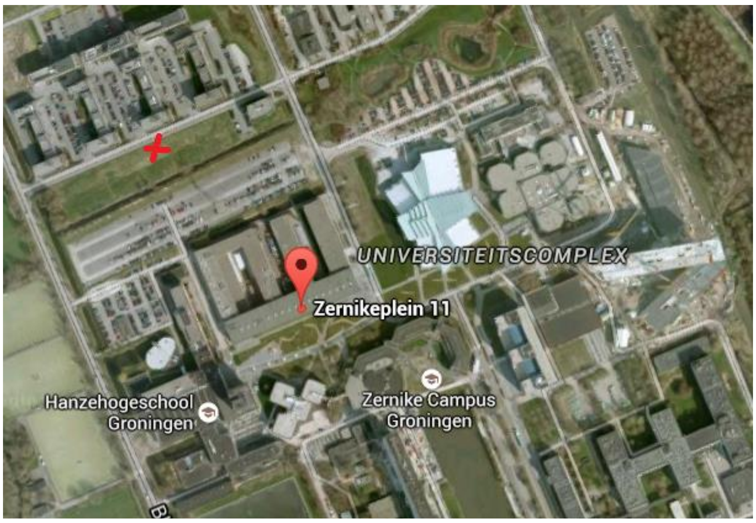


Figure 14 - Location of the first measurement in Zernike

Date	Time	Air temperature (ºC)	Humidity Out (%)	Wind Speed (m/s)	Raditation (W/m2)	Globe temperature (ºC)
30/04/2015	10:54 AM	13,7	58	2,69	220	18,9
30/04/2015	10:55 AM	12,9	61	2,22	269	17,8
30/04/2015	10:56 AM	12,3	60	4,03	233	16,7
30/04/2015	10:57 AM	11,8	61	4,03	223	16,1
30/04/2015	10:58 AM	11,4	62	4,03	207	15,6
30/04/2015	10:59 AM	11,2	63	3,58	207	15,0
30/04/2015	11:00 AM	11,1	65	3,14	207	15,0
30/04/2015	11:01 AM	11,0	67	2,22	207	15,0
30/04/2015	11:02 AM	11,0	68	3,14	100	14,4
30/04/2015	11:03 AM	10,9	67	3,58	113	13,9
30/04/2015	11:04 AM	10,8	67	2,22	148	13,9
30/04/2015	11:05 AM	10,7	70	3,58	148	13,3
30/04/2015	11:06 AM	10,6	69	3,58	148	13,3
30/04/2015	11:07 AM	10,6	69	2,22	109	13,3
30/04/2015	11:08 AM	10,5	69	1,78	102	12,8

As I mentioned above, it was not a warm day. The first measurement was took beside the parking of the Architecture and Civil engineering building. The table above shows the results that we got there. The globe temperature took at least 5 minutes to get a stabilized temperature between 15º and 13º instead of almost 19º. The weather stations was kept inside the building where the temperature is 22º, so this is why during the first five minutes of the measurements the globe temperature had a higher temperature. The first measurement was in a place without any building around the weather station and where the wind was rather strong. Hence, the results for the wind speed were higher (between 1,78m/s to 4,03m/s). Let's see some more measurements to compare results.

Measurement 2:

- Water area
  From 13h08 to 13h19

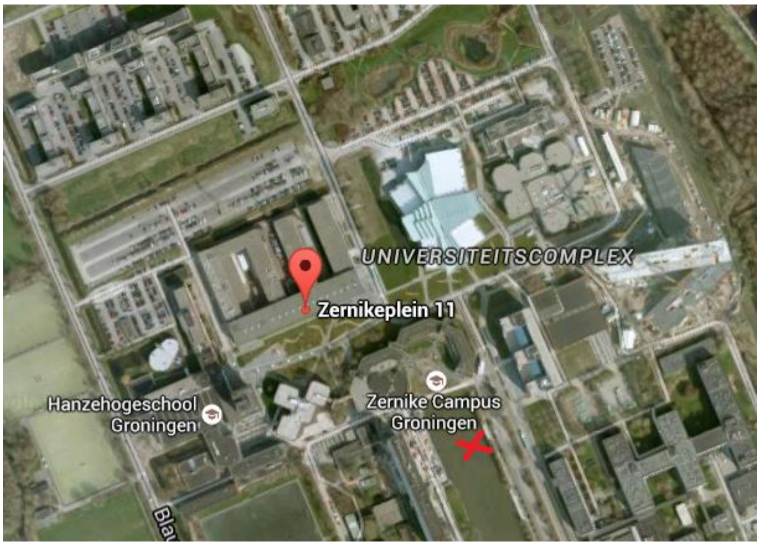


Figure 15 - Location of the second measurement in Zernike

Date	Time	Air temperature (ºC)	Humidity Out (%)	Wind Speed (m/s)	Raditation (W/m2)	Globe temperature (ºC)
30/04/2015	1:08 PM	10,0	54	1,78	53	11,1
30/04/2015	1:09 PM	9,9	54	5,36	53	11,1
30/04/2015	1:10 PM	9,8	55	4,03	49	10,6
30/04/2015	1:11 PM	9,8	55	5,80	54	10,6
30/04/2015	1:12 PM	9,7	55	4,92	69	10,0
30/04/2015	1:13 PM	9,5	56	4,03	98	10,0
30/04/2015	1:14 PM	9,4	57	2,69	139	10,0
30/04/2015	1:15 PM	9,3	58	2,22	165	10,0
30/04/2015	1:16 PM	9,2	59	3,58	172	10,0
30/04/2015	1:17 PM	9,2	58	4,47	160	10,0
30/04/2015	1:18 PM	9,1	59	2,69	139	10,0
30/04/2015	1:19 PM	9,2	60	2,22	125	10,0

On this measurement, we were located on the bridge from the pond. The wind at this moment was quite strong so the results were higher than before. The globe temperature took also 5 minutes to be stabilized at 10ºC. We made a measurement on the pond to have a higher humidity results but we got a lower humidity than the first measurement in the grass behind the parking. We were surprised about this fact because the idea of making a measurement near a water environment was to increase humidity's results. The explanation could be that in the first measurement, which was made quite early (11h00), the dew could influence to the humidity results. In addition, the plants contains water and transmitted it to the air by evapotranspiration. This morning it was raining, so when we made the first measurement, the grass was wet and consequently the atmosphere too.

<u>Measurement 3:</u>

- Between two buildings
  From 13h22 to 13h32
  (It starts raining at 13h28)

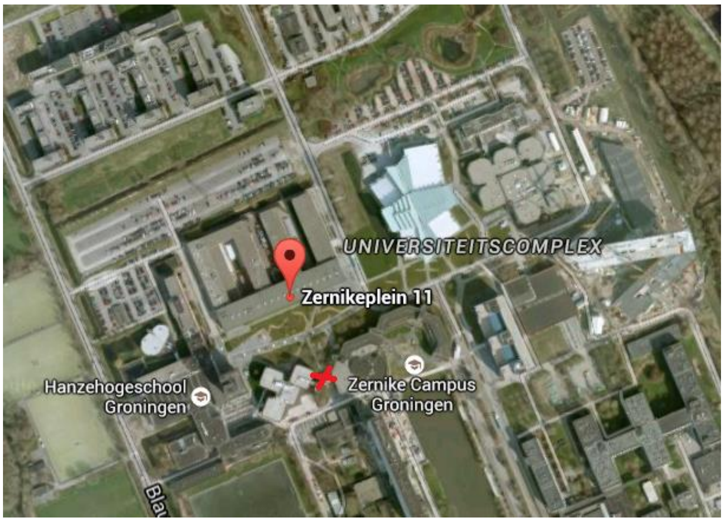


Figure 16 - Location of the third measurement in Zernike

Date	Time	Air temperature (ºC)	Humidity Out (%)	Wind Speed (m/s)	Raditation (W/m2)	Globe temperature (ºC)
30/04/2015	1:22 PM	9,3	59	1,33	49	10
30/04/2015	1:23 PM	9,3	59	0,89	25	10
30/04/2015	1:24 PM	9,4	58	1,33	18	10
30/04/2015	1:25 PM	9,4	58	1,78	16	10
30/04/2015	1:26 PM	9,4	57	2,69	16	10
30/04/2015	1:27 PM	9,4	58	3,14	16	10
30/04/2015	1:28 PM	9,4	59	2,69	16	9,4
30/04/2015	1:29 PM	9,3	59	1,78	16	9,4
30/04/2015	1:30 PM	9,3	59	2,22	16	9,4
30/04/2015	1:31 PM	9,4	59	1,33	16	9,4
30/04/2015	1:32 PM	9,4	59	1,78	18	9,4

This other measurement was took between two buildings because we wanted to see the wind speed results changing. This measurement was the one of the day which gets the lower results for this (between 0,89 to 3,14). Hence, for this measurement we get the expected results. The globe temperature get 6 minutes to be stabilized from 19ºC at the start to 9,40ºC.

7.2.2. Conclusions

After this measurements we learnt to not make some avoidable mistakes and tips for the final measurements in the Suikerbuurt area:

- Wait at least 20 minutes for each measurement to let the globe thermometer get a stabilized temperature. Generally, those measurements took between 5 and 6 minutes to achieve a stabilized temperature. This is important to achieve a valid mean radian temperature, due to the fact that the globe temperature results are going to be used in the formula explained.

- Dry the weather station after each measurement near a water environment to ensure reliable results on the following measurements.

- It is not because we make a measurement near a water environment that the humidity's results are going to be higher. There are other factors influencing those results such as the dew, the wind or the plant's evapotranspiration.

- The weather station was working well. We got the expected results except for the humidity, because we didn't thought about all the factors that could influence to the humidity's results. The temperature was the same as it was expected for this day, the wind speed was stronger at the locations where it was supposed to be, and the globe thermometer achieved a stabilized temperature at the end of each measurement.

7.3. Suikerbuurt area measurements

The day chosen to make the measurements in Suikerbuurt area was the 11th May 2015. We were observing the weather forecasts and we saw that on this day the temperatures were really higher (25º) comparing it with the following days. We were conscious that in summer the temperatures are going to increase more but we needed to make measurements with enough time to analyse results and to write this report before June. According to our measurements, we got the higher air temperature of the day about 25,3º at 15h50 on the sun. If we see in **Eelde Station Weather** the higher temperature of this day between 15h30 al 16h30 was 24,6ºC . There is not too much difference between our weather station data and the official data from Eelde (near Hoogkerk). It has to be mentioned that Eelde is situated in a rural location, so this fact can explain why the temperature there was lower than the measured one in Hoogkerk. Therefore, data shows that there is a little Urban Heat Island effect in the village. During summer, seeing other years, temperatures use to increase until 30ºC and studying the historical data from Groningen temperatures I found that since 1906 the higher temperature was on 23rd August 1944 with 36,8ºC, and then, the second one was on the 28th July 1911 with 35,5ºC *(Koninklijk Netherlands Meteorologisch Instituut. Ministerie van Infrastructuur en Milieu*). Hence, heat problems and people thermal comfort are going to be worst on July and on August. After making an analyses about our results, and knowing the temperature usually reached in summer, some conclusions can be taken for those sunny days coming, which are going to become warmer over the decades.

Before starting the measurements, we need to reflect about the sites where these measurements are going to be done. We need to get different results in order to compare them on the final analyses, so the locations have to meet different criteria. The aim is to know which places are providing more thermal comfort and which places are not thermally comfortable. For this we are going to use the Heat Map (Appendix 3 and Appendix 4) to know where the heat is higher and make some measurements there. The Appendix 1 shows the differences between the land use of the area (private gardens, factory area, shopping area…) and the Appendix 2 shows differences between surfaces (grass, water, paved, asphalt…). By analysing those 3 maps, we selected several different locations with different characteristics: on the sun, on the shade, on a water environment, on a green area, on the asphalt, where the heat is high, where the heat is low, etc.

Figure 17- Colours orange, light blue, green and grey represents measurements on a sunny locations. The rest of the colours (red, dark blue and violet) represents measurements made on the shade. (To see it better see Appendix 1 and 2)

On the picture from the left there are the following places where the measurements were performed:

The first location where we made the measurement was on the red point from the figure 17: the Albert Hein door (shade location). This place is located on the shopping area of Hoogkerk, where a lot of people use to go during the day. Albert Hein is the only supermarket in this area.

Degrees in the shade: 13ºC
Degrees in the sun: 30ºC

Figure 18 - Measurement 1 Suikerbuurt : Albert Heijn (shade)

The second measurement was made on the parking a lot from the supermarket, located in front of the sugar factory and with no shade (sunny location). It is a poor asphalt parking for many cars (60 more or less).
Degrees between 31ºC and 42ºC.

Figure 19 - Measurement 2 Suikerbuurt - Parking lot (sun)

After this measurement we went back to the shopping area, to a sunny place where people would be just passing over. We made the measurement in front of a children's shop (Famoda For Kids).

Degrees in the shade: 31ºC
Degrees in the sun: 38ºC

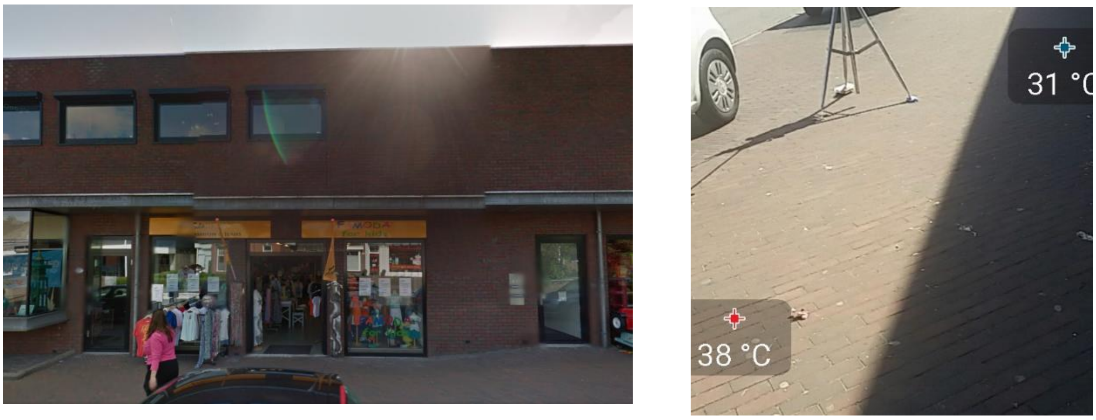


Figure 20 - Measurement 3 Suikerbuurt - Famoda For Kids (sun)

The following two measurements were made near the water environment. One of them was made under a tree to have shade, and the other one was made near some blue banks, with sun.

Figure 21 - Measurement 4 Suikerbuurt: Water environment (shade)

<u>*Under the tree*</u>

Degrees in the shade: 24ºC

Degrees in the sun: 37ºC

Figure 22 - Measurement 5 Suikerbuurt - Water environment (sun)

<u>*Near blue banks*</u>

Degrees in the shade: 27ºC

Degrees in the sun: 42ºC

The next measurement was made in a green area of the Suikerbuurt area. The sensation was good but there was any adult there, just three children were playing with their bikes.

Degrees in the shade: between 21ºC and 25ºC

Degrees in the sun: between 33ºC and 40ºC

Figure 23 - Measurement 6 Suikerbuurt - Green area (shade)

Finally, the last measurement was made very near from the Suikerbuurt green area of the last measurement, in a football field with any shade. Children prefer to play on the green area than in the playing field.

Degrees in the shade: 25ºC

Degrees in the sun: 36ºC

Figure 24 - Measurement 7 Suikerbuurt - Tennis Field (sun)

7.4. Questionnaires

7.4.1. How to perform a questionnaire

As I already explained before, in Chapter II: THEORETICAL REVIEW AND HYPOTHESIS DEVELOPMENT, exactly in the point 5.1.4, the questionnaires need to be done in the same location and at the same hour where the measurements were done. This is important because it allows us to know about the thermal comfort of the subjects that are going to be interviewed. Consequently, we can compare the questionnaires' results with the measurements' results, e.g. if someone reports feeling too warm in a place where the weather station indicates 25 degrees, we can imagine that this situation will be even warmer on a sunny summer day. So we can conclude that this person is not thermally comfortable because this specific location makes people feel too warm. So our next step is to study which are the factors from the environment that make people feel uncomfortable and try to change them by finding sustainable solutions.

We didn't made any questionnaires in Zernike because we had just made a few measurements there to adjust some weather station parameters, as at first it was something new for us and we needed to know how does it work before making the final and conclusive measurements in the Suikerbuurt area.

The questions from the questionnaires were thought and studied. We took an example from the article of "Urban climates" (*E. Johansson et al., 2014*), especially from the point 2.3, which was very useful for this research. This article explains and brings some tips for a good questionnaire. The most important thing is to design a coherent, orderly and meaningful questionnaire; it needs to be easy to fill, with short and concise questions, so people won't have to spend too much time answering all the questions. The questionnaires need to give information about the age, gender and the clothing of the subject. It is necessary to ask this general information because there are some personal factors, as the ones I have previously mentioned, that can affect the thermal comfort of a person.

People who are more affected by heat waves are usually old persons and children. Hence, the age is important to know, as it can influence the results of the reports. The clothing is important as well because it brings an information about how the subject could be feeling. Clothing is made with different materials and it has different colours which influence the weather's perception. In the same way that the grey ball needs to be grey because of reflective radiation from outside environments, the clothing can reflects as well and produce a person to feel different degrees of body heat. If a person wears a black sweater is not the same as if this person wears a white or a light blue sweater. Moreover, if a person is wearing shorts, we can imagine that this person considers that weather as warm, due to he has decided to put shorts to feel thermally comfortable. There are some studies such as the standard *ISO 9920 (2007)*, which specifies methods for estimating the thermal characteristics for clothing ensembles based on values for known attires and includes the influence of body movement, water vapour resistance and air penetration. But in this research we will just ask about basics terms as Jacket, sweater, shirt, t-shirt, pants, short pants or skirt.

There are some other several factors that can affect the thermal perception and this factors need to be asked in the questionnaires. I am referring to factors such as the physical activity of a person. It is not the same thermal sensation if someone is running as if someone is just standing, as the physical activity influences the body heat sensation. So in the questionnaire there are some scales to know the current activity of the subject. The scale consists of 4 levels: standing, sitting, walking and running.

The subjective perception of the thermal environment is something that needs to be taken into account. The subjective perception is a term which can be divided in five subjective judgement scale to describe the thermal state of someone *(ISO 10551 (1995))*. Those five terms are the following ones:

- Thermal perception
  How are you feeling now?
- Thermal comfort
  Do you find this environment comfortable, uncomfortable…?
- Thermal preference
  State how you prefer it to be now: cooler, warmer, neutral…
- Personal acceptability
  On a personal level, this environment is for me: acceptable, unacceptable…
- Personal tolerance
  How satisfied are you with the temperature in your space? Satisfied, dissatisfied…

Generally, those five dimensions are essential and need to be included in the questionnaire, as they provide helpful information. However, other studies made by *Nikolopoulou and Steemers (2003)*, *Nikolopoulou and Lykoudis (2006)* or the one by *Knez et al., (2009)*, have shown that it is also useful to ask about other factors from the subject, such as knowledge/experience, belief/preferences, attitude/expectations or thermal history. This is why I decided to include in the questionnaire the following questions to know about psychological mechanisms involved in thermal comfort assessment:

- Information about their home country and how long have they been in The Netherlands?

- To cover the thermal history, questions like this:
  - For how long are you at this specific location?
  - Where did you come from before being here?
  - Were you outdoors 5 minutes ago?

7.4.2. Suikerbuurt Questionnaires

The idea for those questionnaire, taking into account the best way to ask without making a very heavy questionnaire, was very ingrained in this project.

In this part, I needed people to fill the questionnaires, and unluckily it didn't depend on me, it was more about if the people around decided to complete them. Unfortunately, I could just obtain a total of 17 filled questionnaires at the end of the day, as not many people wanted or did have enough time to do it.

On the one hand, in some of the locations where measurements with the weather station were done, I couldn't find anybody who wanted to answer some questionnaires. This happened to me in places such as near the water environment or in the Suikerbuurt neighbourhood's green area. On the other hand, there were places where I could find more people disposed to answer the questionnaires, as in the shopping area. In some other points, I confronted a third situation, as in the tennis field and in the parking, where I could hardly find anybody but at least a few people answered some questionnaires. For exact locations see Appendix 1 and 2.

The results are going to be analysed in the next Chapter, **Data analysis and results.**

Chapter IV

DATA ANALYSIS AND RESULTS

8. Data analyses

8.1. Mean Radiant Temperature calculations (Tmrt)

Equation (1) (*From Thorsson et al., 2007*):

$$T_{mrt} = \left[(T_g + 273.15)^4 + \frac{1.335 \; x \; 10^8 Va^{0.71}}{\mathcal{E}D^{0.4}} (T_g - T_a)\right]^{1/4} - 273.15$$

The measurements were made with an interval between 21 and 22 minutes. Even though, the first five minutes are not included to get the Mean Radiant Temperature (Tmrt) average because those five minutes are the time estimated for the globe thermometer to get a stabilized temperature. By removing this five minutes we will get more reliable results from the last 16 or 17 minutes measured.

- Measurement 1: Albert Heijn door from 12h55 to 13h10
  Characteristics: Shade location, no trees, quite wind, sidewalk
  Average Tmrt = 25,8ºC

- Measurement 2: Parking a lot from 13h25 to 13h41
  Characteristics: Sunny location, no trees, strong wind, asphalt floor
  Average Tmrt = 64,54ºC

- Measurement 3: Famoda for Kids door from 13h58 to 14h13
  Characteristics: Sunny location, no trees, quite wind, sidewalk
  Average Tmrt = 58,07ºC

- Measurement 4: Tree water environment from 14h23 to 14h39
  Characteristics: Shade location, under a tree, quite wind, grass
  Average Tmrt = 33,30ºC

- Measurement 5: Water environment from 14h49 to 15h04
  Characteristics: Sunny location, no trees, no wind, sidewalk
  Average Tmrt = 60,85ºC

- Measurement 6: Suikerbuurt green area from 15h26 to 15h41
  Characteristics: Shade location, trees, quite wind, grass
  Average Tmrt = 32,98ºC

- Measurement 7: Tennis field from 15h50 to 16h05
  Characteristics: Sunny location, any trees, no wind, cement floor
  Average Tmrt = 61,27ºC

Note: To see detailed calculations see Appendix 6.
The grey tables are the ones of the 5 first minutes data removed to calculate the Tmrt average.

8.2. Graphs

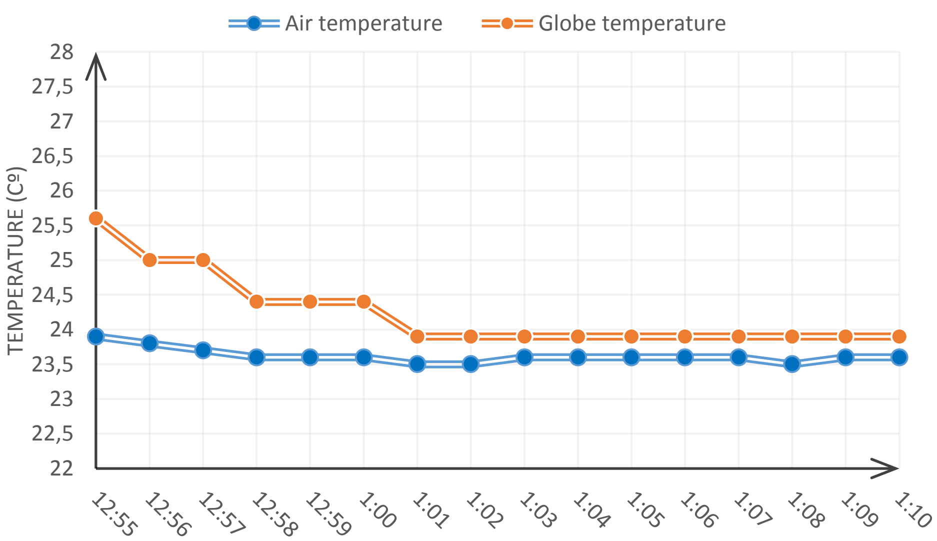
8.1.1. Location graphs

All the location will have their own table and their own graphs about the air temperature, the globe temperature, the wind speed, the humidity, the solar radiation and the mean radiant temperature from the 16 or 17 measured minutes. With those graphs the results are going to be better understood and more clear. As there are lot of tables and a lot of graphs, I just include in the report the table and the graphs from the first measurement (in Albert Heijn door), the rest of results are in the Appendix 8.

8.1.1.1. Measurement 1: Albert Heijn door (16 minutes)

Date	Time	Air Temp.	Out Hum.	Wind Speed	Hi Solar Rad.	Globe Temp.	Tmrt
05/11/2015	12:55 PM	23,6	45	0,4	33	25,6	30,32
05/11/2015	12:56 PM	23,5	44	0,4	32	25,0	28,58
05/11/2015	12:57 PM	23,5	44	0,4	33	25,0	28,58
05/11/2015	12:58 PM	23,6	44	0,4	33	24,4	26,34
05/11/2015	12:59 PM	23,6	44	0,4	33	24,4	26,34
05/11/2015	1:00 PM	23,6	44	0,4	33	24,4	26,34
05/11/2015	1:01 PM	23,6	44	0,4	33	23,9	24,63
05/11/2015	1:02 PM	23,6	44	0,4	33	23,9	24,63
05/11/2015	1:03 PM	23,5	44	0,4	32	23,9	24,88
05/11/2015	1:04 PM	23,6	44	0,4	30	23,9	24,63
05/11/2015	1:05 PM	23,6	44	0,4	28	23,9	24,63
05/11/2015	1:06 PM	23,6	44	0,4	28	23,9	24,63
05/11/2015	1:07 PM	23,5	45	0	28	23,9	23,90
05/11/2015	1:08 PM	23,5	45	0,4	26	23,9	24,88
05/11/2015	1:09 PM	23,6	44	0,4	28	23,9	24,63
05/11/2015	1:10 PM	23,5	44	0,4	28	23,9	24,88

a) Air temperature and Globe temperature graph



Temperatures are decreasing from the minute 5 to the minute 10 where the temperature achieved is 24ºC.

Figure 25- Air and Globe temperature graph

b) Humidity Out graph

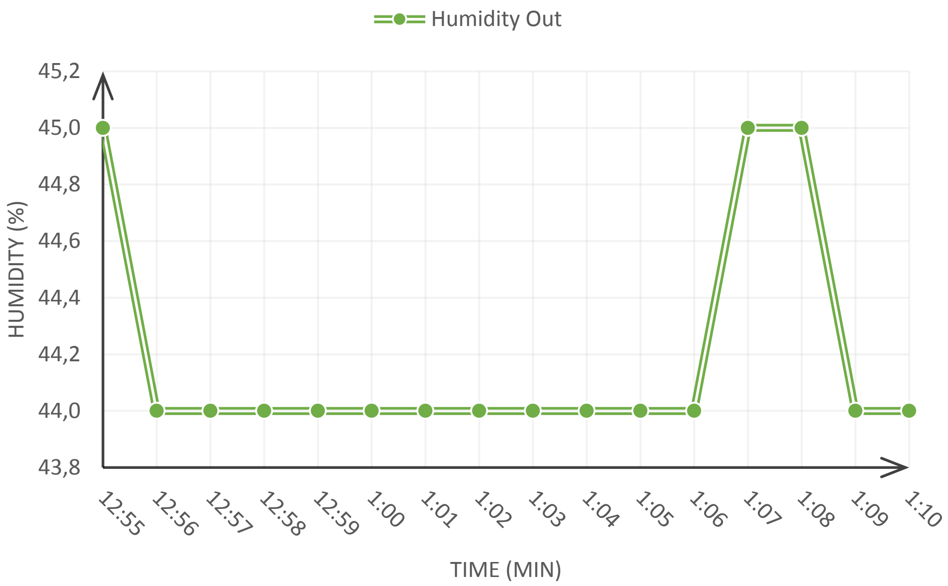


Figure 26 - Humidity graph

The humidity results are between 44 to 45%, comparing to the humidity from the green area (between 45 and 49) (see Appendix 8, point 8.1.1.6.), those results are lower results, implying that there is more existing humidity in green areas than in shade urban spaces.

c) Wind Speed graph

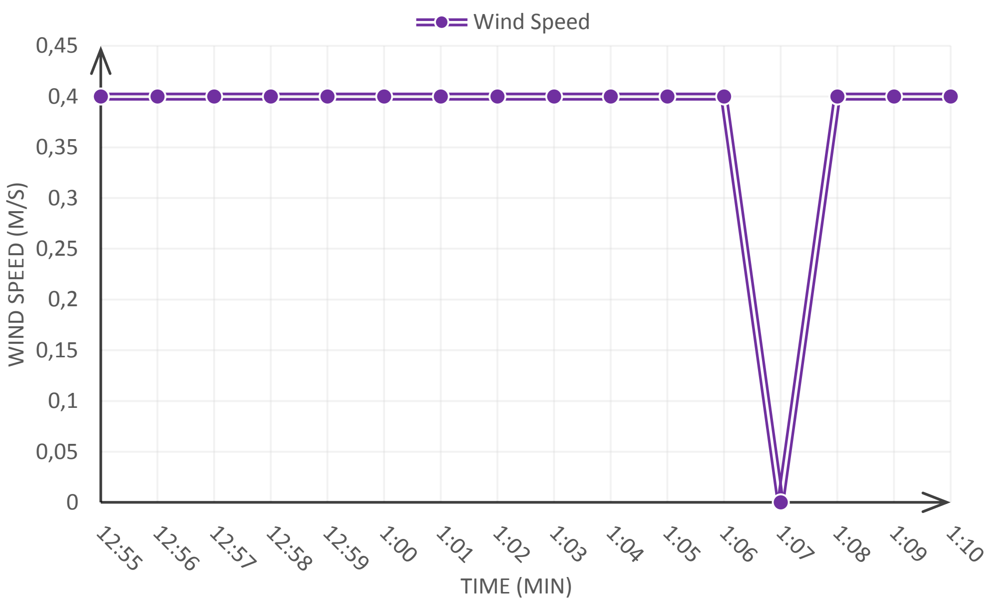


Figure 27- Wind speed graph

The wind speed is really constant, just a peak at 1:07 where the wind was null. In the final conclusion of those data, this poor wind would explain some facts which can be discussed after comparing all the data.

d) High Solar Radiation graph

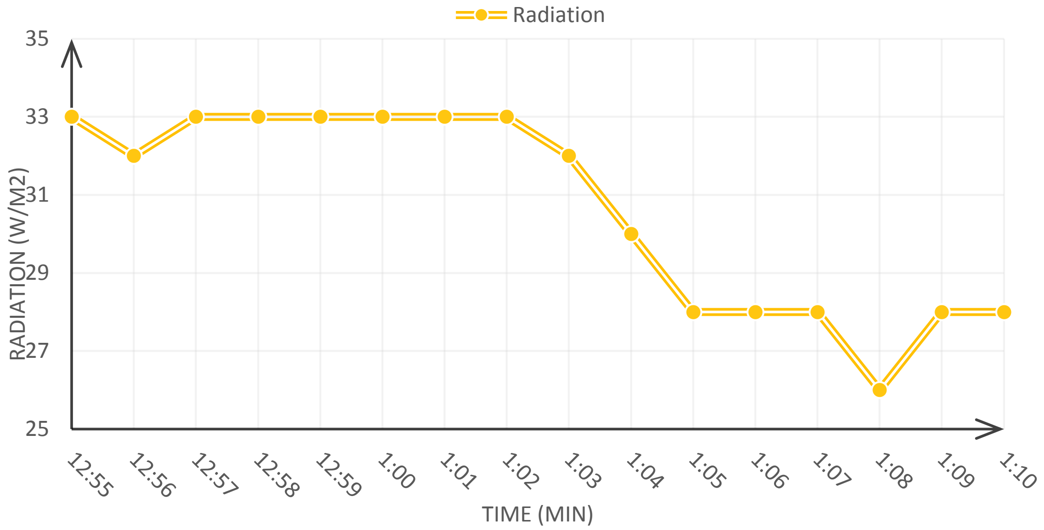


Figure 28 - Solar radiation graph

Naturally, the radiation results are lower due to the fact that this measurement was made in the sunny place. If this graph is compared to the one took in the parking lot (Appendix 8, point 8.1.1.2), we note clear differences between a sunny place and the shade.

e) Mean Radiant Temperature graph

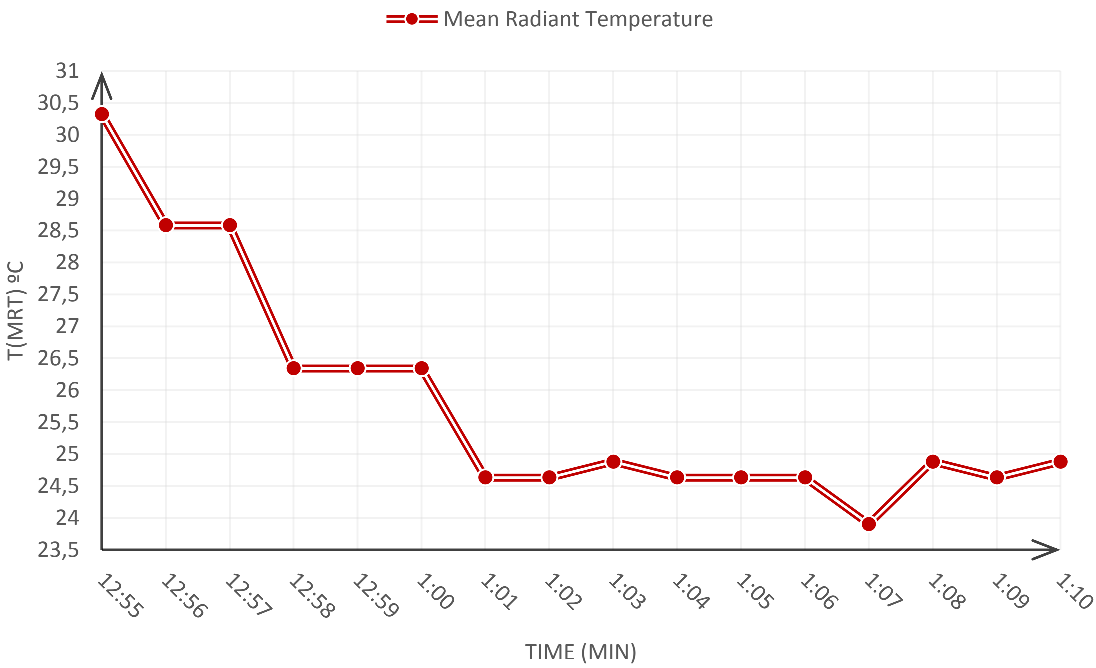


Figure 29 - Mean radiant temperature graph

The mean radiant temperature took many time to get a lower and stabilized results between 23,5ºC and 34,5ºC. To see what it means see point 8.2.2. where all the mean radiant temperatures are going to be analysed.

8.2.2. Unadjusted graphs comparisons

Even if the following graphs may not be the ideal to compare measurements results, there is these three graphs including all the different results for the air temperature, the globe temperature and the mean radiant temperature of each location. I said that it is not the ideal because the measurements were made at different range of time so the outcomes are not too comparable. Even though, it is necessary to show this to compare it to the adjusted graphs of the following point (8.2.3). Besides, this is the exact results from our measurements and some conclusions could be made about differences results between some locations.

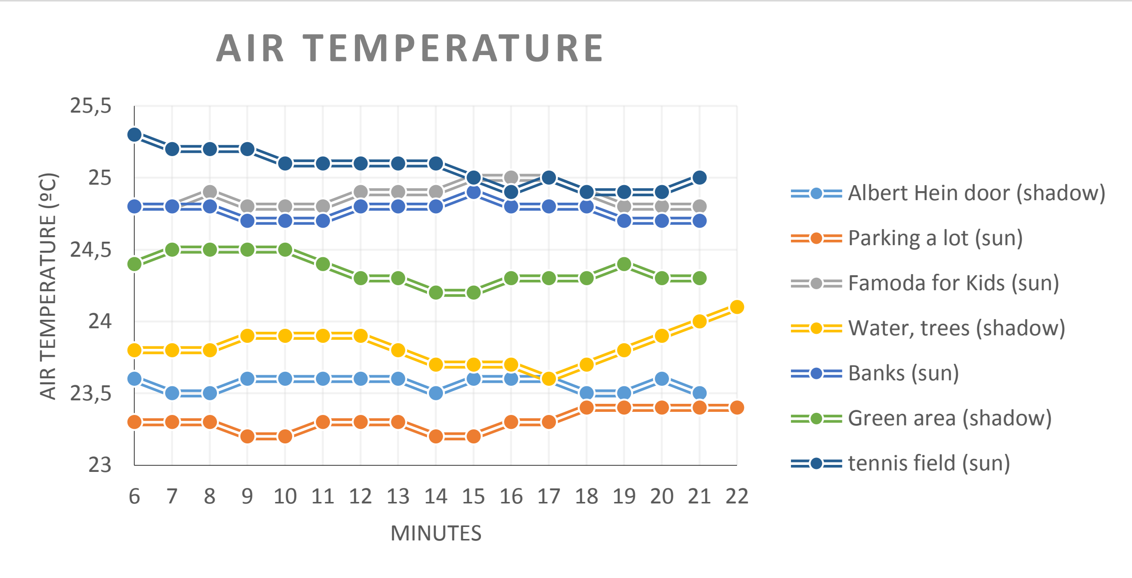


Figure 30 - Air temperatures graphs - Unadjusted comparison

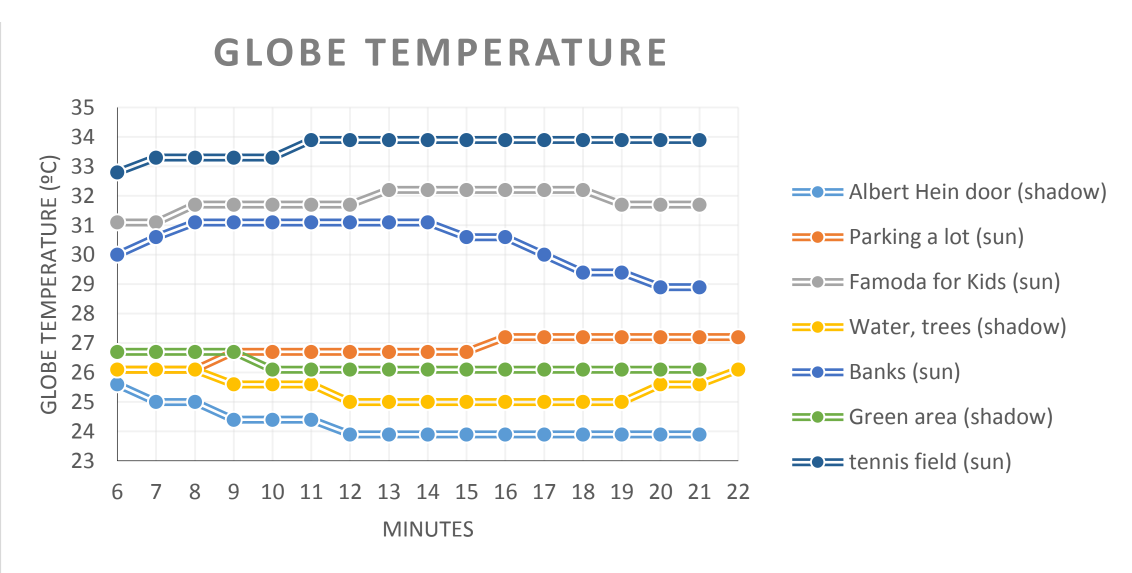


Figure 31 - Globe temperatures graph - Unadjusted comparison

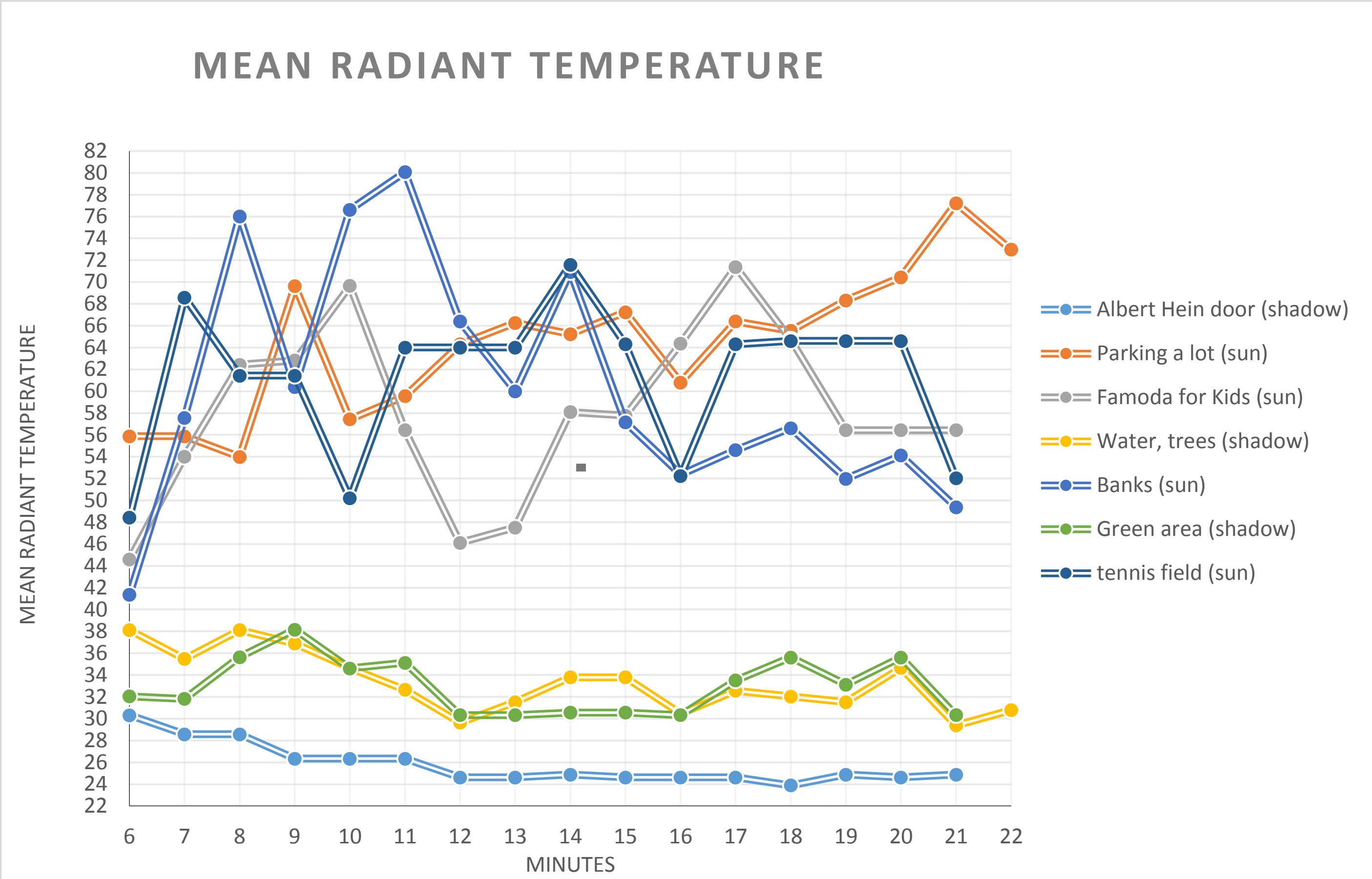


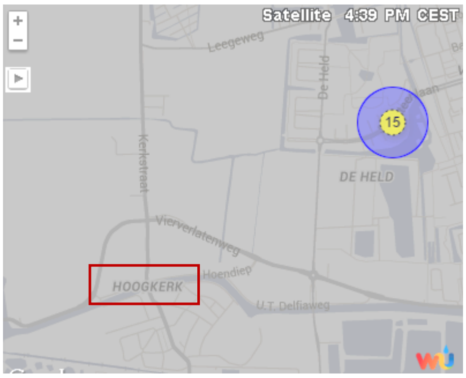
Figure 32 - Mean radiant temperatures graph - Unadjusted comparison

The air temperature graph shows that the higher recorded temperature was in the tennis field. This has a double justification due to the fact that this measurement was made in a sunny location and during the warmer moment of the day. By contrast, the lower temperature was taken in the parking lot. At the time were this second temperature was measured, the temperature was quite high but the wind was really strong (See appendix 8. Point 8.1.1.2) so wind makes temperatures to go down.

The globe temperatures graphs shows the same result for the higher temperature, i.e. in the tennis field; but the lower globe temperature was measured in the water environment, near the banks. This is not an expected result because this location is totally exposed to the sun so this is why an adjusted comparison is necessary.

Mean radiant temperatures results are more realistic even if there is not an adjusted calculation yet. This means that the other factors need to be considered for the final analysis due to they are influencing the final mean radiant results. Therefore, it could be stated that temperatures are not the only relevant to get the thermal comfort results.

8.2.2. Adjusted graphs comparisons



The following graphs depict the comparisons between the results obtained for each location using different climate factors involved in the thermal comfort analyses. As we didn't have enough resources to use 7 weather stations to make all the measurements at the same time, the results are less valid than the ones we desires. We couldn't get data for each factor at the same time in the different locations so, what we decided to do was to look for temperatures for the whole day which on the website are called "Weather Underground". This gives information about the air temperature during a whole selected day. First, it is necessary to choose the closer existing satellite from the place where measurements are done. As it is shown in the picture on the right, we selected satellite number 15. The next step is to introduce 11th May 2015 as the date that will be used. This is what I got from the web for the whole day:

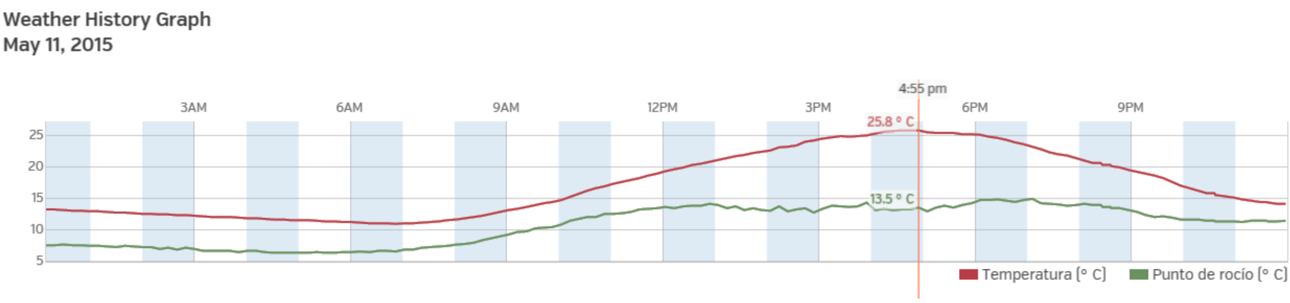


Figure 33 - Maximum temperature of the day from official weather underground website

This chart shows all the temperatures recorded during 11th May 2015. As I mentioned above, the higher temperature measured with the weather station was in the tennis field between 15h50 and 16h05 so, with this chart's data I firstly converted all the data from the other locations to get an approximate temperature on each location at this same range of time. For example, with the satellite, between 12h55 and 13h10, the recorder temperature was 21,1ºC and the temperature recorder at 15h50 was 25,0ºC. The difference between both recorded temperatures is 3,9ºC. Thus with my own data I increased the air temperature measured between 12h55 and 13h10 (Albert Heijn door) which was about 3,9ºC. I did the same for all the locations, increasing the parking lot to a difference of 3.3ºC, the Famoda shop door in 2.4ºC, the water environment, under the tree, in 1.6º, the other water environment in 0.8ºC, the green area in 0.2ºC and the last one wasn't increased at all because it is the reference time. With these data I made a graph with all the different temperatures estimated measures for each location at the same time.

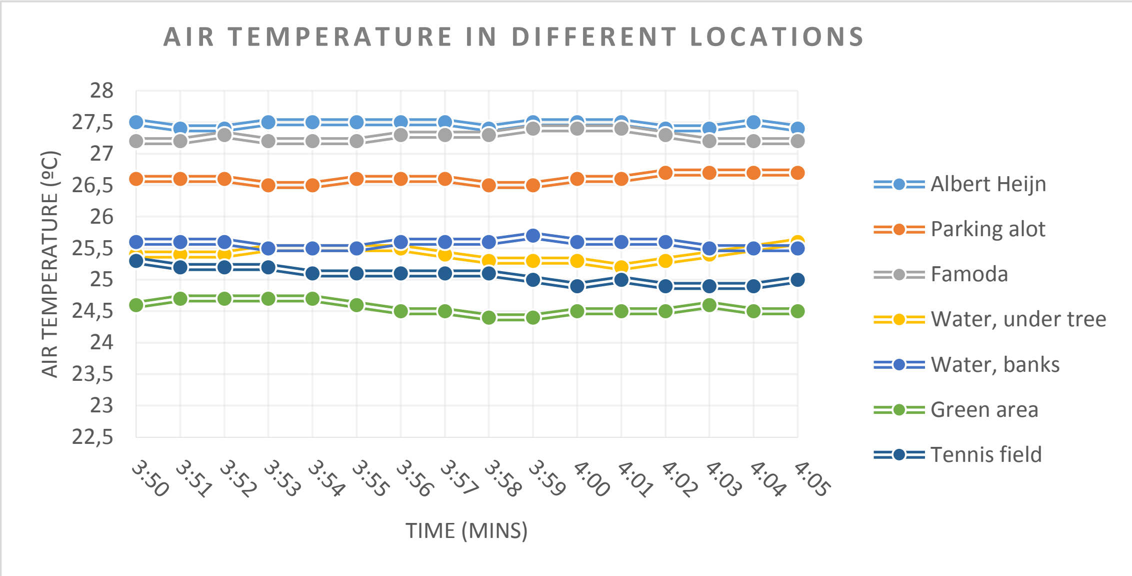


Figure 34 - Air temperatures graph - Adjusted comparison

Between 15h50 and 16h05, the higher temperature recorded in the Suikerbuurt area was was at Albert Heijn location and the lower temperature was at the green area with a difference between them of 3ºC.

Secondly, as the most important to compare at the same location in the warmer moment of the day is the mean radiant temperature, the calculations to get this need to be done again with those new air temperature data. The problem now is that in order to make the formula work it is strictly necessary that the globe temperature is higher than the air temperature so we need to increase the globe temperature as well. What I did was calculate the percentage of increasing temperature from the first air temperature to the adjusted air temperature and apply it to the globe temperature. For example, for the first measurement in Albert Heijn, I increased the temperature about 3,9ºC for the 16 measured minutes, that is to increase the temperature in 16%. Therefore I increased each globe temperature in 16% for this location. For the other locations I increased 14%, 9,5%, 6,7%, 3,2% and 0,8% according to the same rule. The following graph represents the globe temperatures in each location between 15h50 to 16h05.

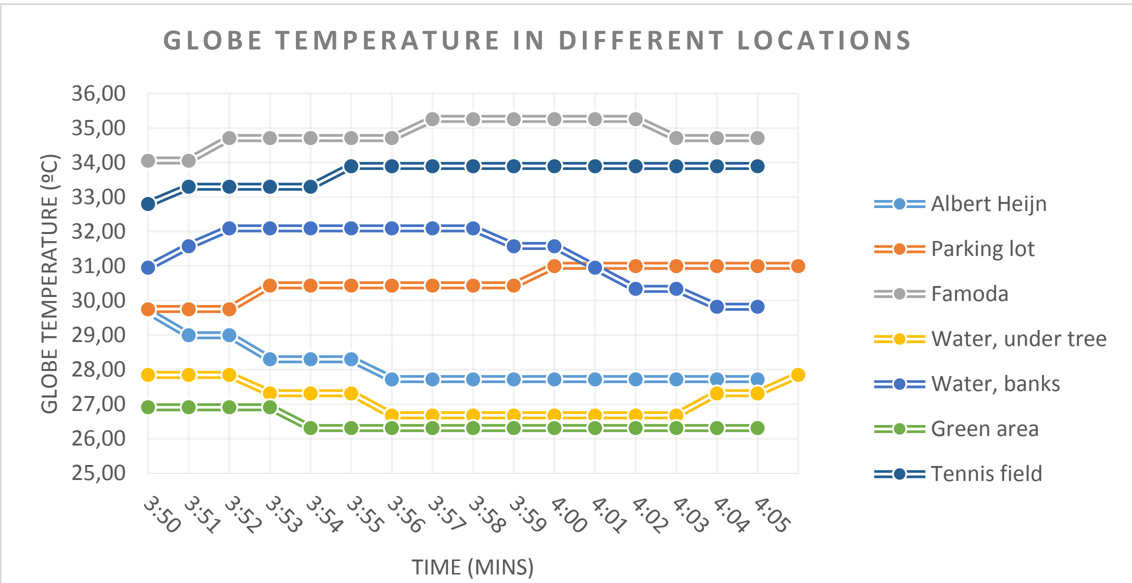


Figure 35 - Globe temperatures graph - Adjusted comparison

In the graph above about the globe temperature between 15h50 and 16h05, the higher temperature is recorded for the Famoda for Kids, in the shopping area; and the lower temperature still being in the green area. The difference between the higher and the lower temperature is of 9ºC.

Now that we have both temperatures approximately estimated for the Suikerbuurt area at the warmer time of the day, a new calculation was made to get the mean radiant temperature for each location at this time. This is the graph obtained:

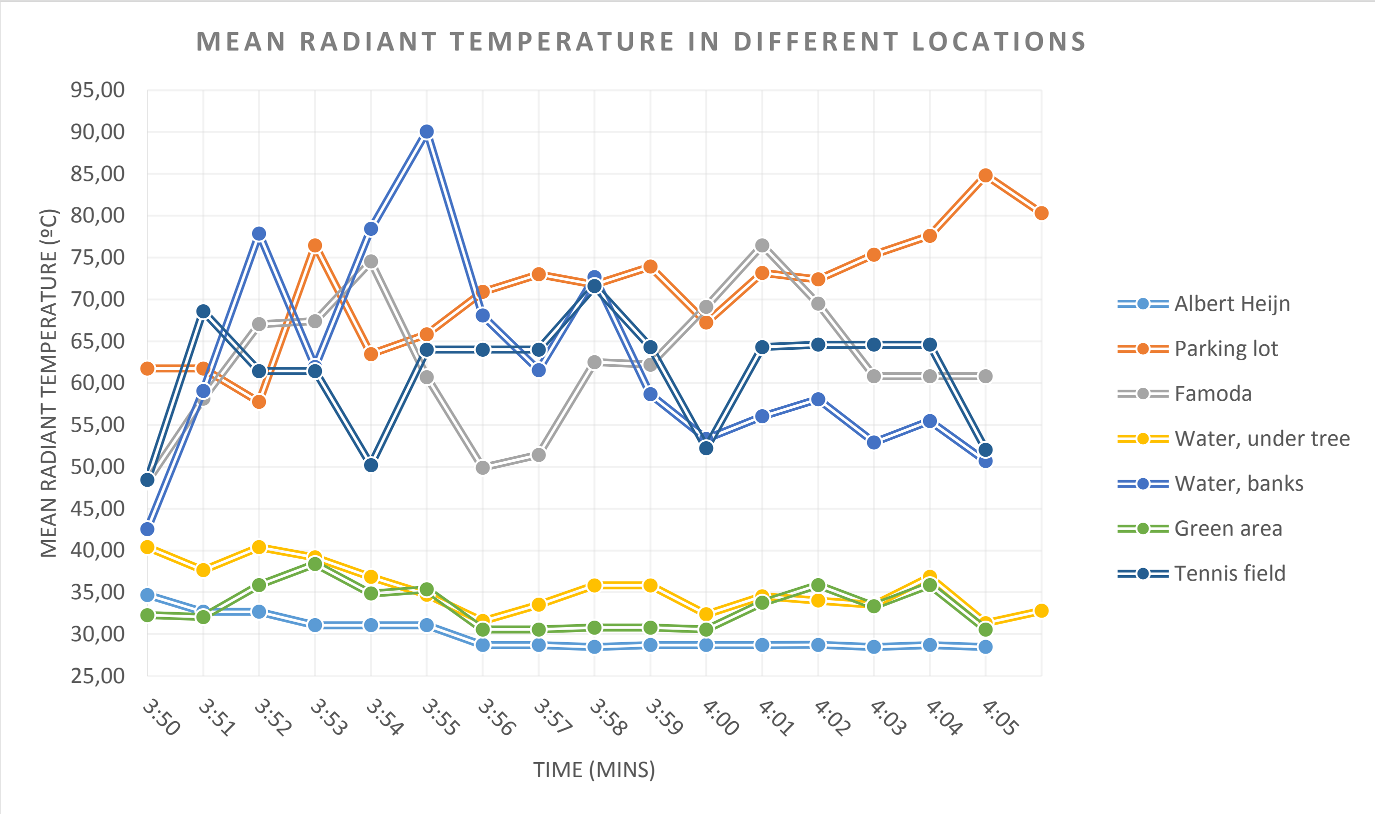


Figure 36 - Mean radiant temperatures graph - Adjusted comparison

The optimal mean radiant temperature is obtained when the lower results are achieved so according to this chart the better results were in the Albert Heijn, green area and water (under a tree) environment. The worst results, (with a significant difference) are in the other locations, being the worst of all in the water (near banks) environment and in the parking lot.

These results are according to the Hypothesis development (Point 6 of this report) since the thermal comfort is worst in sunny places than in shade locations as it was expected.

8.3. Results analyses

8.3.1. Measurements

All these graphs represent the results of the measurements made during May 11th. In the first point (8.2.1. Locations' graphs, see Appendix 8), each weather parameter has its own graph for each different location. In the second point (8.2.2. Graph's comparisons), all the graphs represent the differences between air temperature, globe temperature and mean radiant temperature on the seven different locations and at the same range of time. I didn't make comparisons between all the climate's factors results because this comparison would not be entirely valid due to the fact that the measurement of each location was made at different times. However, I made some comparison between the three factors that could be adjusted later to see differences between both results. The adjusted graphs shows more expected and more logical results than the unadjusted ones so this is why it is important to measure in the same range of time.

As we can see in the first adjusted graph about the air temperature, the higher estimated temperature was found at the Albert Heijn door (27,5ºC) and the lower temperature was in the green area (24,4º). Those results were not expected because the Albert Heijn door was a shade location where temperatures should be lower than the obtained. Nevertheless, we must keep in mind that Albert Heijn is located in an urban area, exactly on a shopping area, where temperatures are higher than the ones in a rural area. The presence of the shade is what makes the mean radiant temperature be lower. This is an evidence about how the shade can improve the thermal comfort of an urban location. Besides, the parking lot got too much lower temperatures and therefore the results for this location weren't the expected either. However, there is an explanation about why temperatures were so low in the asphalt parking if the measurements were taken in the sun. If we take a look to the wind speed graph (Appendix 8, point 8.1.1.2)), we realize that in the parking lot the wind was really strong compared to other wind speed results from the rest of locations. The wind speed is an important and relevant factor that needs to be strongly considered due to the fact that it can reduce temperatures. This is what happened in the parking lot, where the strong wind speed influenced the final outcome and the temperature was lower than the expected one.

Regarding the adjusted globe temperature measurement graph, the four higher results were measured in sunny locations: in the shopping area (Famoda), in the tennis field, in the blue banks near the water environment and in the parking lot, respectively. As we explained just above, the wind can influence results so this can explain why the parking lot is the last classified of those four measurements. Within the other three locations, the one having the lower temperature is the one being near the water environment; so the water could be a factor which can decrease the temperature some degrees.

The higher results for humidity (See appendix 8) were taken in the green area, so the results in the green area are even higher than the results obtained near a water environment such as the waterway. This fact implies that the green area gives humidity to the atmosphere because of plants evapotranspiration. This confirms the conclusion made during Zernike's measurements where the grass' humidity results were higher than the humidity results of the bridge from the pond. To understand it better it could be interesting to take an eye on the humidity's unadjusted graph due to the fact that the humidity is not going to change as much as temperatures and a this comparison would give clearest results.

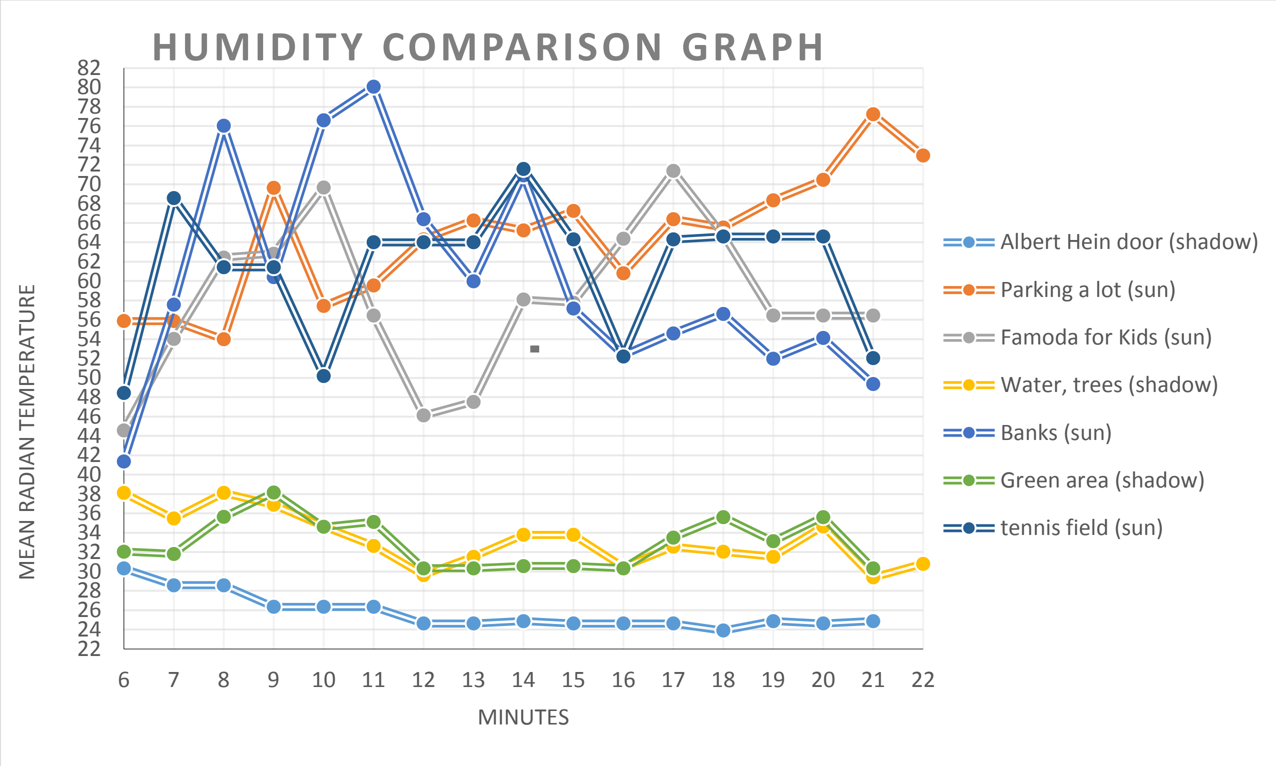


Figure 37 - Unadjusted Humidity graph

About the Radiation graph, it was clear that the higher results would be taken on sunny locations whilst the lower results were taken on shade places, as shows the radiation's graphs from the Appendix 8.

The mean radiant temperature is better when the results are lower, so according to the graph (figure 36) and in the following order, the better locations are the Albert Heijn door, the Suikerbuurt green area and the water environment (under the tree). Even strong wind can't make a sunny place be thermally comfortable as we can see in this conclusive graph where the parking lot has the higher mean radiant temperature results along with those from banks of the water environment.

8.3.2. Questionnaires

About the questionnaire, there is not too much to say. All the interviews are going to be included in the Appendix 7. Even though, there is one aspect that needs to be mentioned. All the people interviewed were answering to the activity question as they were walking or passing over except one person. There was a man sat under the tree, near the waterway, where the fourth measurement was taken and he told us that he used to go to this point and stay there three hour per day (when the weather is good) because he felt relax there. He didn't even wanted to answer if he was sat, walking, standing or running, he just wrote in the questionnaire that he was relaxed. The rest of the people just answered that they were feeling good and comfortable. Almost all of them said that they didn't wanted to be warmer or cooler. So from this experiences, people felt at ease.

8.3.3. Both results analyses

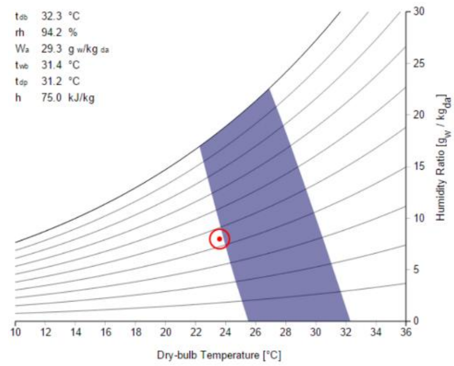
To make a conclusion including both experiences (measurements and questionnaires), there is a website *"CBE Thermal Comfort Tool"* which can calculates the thermal sensation using data from the measurements and from the subjects answers.

On one hand what we need to do is calculate the average of some measurement's data from each location. Specifically, we need the air temperature average, the wind speed average, the humidity average and the mean radiant temperature average. On the other hand, what we need from the questionnaires is information about clothing and about the activity level of the subjects (metabolic rate). With all this data we can get the thermal sensation or the thermal comfort of people interviewed. As I already mentioned before, it was hardly to find people in each location where the measurements were done so we just have information about the 5 following places:

A) The Albert Heijn door

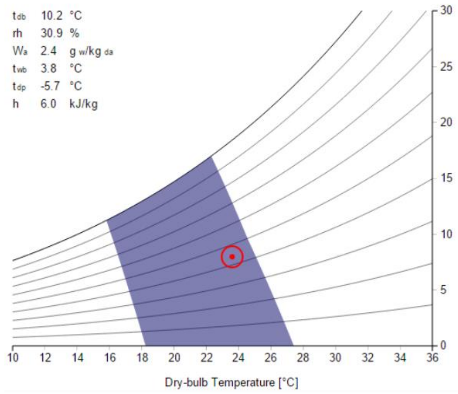
❖ Average Air temperature: 23.56ºC
Average Mean radiant temperature: 25.80ºC
Average Wind speed: 0.37 m/s
Average Humidity: 44.19%
Activity: Standing
Clothing: trousers, short-sleeve t-shirt, socks, shoes

Results:
PMV: -0.55
Sensation: Slightly cool
SET: 23.4ºC



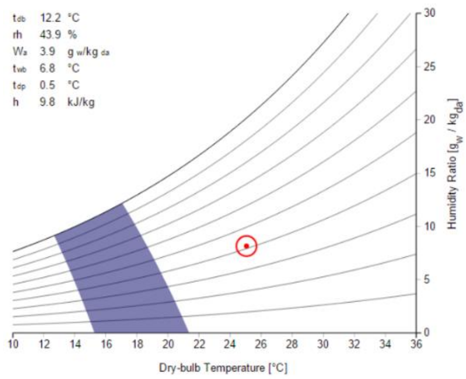
❖ Average Air temperature: 23.56ºC
Average Mean radiant temperature: 25.80ºC
Average Wind speed: 0.37 m/s
Average Humidity: 44.19%
Activity: Walking
Clothing: trousers, short-sleeve t-shirt, socks, shoes

Results:
PMV: 0.34
Sensation: Neutral
SET: 27.0ºC



❖ Average Air temperature: 23.56ºC
Average Mean radiant temperature: 25.80ºC
Average Wind speed: 0.37 m/s
Average Humidity: 44.19%
Activity: Cycling
Clothing: trousers, short-sleeve t-shirt, socks, shoes

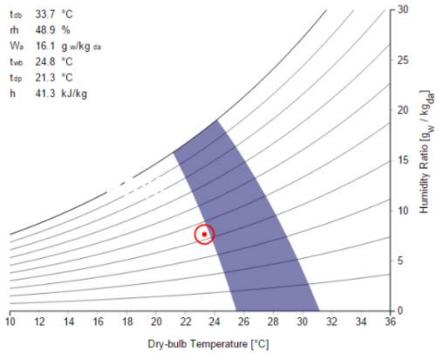
Results:
PMV: 1.24
Sensation: Warm
SET: 31.6ºC



B) Parking a lot

- Average Air temperature: 23.30ºC
  Average Mean radiant temperature: 64.53ºC
  Average Wind speed: 4.39 m/s
  Average Humidity: 42.94%
  Activity: Walking
  Clothing: trousers, short-sleeve t-shirt, socks, shoes

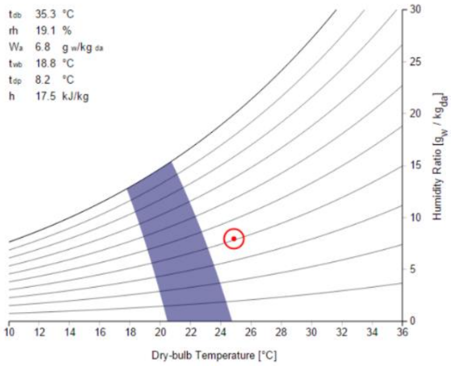
  Results:
  PMV: -0.57
  Sensation: Slightly cool
  SET: 28.6ºC



C) Famoda for Kids (shopping area)

❖ Average Air temperature: 24.87ºC
  Average Mean radiant temperature: 58.07ºC
  Average Wind speed: 1.02 m/s
  Average Humidity: 40.62%
  Activity: Standing
  Clothing: trousers, short-sleeve t-shirt, socks, shoes

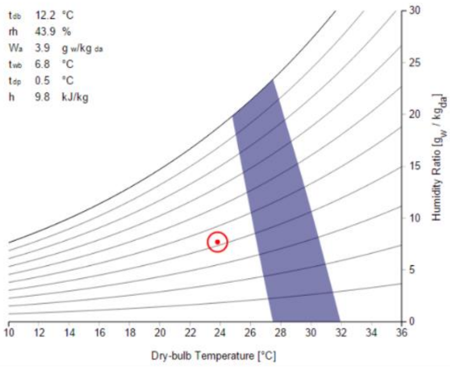
  Results:
  PMV: 0.98
  Sensation: Slightly warm
  SET: 31,8ºC



D) Water environment (under a tree)

❖ Average Air temperature: 23.82ºC
  Average Mean radiant temperature: 33.30ºC
  Average Wind speed: 1.19 m/s
  Average Humidity: 41.88%
  Activity: Sitting and relax
  Clothing: trousers, short-sleeve t-shirt, socks, shoes

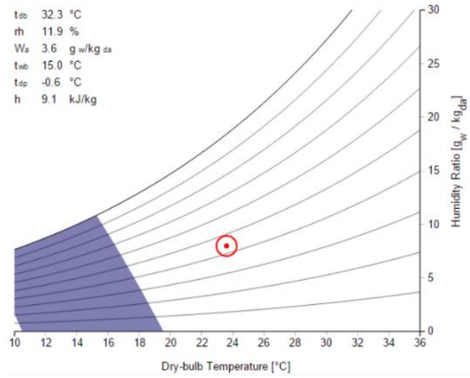
  Results:
  PMV: -1.32ºC
  Sensation: Slightly cool
  SET: 23.0ºC



E) <u>Tennis field</u>

- Average Air temperature: 25.06ºC
  Average Mean radiant temperature: 61.27ºC
  Average Wind speed: 0.82 m/s
  Average Humidity: 41.19%
  Activity: Waking around
  Clothing: skirt, short-sleeve t-shirt, socks, shoes

  Results:
  PMV: 1.58ºC
  Sensation: Warm
  SET: 34.2ºC



Note: In those Psychrometric charts the abscissa is the dry-bulb temperature, and the mean radiant temperature (MRT) is fixed, controlled by the input-box. Each point on the chart has the same MRT, which defines the comfort zone boundary.

The blue area represents where the thermal comfort for each location is, and the red point represents the subject’s sensation of each situation. According to those graphs we just have a result within a person feel in thermal comfort: the person **walking** around the **Albert Heijn door** between **12h50 and 13h10**.

9. Discussion

Suikerbuurt is a neighborhood located at Hoogkerk, a village in the West of Groningen, in a semi-urban environment. I chose this place because I found it was an interesting area where people were involved with their life's quality conditions. Neighbours are aware about problems from their own homes and they are constantly worried about their natural troubles such as humidity, mold and others problems related to their houses. They created a group called "Healthy Hoogkerk" to work together and fight against these issues but the limited economic means of the people living and working there made it difficult for them to come up with solutions and implement them. I would like to make a research about heat problems and people's thermal comfort because I would like to help this neighborhood to get a better livability. Even though, for the discussion I want to enlarge the scope of the problem and even aggravate it taking a look to an urban area such as Groningen's city center, regardless the weather is always warmer than in a rural area.

In order to do this, by looking at the "weather underground" website and introducing the same date as the one followed in the study in the Suikerbuurt area, i.e. the 11th May 2015, we can know the exact temperature during this day in Groningen. We need to choose the closer satellite within the city and study its results.

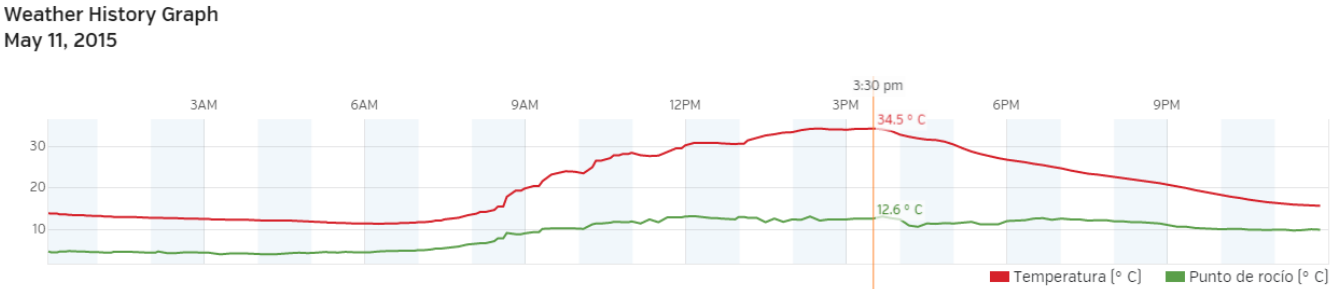


Figure 38 - Higher temperature in Groningen

According to this chart, the higher temperature of the day was 34.5ºC which compared to the higher temperature estimated in Hoogkerk (27,5ºC) is a difference of 7ºC, which is a considerable difference (these are data from amateur weather stations and the accuracy of the measurements cannot be guaranteed). This serves as an example about how urban areas make temperatures go up and how rural areas temperatures are never higher than those in the cities. The climate effect of the cities can intensify the thermal stress of the residents, especially during the summer were the heat waves are more pronounced. This phenomenon is called the "island heat effect". As we realized in this research, the wind is an important factor that can make temperatures go down or just find a better thermal sensation in a sunny place. The problem is that in the cities, there are many factors keeping off the wind blow, I am referring to high buildings, narrow streets… Besides, in cities there are not many green spaces and even if there are green spaces there are located in limited and smaller areas. Green areas are important to make temperatures go down due to the presence of dew during the morning, the humidity in the air as a result of plants evapotranspiration and the shade produced by trees. Humidity, radiation, wind speed and all the factors studied in this research are relevant for the final thermal comfort results. It is essential to include shade, water and green spaces in urban areas to achieve a higher thermal comfort for inhabitants during strong heat waves, and it is important as well to find a balance between the rural and the urban areas.

If we take a look to the Appendix 9 which is the Heat Map with adjusted air temperatures (black) and adjusted mean radiant temperature (red), it can be stated that results which show where a model does not match reality. In these map, temperatures measured are wrote down in the exact points where measurements were done. The aim to point both temperatures (meant radiant temperature and air temperature) is to know with which data this map is more accurate. As we can see, heat map is not very related with thermal comfort results; it is more related to air temperature. As I have demonstrated in the analysis, thermal comfort (mean radiant temperature) is very dependent on being in the shade. If you are by water or in a park and not in the shade then the Tmrt is still high (see map, point in water environment, near banks (62,3ºC) compared to shade in Albert Heijn Tmrt (29.9ºC)). Besides, in the parking lot, the air temperature was lower as the expected one but in the heat map the parking has the most intensive orange colour. This is translated as the air temperature doesn't take into account the wind factor as the mean radiant temperature does. If the heat map would be influenced by Tmrt, the parking area wouldn't be so orange. The higher air temperatures are related with the most intensive colours of the map whilst the mean radiant temperature is not reliable with the heat map colours. So heat map is based in air temperatures.

Our studied data predicts that if bigger cities' urban design don't change at all, the extreme heat waves, occurring more frequently and with a higher intensity due to the global warming, will increase the inhabitant's heat stress compared to their surrounding rural area. To show how temperature is increasing in the past decades I made a graph about maximum and minimum temperatures since 1970 to 2014 in Groningen. (Elde)

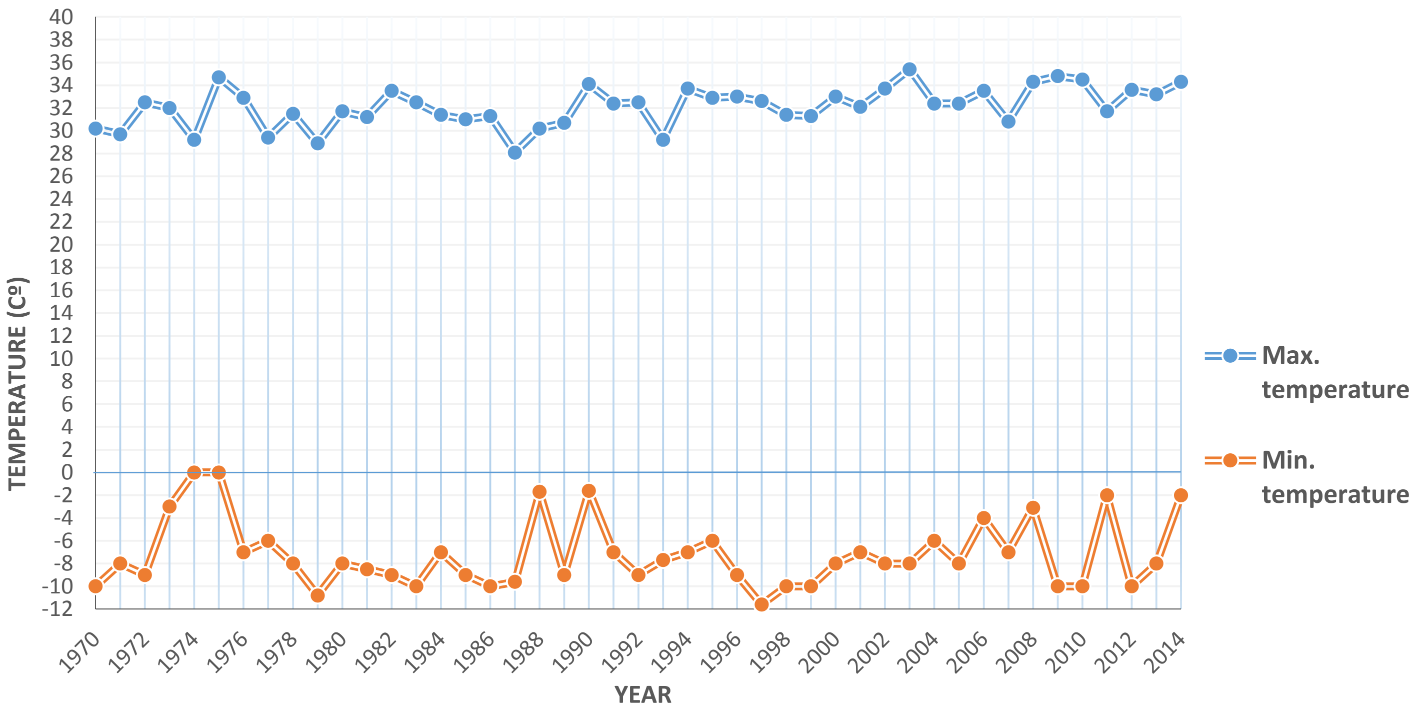


Figure 39 - Extreme temperatures in Groningen from 1970 to 2014. Source: Eelde KMNI official website

The charts shows how over the years the maximum temperature is becoming higher. Even if there are some higher temperatures during the 70's or 80's, it is important to highlight that the results as a whole; we can observe how the blue line representing the maximum temperature of each year is increasing. In contrast, there is not a clear evolution for the minimum temperatures of each year which are represented by the red line. Maybe a study about cold waves during the winter should be carried out to discover climate change's impact during the winter period.

Chapter V

NEW CONCEPT DESIGN

10. Design descriptions

After the research, the analysis, the remarks and conclusion what is clear is that there are some problems in the Suikerbuurt area linked with thermal comfort and climate conditions that require to be fixed to create a sustainable neighborhood for the future. Some existing aspects are in need to be treated urgently, such as the parking lot where the heat temperature is really high and the wind speed is extremely strong.

On the other hand, the floods from the rain water and storms are another annoying problem of the neighborhood. My fellow student Wangi Kusuma is making a research about those problems in the area so she, my other fellow student Catra Raditya, who is studying the thermal comfort too, and I were designing a new concept design for this quarter. The main changes are the following ones:

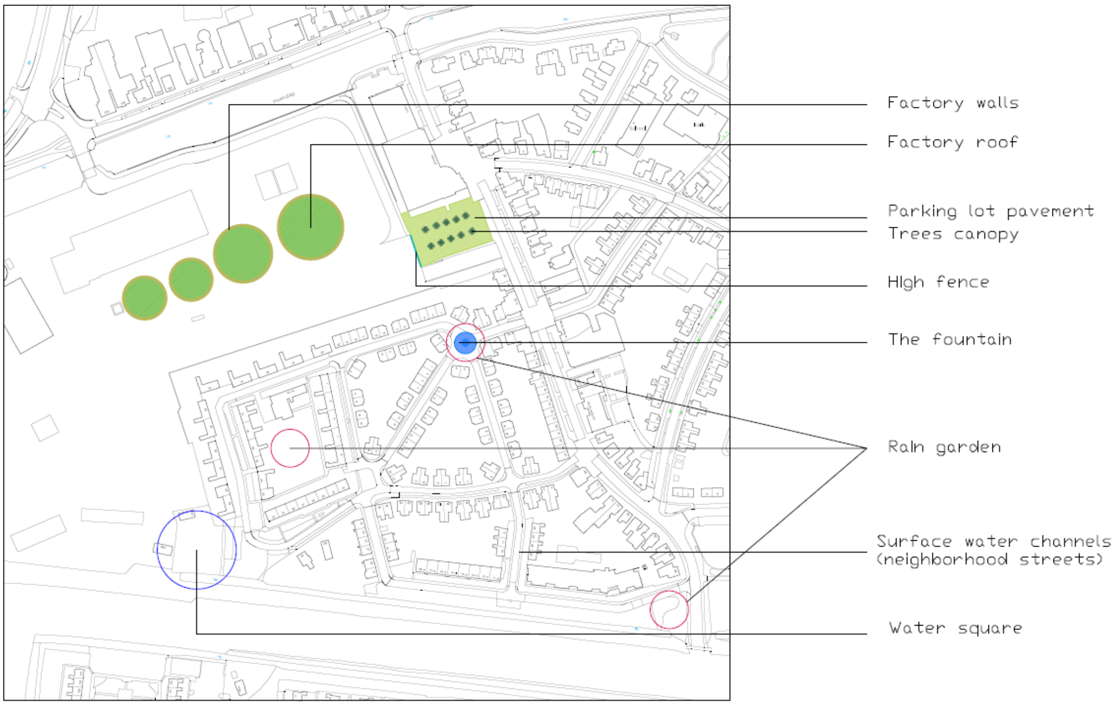


Figure 40 - New concept design map

In the following paragraphs, all these changes are going to be described in detail, explaining and justifying the advantages of each improvement and the rationalization of our choices.

1. <u>Green high fence</u>
   Install a high green fence between the parking lot and the sugar factory area instead of the existing one which is ugly and where the wind can easily pass through producing the high results measured and analysed in **Chapter III**. Even if the wind can improve a bit the air temperature, at the en, the thermal comfort wasn't good. The new fence could be something like the picture below, which shows the idea of a steel fence with a lot of vegetation. The picture shows a not too much high fence but our idea is to get a high one to interfere with the ugly view from the sugar factory.

   Reasons and advantages explaining our choice:
   - ✓ A high fence can brake the wind coming from or going to the sugar factory.
   - ✓ The vegetation can help to decrease temperatures in the parking.
   - ✓ This element can reduce the noise coming from the factory trucks.
   - ✓ Beautiful solution to give a better appearance to the parking lot.
   - ✓ Increase the thermal temperature by decreasing the wind speed and increasing shadow due to the height of the fence

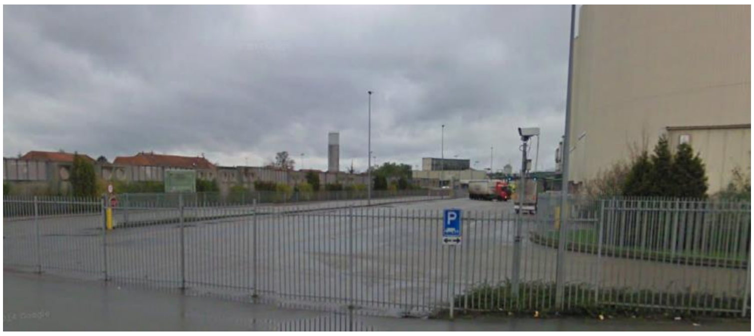


Figure 41 - Currently fence in Suikerbuurt

Figure 42 - New high fence

2. <u>Fountain</u>
   Installs a fountain within the neighborhood, exactly where the tree was cut some months ago.

   Reasons to put a fountain in the neighborhood:
   - ✓ Create a space for neighbours to stay on a warm day near a water environment.
   - ✓ Use groundwater as a storage to provide water fountain, helping to avoid floods in the neighborhood.
   - ✓ Beautiful space within the neighbourhood, with plants and banks, improving the area livability and making a more attractive space to stay.

Figure 44 - Currently Suikerbuurt neighborhood

Figure 43 - The fountain

3. Parking lot

3.1. Replacing the asphalt floor by another sustainable material as a grass pavers

There are many reasons to carry out this improvement:

- ✓ It is more effective than asphalt to keeping the temperature of the parking lot down.
- ✓ It would be well hydrated vegetation, staying cooler than ambient air.
- ✓ The vegetation can shade the ground to a lesser extent
- ✓ The rain water will be absorbed into the ground to help cool the parking lot's pavement.
- ✓ It would improve the parking's appearance taking the advantage of this fact to use it for another purpose such as a market or a cafeteria where people could stay longer. To create this it is necessary to carry out another improvement there.

Figure 46 - Currently asphalt parking lot

Figure 45 - New pavement for the parking lot

3.2. Create shadow with trees covering a big portion of the parking

At the start we though about installing some solar canopies to create the needed shade in the parking to decrease the soil temperatures. But after being thinking and discussing we realized that those canopies would likely prevent the vegetation's growth on the new installed pavement. Consequently we though in this new option which could contribue to decrease the thermal comfort creating a sustainable and nice space.

Advantages:

- ✓ Offer shade to the cars and to the whole area which is really big (about 2.438,14m2)

- ✓ Decrease the soil temperature
- ✓ Increase the mean radian temperature and the people's thermal comfort
- ✓ Utilize mother nature to create oxygen and help to the exchange of CO_2 emissions

Figure 48 - Currently sunny parking lot

Figure 47 - Solar canopies

Figure 49 - Tree canopy

Even though, there are some aspects which need to be considered. The grass can attracts some insects which can stay around the parking lot. This could be bad for people who have moderate to severe allergies. Another issue is the natural strong of the vegetation, which can destroy the pavement over the years. This is why the maintenance is an important detail to be considered due to the fact that the grass needs also to be regularly cut and the trees needs to be kept. This is an extra cost added to the whole transformation of the parking which is expensive in general due to the ecological new pavement (See Cost Estimations, Chapter VI).

For this reason, it would be a good idea to increase the activity of the parking and not using it just to park the car because people would not enjoy of this ecological new space. Some activities could be carry out there as it is a big area. A market or even a mobile cafeteria could be installed in a small area of the parking to let people enjoy of this place and profiting of it as it is located near a shopping area.

4. <u>Green factory's walls and roof</u>

   The sugar factory is made with metal materials which increases a lot the temperature of the area and of the own building. All the walls and the roof are made by this warm material so the idea is to create something different.

Figure 51 - Currently Sugar factory

Figure 50 - New Factory design

Advantages:

- Decreasing the temperature of the factory and the surrounding area by using vegetation covering some walls and roofs of the building.
- Making a sustainable building instead of a steel and non-ecological edifice.
- Improving the design of the factory and the appearance of the neighborhood
- Creating news activities connecting people working in the factory with people living in the Suikerbuurt area. Creating a new concept design of the factory it can be implemented the idea of introducing the neighbourhood in the factory activity, creating children excursions there to know how the plant works or family's activities during weekends linked with the sustainability to increase the awareness of the people.
- Increase ties between the neighborhood to achieve a better social support

Figure 52 - Neighborhood activities in the factory

5. Rain systems

The Netherlands is a country where it rains a lot during the whole year. It is logical to try to take profit from the rain water to create new sustainable system as the rain garden, the water square of the surface water channels. In the following point, the advantages to install those systems are going to be explained.

5.1. Rain garden

The advantages of these gardens:

- This garden takes advantage of rainfall and strormwater runoff in its design and plant selection.

- It is usually a small garden which is designed to withstand the extremes of moisture and concentrations of nutrients that are found in stormwater runoff.
- On the surface, the rain garden looks like an attractive garden, providing an habitat for birds and many beneficial insects
- Below the surface, a number of processes are occurring which mimic the hydrologic action of healthy forest. It is an ecological solution based in natural's mother.
- Soils need to be engineered and appropriate for plants selected
- The garden clean and reduce in volume the stormwater once it enters the rain garden.
- Nitrogen and phosphorus levels and overall sediments loads in the stormwater are reduced by the action of the plants.
- Positive cumulative effect on both the volume and quality of stormwater runoff.
- Capturing runoff in a rain garden allows water to soak into the ground rather than flowing into streets and storm drains.
- Rain garden avoid the dirty runoff that enters storm drains was sent directly to receiving water (rivers, lakes, ponds…) causing erosion, water pollution, flooding and diminished groundwater. So it is helping protect streams and lakes from pollutants carried out by stormwater
- Helping protect communities from flooding and drainage problems
- Improve the beauty of yards and neighborhoods
- Helping the evapotranspiration from the vegetation

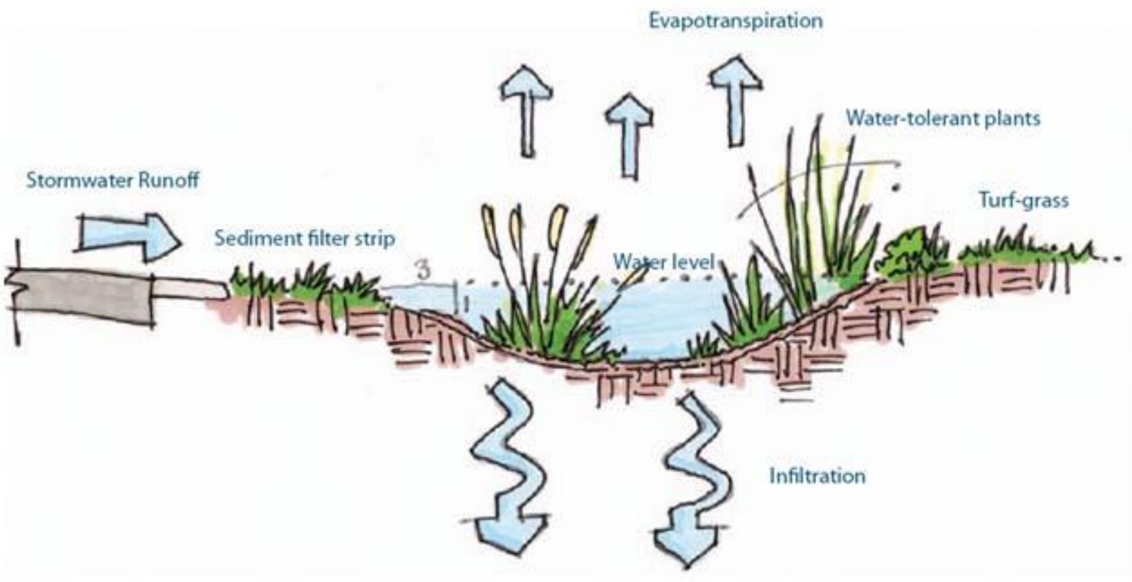


Figure 53 - Scheme rain garden

5.2. Water square

Advantages:

- Water square combines water storage with the improvement of the quality of urban public areas.
- It create environmental quality and identify to central spaces in neighborhoods.
- This system has two functions. On one hand, most of the time the water square will dry and in use as a recreational space (sports area or hilly playground). On the other

hand, when heavy rains take place, rainwater collected from the neighborhood will flow into the water square

- Rain water is filtered before running into the square
- Water can be after run off into the nearest open water (the water way), like this, the system is becoming a measure to improve the quality of the open water in urban environments.

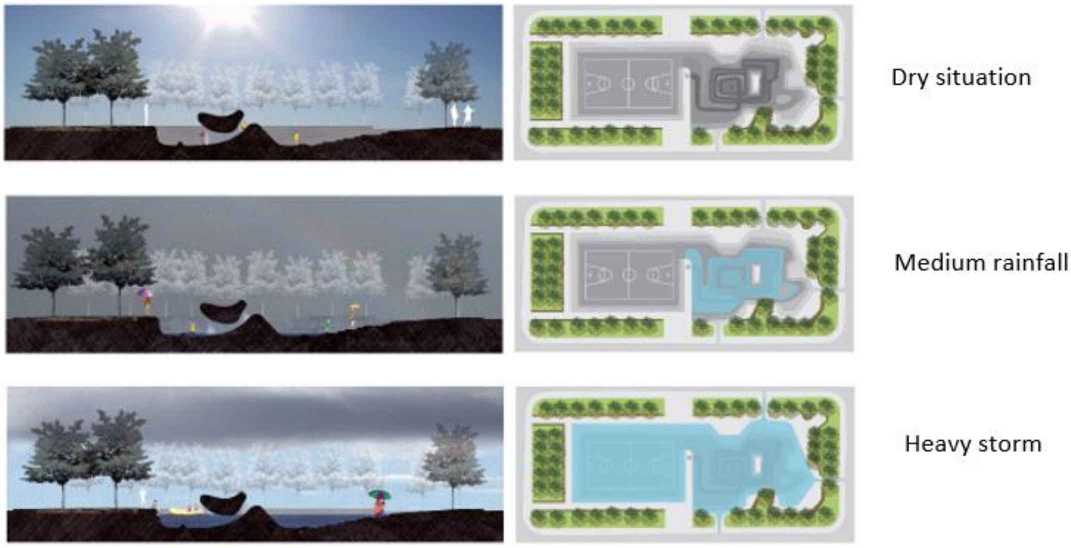


Figure 54 - Water square during its three different phases

5.3. <u>Surface water channels</u>

Advantages:

- Very simple system where water flows along whereby they can have a variety of cross sections to suit the urban landscape, including the use of planting to provide both improvement visual and water treatment.
- Easy to construct due to the fact that the systems consists just in an open surface water channels with hard edges
- Effective in water and pollution treating
- Channels can act as pre-treatment to remove silt before water is conveyed into further features
- Visually attractive in urban landscapes
- Amenity value for the local community

Figure 55 - Urban surface water channel

11. Cost estimation

1. High fence

1.1. Requirement

Long	High
(m)	(m)
54	3

1.2. Selected Design

1.3. Selected Material

Double Wire Fence					
Height*Width Panel mm	Mesh Size mm.	Wire Diameter			Post of Height mm
		Wire Dia mm	Wire Dia mm	Wire Dia mm	
630 * 2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	1100
830*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	1300
1030*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	1500
1230*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	1700
1430*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	1900
1630*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	2100
1830*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	2400
2030*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	2600
2230*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	2800
2430*2500	50*200	8*2 + 6	6**2 + 5	6*2 + 4	3000

Type	Price per unit
Double Mesh Fence Material	17.87 €

1.4. Material Cost Estimation

Material Cost Estimation = Panel required x price/unit + seed price
= 44 unit x 17.87€/ m^2 + 50€
= **836,28 €**

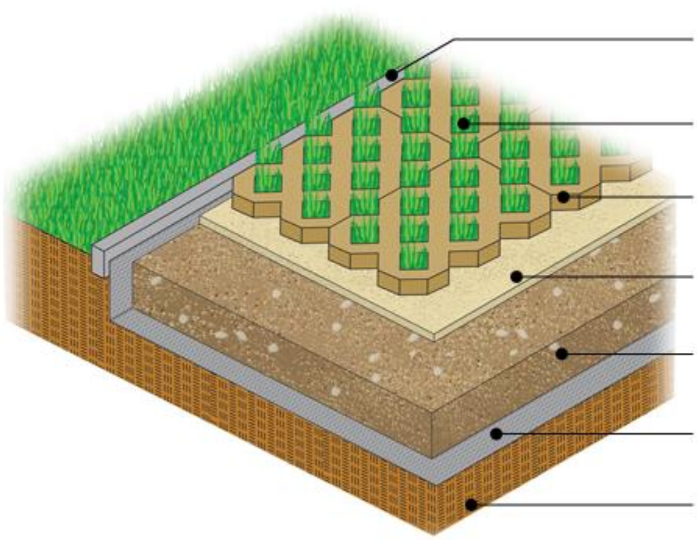
2. The fountain

3. Green Ecological Pavement

3.1. Requirement

Area of the parking: **2438,14m²**

3.2. Selected design



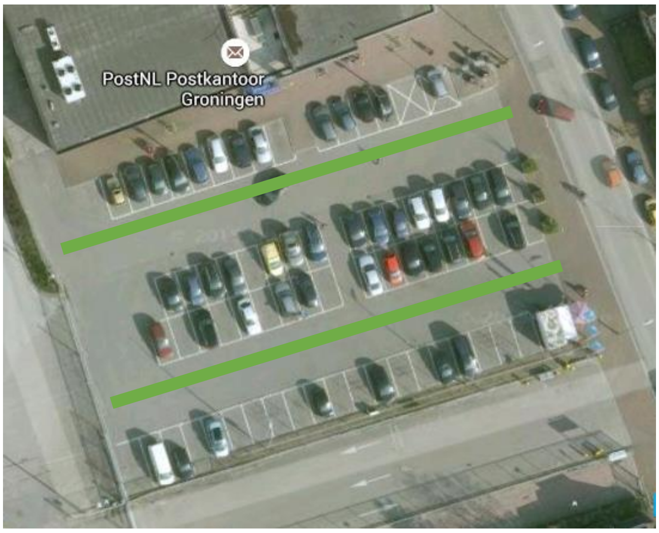
3.3. Table of characteristics

Type of pavement: TURFSTONE	**Applications**	**Performance**	**Installation details**	**Maintenance**	**Costs**
This product is a light-duty concrete paver, with approximately 60% impervious area. The diamond-shaped openings within the lattice pattern can be filled with either soil and grass, or gravel. The pavers are 16" x 24", and come in three heights (3 cm, 8 cm, and 10 cm) 	Suitable for overflow parking areas, emergency vehicle access roads, patios, driveways and embankments.	The average compression strength of the Turfstone manufactured by Unilock is 720,000 l bs/ft2 (5000 psi), with no individual unit less than 648,000 l bs/ft2 (4500 psi). The pavers have a lifetime guarantee and are easy to repair.	May be installed by contractor. A gravel base may be required to provide additional stability, based on soil type and use expectations. The base is usually 6” of compacted gravel, but can vary based on intended use. Geotextile reinforcement is recommended between the subbase and gravel base for vehicular traffic. The pavers are embedded in ~ ¼ to ½ inch of concrete sand, and should not be compacted. The final level of topsoil should be flush with surface	Maintenance for grass-filled pavers includes mowing, irrigation, fertilization, and seeding. Deicing salts should not be used because it will kill the grass. A snowplow may be used to clear the surface. The blade does not need to be lifted.	Price of paver: 31.10€/m^2

3.4. Material selected and unit price

Product/Material	Total area (m^2)	Price/Unit (€/m^2)	Price (€)
Remove asphalt	2438,14	4,70	11.459,26€
Placement new pavement	2438,14	31,10	75.853,14€
Seeding grass	2438,14	5.82	14.189,97€
Total cost estimation			**101.502,37€**

4. <u>Canopy trees cover</u>



- 2 lines of 43 meters with 14 trees each one.
- Total = 28 trees in the parking.

4.1. Selected design

Firstly it is necessary to know the kind of tree that are already living in the surroundings to ensure its survival. Before choosing the species, an evaluation of the properties of the site must be done to ensure a good development of the trees. Take care of some factors such as the soil's characteristics, the light exposure, slope, wind exposure, soil texture, soil pH…

I have no idea about which kind of tree could be planted there, but I was looking for prices about urban trees. The most effective tree would be that one which allows the light to pass during winter and create shade during summer days, for example the Deciduous.

4.2. Characteristics

Deciduous means "tending to fall off", and it is typically used in order to refer to trees or shrubs that lose their leaves seasonally (most commonly during autumn) and to the shedding of other plant structures such as petals after flowering or fruit when ripe. In a more general sense, deciduous means "the dropping of a part that is no longer needed" or "falling away after its purpose is finished". In plants it is the result of natural processes. The perimeter of the tree trunk could be between 12 and 16 cm. Depending on this perimeter the prices may change.

4.3. Material selected and unit price

Plantation:

Verifying readiness and Deciduous plantation in middle ground with manual means, tuffing own land and 50% of fertilized soil, tamped earth and first watering.

Product	Amount/unit	Price (€)	Amount (€)
Gardener	0,072 / h	16,26	1,17
Labour	0,611 / h	14,12	8,63
Fertilized topsoil	0,108 / m^3	15,00	1,62
Water	0,050 / m^3	1,05	0,05
Total			11,47

The tree price:

Type of Deciduous Tree: Liquidambar

Price = 85€ per unit

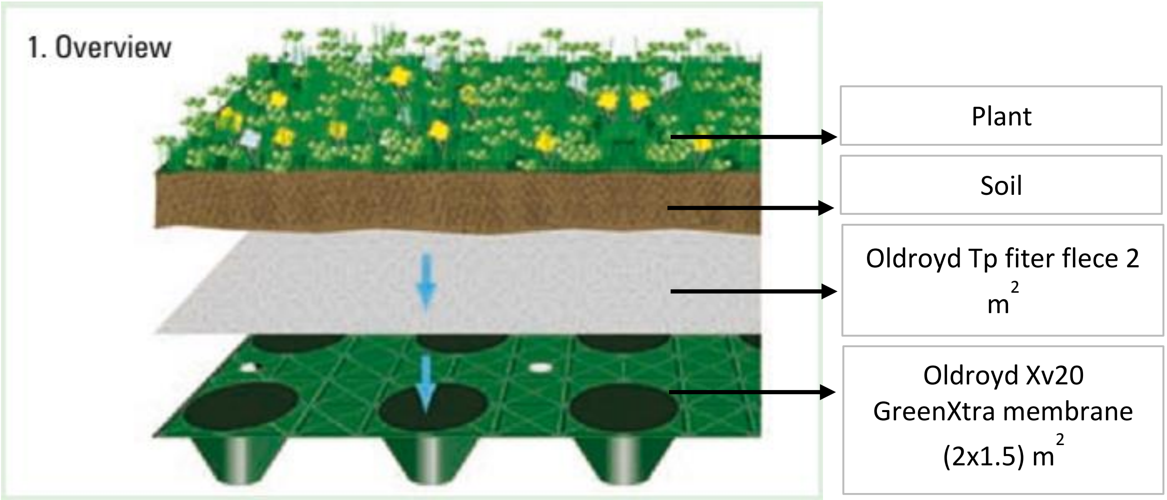
Product/Material	Acquiring number	Price/unit (€/m^2)	Total price (€)
Deciduous	28	85,00	2380,00
Plantation	28	11,47€	321,15€
Total price			2.701,15

5. Green factory's roof

5.1. Requirement

Code	Area (m^2)
1	2124
2	1590
3	855
4	855
5	2867
6	1330
7	820
Total Area	10442

5.2. Selected Design



5.3. Selected Materials and unit price

Product/Material	Price/unit		Price/m²
Plant	€ 888.75	per hectare	€ 0.09
Soil	€ 219.95	per 1 m³	€ 65.99
Oldroyd Tp filter flece	€ 6.68	per 2 m²	€ 3.3
GreenXtra membrane	€ 48	per (2x1.5) m²	€ 16.1
		Total	€ 85.52

5.4. Material Cost Estimation

Material Cost Estimation = Area required x price/m^2

= 10442 m^2 x 85.52€/ m^2

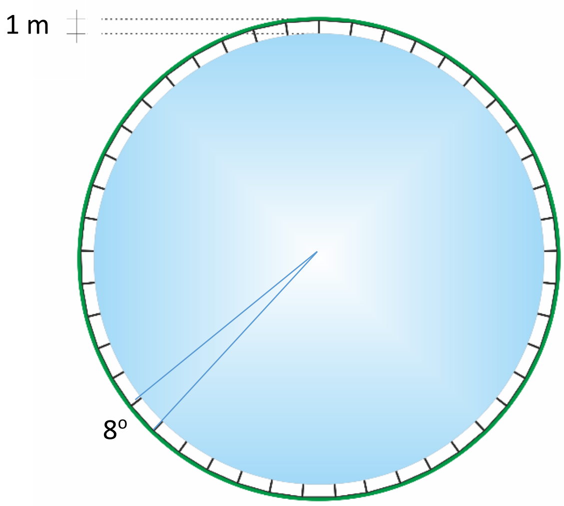
= **892.999,84 €**

6. Green covering factory's walls

6.1. Selected Design

Top View for Green Covering on one Silo

Type	Price
Double Mesh Fence Material	17.87 €/unit
Vines Seeds	250 € in total



Double Wire Fence					
Height*Width Panel mm	Mesh Size mm.	Wire Diameter			Post of Height mm
		Wire Dia mm	Wire Dia mm	Wire Dia mm	
630 * 2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	1100
830*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	1300
1030*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	1500
1230*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	1700
1430*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	1900
1630*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	2100
1830*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	2400
2030*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	2600
2230*2500	50*200	8*2 + 6	6*2 + 5	6*2 + 4	2800
2430*2500	50*200	8*2 + 6	6**2 + 5	6*2 + 4	3000

6.2. Requirement

Code	Perimeter	High	Surface Area	Panel Needed
Unit	(m)	(m)	(m^2)	(pieces)
Tube 1	163	20	3267	333
Tube 2	141	20	2827	222
Tube 3	104	20	2073	222
Tube 4	104	20	2073	222
			Total	998

6.3. Material Cost Estimation

Material Cost Estimation = Panel required x price/unit + seed price
= 998 unit x 17.87€/ unit + 250 €
= **18.084,26 €**

7. The fountain

7.1. Background analysis

Description	Duration (h)	Type of worker	Number of workers	Hourly cost worker (€)	Total cost
Regulations	16	Project manager	1	90.00	**1.440,00€**

7.2. Logistics

Description	Materials and equipment	Unit	Price/unit (€)	Total (€)
Materials	Concrete	150 m3	90,00	13.500,00
	Pumps	1	65,95	65,95
	Paints	200 m2	30,00	6.000,00
	Concrete tipper	1	70,00	70,00
	Bulldozer	1	120,00	120,00
	Excavator	1	139,00	139,00
			TOTAL COSTS	**19.894,95 €**

7.3. Soil works

Description	Duration (h)	Type of worker	Number of workers	Hourly cost worker (€)	Total Cost (€)
Land clearing	24	Labourer	3	50,00	3.600,00
Ground excavations	40	Labourer	3	50,00	6.000.00
				TOTAL COSTS	**9.600,00 €**

7.4. Finishing

Description	Duration (h)	Type of worker	Number of workers	Hourly cost worker (€)	Total Costs (€)
Construction	32	Labourer	2	50,00	3.200,00
Paint works	8	Painter	1	35,00	280,00
				TOTAL COSTS	**3.400,00 €**

7.5. Total Fountain Costs

Description	Costs (€)
Background analysis	1.440,00
Soil Works	9.600,00
Finishing	3.400,00
Materials	19.894,95
TOTAL COSTS	**34.334,95 €**

8. Open water channels

8.1. Background Analysis

Description	Duration (h)	Type of worker	Number of workers	Hourly cost worker (€)	Total cost
Regulations	16	Project manager	1	90.00	**1.440,00€**

8.2. Soil works

Description	Duration (h)	Type of worker	Number of workers	Hourly cost worker (€)	Total Cost (€)
Land clearing	24	Labourer	3	50,00	3.600,00
Ground excavations	40	Labourer	3	50,00	6.000.00
				TOTAL COSTS	**9.600,00 €**

8.3. Finishing

Description	Duration (h)	Type of worker	Number of workers	Hourly cost worker (€)	Total Costs (€)
Pavement Installation	40	Labourer	3	50,00	6.000,00
				TOTAL COSTS	**6.000,00 €**

8.4. Logistics

Description	Materials and equipment	Unit	Price/unit (€)	Total (€)
Materials	Filling Sands	336	30,00	10.080,00
	Paving Blocks	840	15,50	13.020,00
	Bulldozer	1	120,00	120,00
	Excavator	1	139,00	139,00
			TOTAL COSTS	**23.359,00 €**

8.5 Total Open Water channels costs

Description	Costs (€)
Background analysis	1.440,00
Soil Works	9.600,00
Finishing	6.000,00
Materials	23.359,00
TOTAL COSTS	**40.399,00 €**

9. Watersquare

9.1. Background analysis

Description	Duration (h)	Type of worker	Number of workers	Hourly cost worker (€)	Total cost
Regulations	16	Project manager	1	90.00	**1.440,00€**

9.2. Soil works

Description	Duration (h)	Type of worker	Number of workers	Hourly cost worker (€)	Total Cost (€)
Land clearing	24	Labourer	3	50,00	3.600,00
Ground excavations	40	Labourer	3	50,00	6.000.00
				TOTAL COSTS	**9.600,00 €**

9.3. Finishing

Description	Duration (h)	Type of worker	Number of workers	Hourly cost worker (€)	Total Costs (€)
Construction	32	Labourer	2	50,00	3.200,00
				TOTAL COSTS	**3.200,00 €**

9.4. Logistics

Description	Materials and equipment	Unit	Price/unit (€)	Total (€)
Materials	Soils	1200	37,50	45.000,00
	Concrete tippers	1	70,00	70,00
	Bulldozer	1	120,00	120,00
	Excavator	1	139,00	139,00
Project Manager (32h)			90,00/h	2.880
			TOTAL COSTS	**48.209,00 €**

9.5. Total Watersquare Costs

Description	Costs (€)
Background analysis	1.440,00
Soil Works	9.600,00
Finishing	3.200,00
Materials	48.209,00
TOTAL COSTS	**62.409,00 €**

10. Rain garden

10.1 Background analysis

Description	Duration (h)	Type of worker	Number of workers	Hourly cost worker (€)	Total cost
Regulations	16	Project manager	1	90.00	**1.440,00€**

10.2. Soil works

Description	Duration (h)	Type of worker	Number of workers	Hourly cost worker (€)	Total Cost (€)
Land clearing	24	Labourer	3	50,00	3.600,00
Ground excavations	40	Labourer	3	50,00	6.000.00
				TOTAL COSTS	**9.600,00 €**

10.3. Finishing

Description	Duration (h)	Type of worker	Number of workers	Hourly cost worker (€)	Total Costs (€)
Construction	32	Labourer	2	50,00	3.200,00
Vegetation layer	16	Labourer	2	50,00	1.600,00
				TOTAL COSTS	**4.800,00 €**

10.4 Logistics

Description	Materials and equipment	Unit	Price/unit (€)	Total (€)
Materials	Soils	1225	45,00	55.125,00
	Bulldozer	1	120,00	120,00
	Excavator	1	139,00	139,00
Project Manager (32h)			90,00/h	2.880
			TOTAL COSTS	**58.264,00 €**

10.5. Total Rain garden costs

Description	Costs (€)
Background analysis	1.440,00
Soil Works	9.600,00
Finishing	4.800,00
Materials	58.264,00
TOTAL COSTS	**74.104,00 €**

11. Final cost estimation for the new concept design

Improvement	Amount (€)
High Fence	836,28
Fountain	34.334,95
Green Pavement	101.502,37
Trees Canopy	2.701,15
Green factory's roof	18.084,26
Green factory's walls	892.999,80
Rain garden	74.104,00
Open water channels	40.399,00
Watersquare	62.409,00
Total Estimation Cost	**1.227.370,81 €**

The most expensive improvement, with a considerable difference, is the green factory's roof with a price about 892.999,80€. This high price is due to the fact that the four tubes from the factory are really big and to consider a reform there would be necessary to use a lot of materials, workers and to expend a lot of hours. The option needs to be reconsidered.

The initial investment on the project could be very expensive, especially considering the green factory's walls improvement. However, it might be said that all the expensive investment will be paid back in a long term future, and not only in the economical field, but mainly in the environmental part. The benefits of the environmental feedback is not only because of the reduced heat stress and urban island effect, but mainly because of the raise of the awareness of the people.

Chapter VI

CONCLUSION AND REMARKS

12. Conclusion

12.1. Remarks

This research helps us to realize how climate changes can affect over the years inhabitants of the whole planet. Personally, I never thought before about these problems. I've always thought that climate change was really annoying for those countries or areas where the heat was extremely high. I've never thought that in the Northern countries, like the Netherlands, these type researches were so active. Now I can understand how each country needs to be worried about this fatal phenomenon which can't be stopped for at least the 10 following years if we start changing now consumer's behaviour on energy.

To make this research I read many articles explaining different problems involved with climate change. Unluckily, this research doesn't cover neither a big area nor several different areas. This study has just focused in a village of Groningen, so I just can make some conclusions within those results. Even though, I read many articles (see bibliography) about this topic where studies similar to this one were made in several cities from the Netherlands, leading to similar results as mines. It could be stated that green spaces improve thermal comfort in physical as well as in physiological terms. Our study has demonstrated the differences between urban areas within Hoogkerk and green spaces within the Suikerbuurt neighborhood, obtaining clear results about the final thermal comfort on those places. This thermal comfort could be determined from the mean radiant temperature calculations and with some questionnaires provided. I need to make a parenthesis to indicate for next researches that the questionnaires should be clearer due to the fact that a lot of subjects didn't answer one or two questions about their "thermal history", which makes less reliable the results. For this research I read about other questionnaires results that other different studies made about the same topic. What it could be stated with those questionnaires is that people generally perceived green urban environments as thermally comfortable so the evaluation of the thermal comfort effect of green spaces was positive. According to other studies made by Klemm W. et al. (2014), the experienced thermal comfort of green environments was larger than the experienced comfort of water and built environments.

Also, the measurements' results affirm the same conclusion. We got better results for the green area located in the Suikerbuurt neighborhood than near the water environment under a tree. We demonstrated that the measures of the parameters were reliable, so this conclusion is valid. The preference of the thermal comfort can be explained by spatial characteristics of the environment, this is why the outdoor thermal comfort depends largely on the design of the urban areas. Here the main research question can be introduced because this remark makes us think about "How can thermal comfort design solutions be integrated into a typical urban development project in the Netherlands?" To increase people's perception of thermal comfort it is necessary to increase urban green areas. In our study it was demonstrated, and in other studies it was demonstrated as well, that the green spaces are like Cool Islands within a city. If we take a look to the heat map of the Appendix 3 we can note how big is the difference between the places where the red is the predominant colour (in urban spaces) than the places where it is the green colour (green areas). This is called Cool Island. If the phenomenon of heat island needs to be stopped it should be logical to introduce more Cool Island into urban areas (where the heat island effect is more pronounced) to counteract it.

Popular beliefs could be confirmed as the green spaces are appreciated for city's thermal conditions on warm days. This is important because citizens rely on thermally comfortable outdoor spaces for daily outdoor activities on warm summer days. People's free time used to be restricted to short periods due to the intensive life level that humans use to carry out. Hence, green spaces are needed within their living environment, which could be also an escape for people without private outdoor spaces. To conclude with this part, as it was demonstrated in this study, green areas are necessary in urban areas, where human's activity, materials used within cities, poor vegetation, etc. are warming the city and increasing the heat island effect. To increase the thermal comfort it's necessary to create "cool islands" (green areas) in spaces where people go on a daily basis. This small-scale study based on the Suikerbuurt area can give answers to larger-scale within The Netherlands and even within the planet. Climate is changing and solutions need to be integrated as soon as possible.

What is important to keep in mind is that the problem is already known, the change is needed and the urban planners, policy makers and city managers need to anticipate the increasing urban heat due to climate change starting with new urban designs to counter thermal comfort effects on the inhabitants. More studies need to be taken into account to provide healthy and thermally comfortable living environments in the future.

12.2. Further researches

For further researches there are many aspects that would be interesting to be studied. In this case, the research was made in a specific area of Groningen, The Netherlands. Thermal comfort studies are focused in the thermal sensation of the people and this is what it was made in the Suikerbuurt area. The aim is to investigate about the six factors influencing the thermal comfort such as the air temperature, relative humidity, the wind speed, the clothing, the metabolic rate and the mean radiant temperature. Even if the radiation is not usually mentioned in other studies, we took this into account in this research due to the fact that the presence of some trees covering areas can make temperature to go down due to the shade that the tree can produce. This shade is what makes radiation decrease. The study and the results were made in a rural area where the temperatures use to be lower than in urban areas as it was mentioned in the **Discussion** of this report. Therefore, future works could include studies to consider other climate zones throughout The Netherlanlds.

We demonstrated that a large part of the variance of general preferences of thermal comfort can be explained by spatial characteristics of the environment. This implies that people's perception of thermal comfort could be increased by creating urban green areas. Even though, we don't know yet about the influence of urban green spaces on the actual behaviour of citizens. Moreover, we don't know whether about the impact of the heat island phenomenon on vegetation and on the evolution of the period that exists before the vegetation reaches its climax or final shape. It would be interesting to make some studies about how is the interaction about vegetation in the streets, squares or avenues to know where and how is the best way to design a green area within a city to decrease temperatures on the warmest days of the year. There are four different ways to plant vegetation: covering vegetation, isolated trees, grove or lines of trees. It is not the same to put an isolate tree in a garden on a rural area than to plant this same tree in the middle of the city center suffering the heat island phenomenon. Hence, a classification of vegetation should be done in further researches to get expected results on a warm day.

The best way to know how green spaces are more effective in urban areas is making several studies where temperature is constantly high during the summer and where people know how to fight against heat waves. Using this method, the cities which are less habituated to the increasing temperature can take solutions from countries such as Morocco, Tunisia, Italy, Spain and other south-countries. By comparing outdoor comfort studies conducted in several season, in regions with different climates, it would be possible to evaluate the effect of changes in the current climate conditions on the temperature range within which people feel comfortable outdoors and applies each solution to other regions such as the North-Europe countries, where people is unaccustomed to high temperatures.

Those studies based in Mediterranean climate could be very helpful to know about where people feel thermally comfortable and why. That's it to know about which solutions area already implemented and why are they working. Several studies have demonstrated that the perception of thermal comfort is related to naturalness and positive experience with the environment. Meanwhile, other studies stated that people's perceived thermal comfort is affected by their own perception of spatial environments. So the question should be how people actually perceive thermal comfort.

Another important thing that should be taken into consideration within an urban area, in addition of the green spaces design, is the form and the orientation of a building. Within a city, the most important elements are the buildings. There are many kinds of cities, ones having big building in the whole urban space and other having small buildings, but at the end all the cities are based on those structures. The climatic conditions with respect to thermal comfort in buildings should be largest studied. The different location of buildings within a city can change the impact of climate and thermal comfort. The orientation of a building will always depending on the climate (tropical, subtropical or temperate) but the aim is to ensure the minimum incident solar radiation during the overhead period. For further researches, a good article to read is the one wrote by Hasse M. and Amato A. in 2009.

For additional researches, maybe it would be interesting to be focused in the people characteristics such as clothing and the metabolic rate (activity level) to get some comparison about some subjects being at the same place, with the same clothing but making different activities. For example, in Spain, each summer we have TV publicity which introduce some advices about what should be done on a warm day and what shouldn't be done. One of those advices is about the activity level during a very warm day. The metabolic rate of a subject can enormously affects the thermal comfort of this person. Making a study about which activities are within the acceptable range for warm days depending on the results of this study, could be done to know how the metabolism rate can change our thermal comfort.

In conclusion, there are several studies which could be made to still fighting against the climate change and helping people to endure the coming heat waves:

- Make more researches like this within urban areas (city center), where heat island phenomenon is more pronounced; as the Suikerbuurt is located on the edge of Groningen.
- Investigate ability of urban vegetation to cope with increased temperatures
- More details about how different types of vegetation are able to decrease the temperature within a city
- Focus researches in countries adapted to warmer climate to know about the strategies used there during heat waves and apply it to North countries

- Building urban design. More investigation details about form and orientation of new buildings.
- Perform more studies about people's perception, focused on how the activity level can change the thermal comfort
- Increase researches for outdoor thermal comfort. It is more difficult to get accurate results for outdoor due to the variable factors involved in the environment. The indoor thermal comfort depends on factors which normally doesn't suffer any change whilst the outdoor environment is in constantly movement

Chapter VII

BIBLIOGRAPHY

12. References

12.1. Articles

- Bell S., Cornford D. and Bastian L. (2015)
  "How good are citizen weather stations?"
  Department of Computer Science, Aston University, Birmingham

- Harlan S.L., Brazel A.J., Prashad L. et al (2006).
  "Neighbourhood microclimates and vulnerability to heat stress"
  Social and Science Medicine. ELSEVIER

- Hasse M. and Amato A. (2009)
  "An investigation of the potential for natural ventilation and building orientation to achieve thermal comfort in warm and humid climates"
  Solar Energy. ELSEVIER.

- Hodder S.G. and Parsons K. (2007)
  "*The effects of solar radiation on thermal comfort."*
  Internation Journal of Biometeorology. Volume 51. Issue 3. Pages 233-250.

- Honjo T.(2009)
  "Thermal Comfort in outdoor environments"
  AIRIES Global Environmental Research. Faculty of Horticulture. Chiba University, Japan.

- Höppe P. (2002)
  "*Different aspects of assessing indoor and outdoor thermal comfort."*
  Energy and Buildings. ELSEVIER.

- Johansson E., Thorsson S., Emmanuel R. and Krüger E. (2014)
  "Instruments and methods in outdoor thermal comfort studies – The need for standardization"
  Urban Climate. ELSEVIER.

- Klemm W., Heusinkveld B.G., Lenzholzer S., et al. (2014)
  "Building and environment. Psychological and physical impact of urban green spaces on outdoor thermal comfort during summertime in The Netherlands."
  Built and Environment. ELSEVIER.

- Matzarakis A., Mayer H. and Rutz F. (2002)
  "*Radiation and thermal comfort"*
  Meteorological Institute, University of Freiburg, Germany

- Population Division of the Department of economic and social affairs of the UN (2011)
  "*Urban green-blue grids for sustainable and resilient cities."*
  ATELIER GROENBLAUW.

- Stewart I.E , Oke T.R. and Krayenhoff E.S. (2013)
  "Evaluation of the 'local climate zone' scheme using temperature observations and model simulations."
  International Journal of Climatology. ROYAL METEOROLOGICAL SOCIETY (RMetS)

12.2. The internet

- EPA (2014). The climate change

http://www.epa.gov/climatechange/basics/
(Viewed on March 2015)

http://www.epa.gov/climatechange/impacts-adaptation/health.html#impactsextremeweather
(Viewed on March 2015)

- EPA. Climate adaptation area

http://www.ruimtelijkeadaptatie.nl/en/climate-adaptation-atlas
(Viewed on February 2015)

- EPA (2014). Heat island effect

http://www.epa.gov/hiri/
(Viewed on February 2015)

- EPA (2014). Heat stress

https://eu-smartcities.eu/content/urban-heat-stress-urban-heat-island-uhi-phenomena
(Viewed on March 2015)

- EPA. Thermal comfort

http://www.hse.gov.uk/temperature/thermal/measuring.htm
(Viewed on March 2015)

- British Standard BS EN ISO 7730 *(HSE _ Health and Safety Executive)*

http://www.hse.gov.uk/temperature/thermal/explained.htm
(Viewed on March 2015)

- EPA (2011). Blue grids

http://www.urbangreenbluegrids.com/about/introduction-to-green-blue-urban-grids/
(Viewed on March 2015)

- *Netherlands facts, information. Encyclopedia. 2007*

http://www.encyclopedia.com/topic/Netherlands.aspx
(Viewed on April 2015)

- Innova AirTech Instruments (1997)

http://www.blowtex-educair.it/DOWNLOADS/Thermal%20Comfort.htm
(Viewed on May 2015)

- Anenometer (Wind Speed measurement)

http://www.saylor.org/site/wp-content/uploads/2011/04/Anemometer.pdf
(Viewed on April 2015)

- KNMI. Klimatologie index

http://www.knmi.nl/klimatologie/daggegevens/index.cgi
(Viewed on May 2015)

- Weather underground

http://www.wunderground.com/personal-weather-station/dashboard?ID=IGRONING118#history/s20150511/e20150511/mdaily
(Viewed on May 2015)

- Parking lot concept design

http://macaulay.cuny.edu/eportfolios/greenparking/green-parking-propostion/
(Viewed on May 2015)

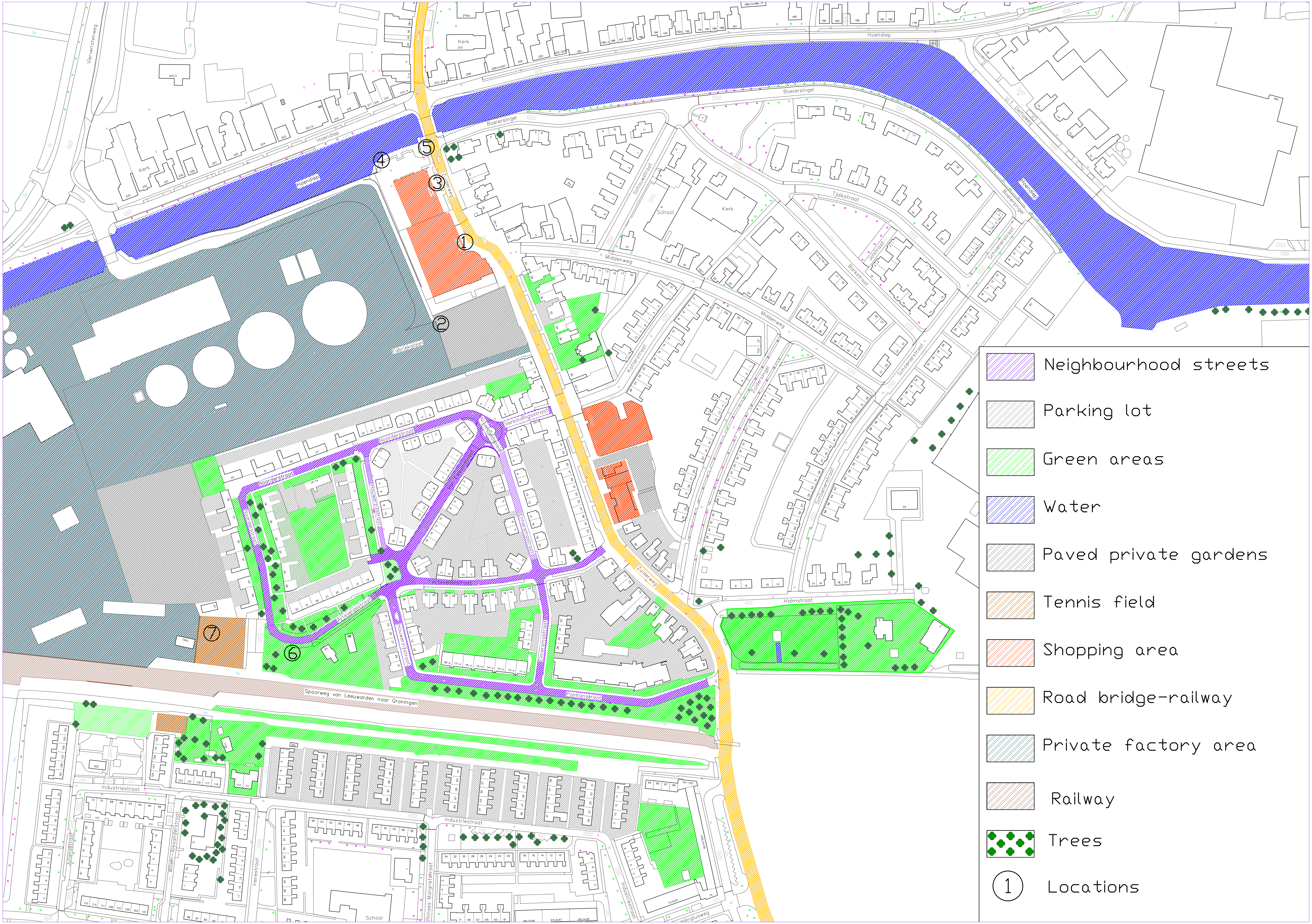
- Estimation Costs

http://www.coastal.ca.gov/NPS/lid/PermeablePavement-What%27sitDoingonMyStreet.pdf

http://www.five.es/basedatos/Visualizador/Base14/index.htm
(Viewed on May 2015)

Appendix

Appendix 1: Land Use map



Neighbourhood streets
Parking lot
Green areas
Water
Paved private gardens
Tennis field
Shopping area
Road bridge-railway
Private factory area
Railway
Trees
Locations
1
2
3
4
5
6
7
Hoendiep
Boelersingel
Middenweg
Zuiderweg
Halmstraat
Tjalkstraat
Schoenerstraat
Schouwstraat
Kotterstraat
Barkstraat
Fabriekslaan
Noorderstraat
Verbindingsstraat
Palmanstraat
Vierverlatenweg
Spoorweg van Leeuwarden naar Groningen
Industriestraat
Julianastraat
Willem-Alexanderstraat
Irenestraat
Prinses Margrietstraat
Kerk
School

Appendix 2: Surfaces map

Outdoor tile cement (stone effect)
Asphalt parking
Green areas
Water
Paved private gardens
Tennis field (cement)
Flat roof
Tiles roof
Methal roof
Railway
Trees
Locations
Hoendiep
Boeiersingel
Middenweg
Tjalkstraat
Barkstraat
Schoenerstraat
Zuidersingel
Kottenstraat
Schouwstraat
School
Kerk
Fabriekslaan
Noorderstraat
Verbindingsstraat
Emmersstraat
Zuiderweg
Halmstraat
Polmanstraat
Spoorweg van Leeuwarden naar Groningen
Industriestraat

Appendix 3: Heat map

Appendix 4: Quick scan tool for heat stress: How to help the urban planner

Quick scan tool for heat stress: How to help the urban planner

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Introduction

Climate change is expected to cause more prolonged heat waves. Unfortunately, cities in Western Europe have not been designed to endure heat waves. To make municipalities aware of the health dangers of urban heat, and to help them find heat reducing measures, a quick scan tool has been developed based. Results are presented in GIS maps.

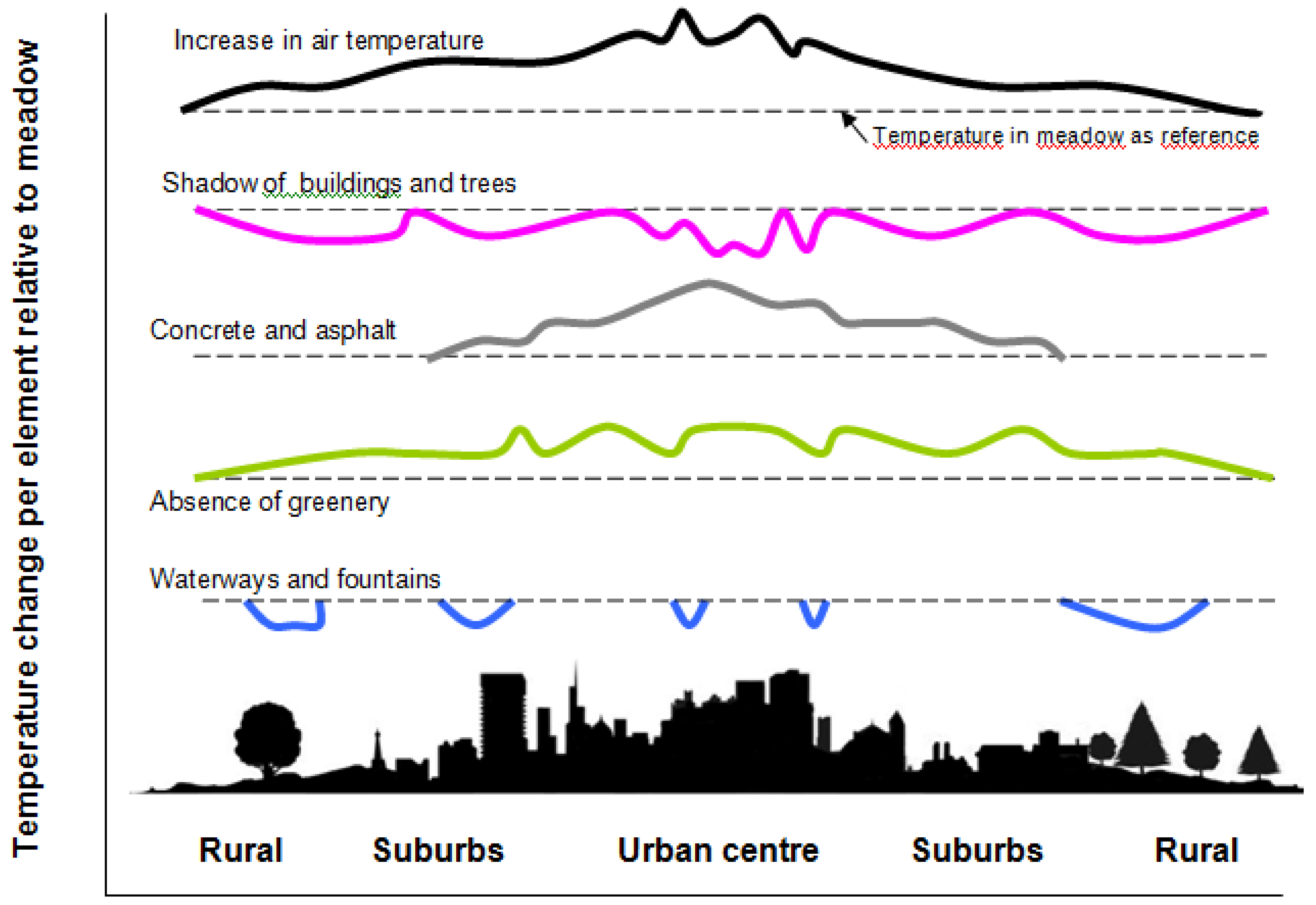


Figure 1: Principle of quick scan heat stress model: Increase in air temperature is the summation of several effects and presented relative to the rural temperature of a meadow.

Methodology

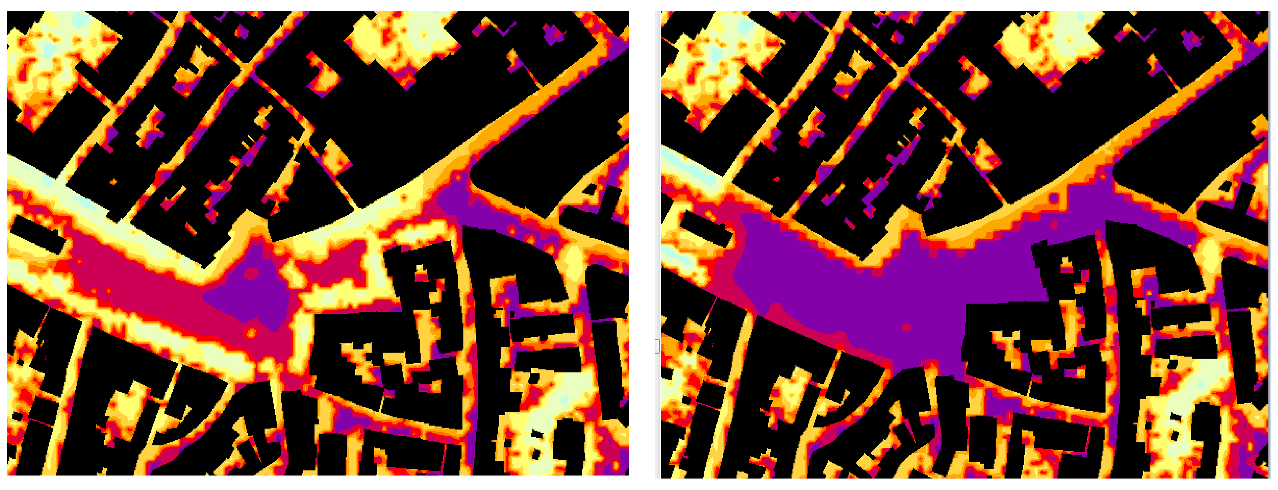
A quick scan tool has been developed using readily available data like:

- Ground use (building, paved, unpaved)
- Elevation map showing buildings and trees ➔ shadow
- Aireal photographs ➔ greenery
- Availability of water
- General effects of western wind

The maps show either differences in the air temperature or the comfort temperature (Physiological Equivalent Temperature) in the afternoon of a hot day.

Validation

Several recently finished research projects have been used to underpin the setup of the model. The model results have been compared with satellite images and with on-site measurement data. Workshops with relevant stakeholders (municipalities and provinces) have delivered further input to make the model suitable for municipal practitioners.



White: ref.temp (outside city)
Orange= +2 d °C
Purple: + 7 °C
Black: buildings

Figure 2: Afternoon max comfort temperature at town square with and without trees

Computed air temperature in Groningen during heat wave
Red = high temperature
Yellow = reference temperature (outside city)
Blue = low temperature

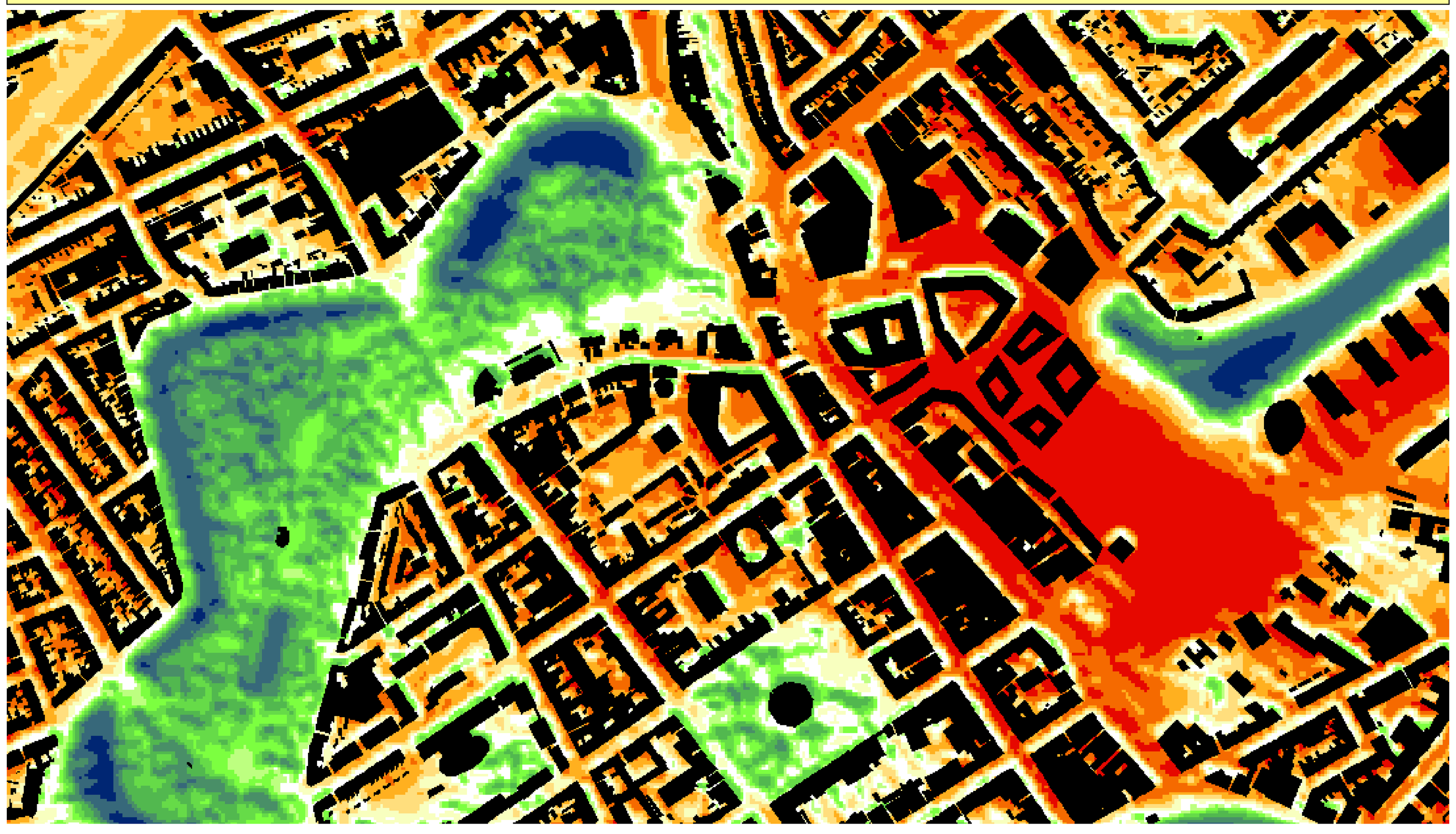


Figure 3: Urban heat map: Detailed city map showing the expected temperatures during a heat wave for the city of Groningen

Research Results

Using computed heat maps during stakeholder workshops proved useful in creating awareness for possible increased heat stress due to climate change and to discuss possible coping strategies. The results are presented using accurate local data maps and show recognizable local effects, like the daytime cooling effect of shadow behind buildings and trees or near water. Therefore, the maps are easily understandable for stakeholders and are seen as a valuable start for addressing urban heat stress.
The maps result in discussions on the need of measures. It appeared still too difficult to decide on what level of heat stress (or which max. temperature) was acceptable. The maps however often resulted in extra arguments for the need of trees in urban areas

Recommendations

In order to help municipalities to come to practical steps, we recommend continuing in the following way:

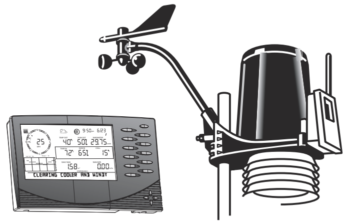
- Further investigate what threshold levels for air temperature and comfort temperature are suitable to help municipalities in addressing urban heat stress.
- Refine the quick scan urban heat stress model by implementing surface color variation, anthropogenic heat, hanging gardens, green roofs, etc..

ECCA Copenhagen 2015

Appendix 5: Weather station

Wireless Vantage Pro2™ & Vantage Pro2™ Plus Stations

(Including Fan-Aspirated Models)



6152 6162
6153 6163

Vantage Pro2™ (6152, 6153) and Vantage Pro2™ Plus (6162, 6163) Wireless Weather Stations include two components: the Integrated Sensor Suite (ISS) which houses and manages the external sensor array, and the console which provides the user interface, data display, and calculations. The ISS and Vantage Pro2 console communicate via an FCC-certified, license-free, spread-spectrum frequency-hopping (FHSS) transmitter and receiver. User-selectable transmitter ID codes allow up to eight stations to coexist in the same geographic area. The frequency hopping spread spectrum technology provides greater communication strength over longer distances and areas of weaker reception. The Wireless Vantage Pro2 Plus weather station includes two additional sensors that are optional on the Vantage Pro2: the UV sensor and the solar radiation sensor.

The console may be powered by batteries or by the included AC-power adapter. The wireless ISS is solar powered with a battery backup. Use WeatherLink® for Vantage Pro2 and Vantage Vue® to let your weather station interface with a computer, to log weather data, and to upload weather information to the internet.

The 6152 and 6162 rely on passive shielding to reduce solar-radiation induced temperature errors in the outside temperature sensor readings. The Fan-aspirated 6153 and 6163 combine passive shielding with a solar-powered fan that draws outside air in over the temperature and humidity sensors, providing a much more accurate temperature reading than that available using passive shielding alone.

Integrated Sensor Suite (ISS)

(Includes product numbers: 6152, 6153, 6162, 6163, 6322, 6323, 6327 & 6328)

Operating Temperature	-40° to +150°F (-40° to +65°C)
Non-operating Temperature	-40° to +158°F (-40° to +70°C)
Current Draw (ISS SIM only)	0.14 mA (average), 30 mA (peak) at 4 to 6 VDC
Solar Power Panel	0.5 Watts (ISS SIM), plus 0.75 Watts (Fan-Aspirated)
Battery (ISS SIM /Fan-Aspirated)	CR-123 3-Volt Lithium cell / 2 - 1.2 Volt NiCad C-cells
Battery Life (3-Volt Lithium cell)	8 months without sunlight - greater than 2 years depending on solar charging
Battery Life (NiCad C-cells, Fan-Aspirated)	1 year
Fan Aspiration Rate (Fan-Aspirated only)	
Intake Flow Rate, full sun	190 feet/min. (0.9 m/s)
Intake Flow Rate, battery only	80 feet/min. (0.4 m/s)
Sensor Chamber Flow Rate, full sun	500 feet/min. (2.5 m/s)
Sensor Chamber Flow Rate, battery only	280 feet/min. (1.4 m/s)
Connectors, Sensor	Modular RJ-11
Cable Type	4-conductor, 26 AWG
Cable Length, Anemometer	40’ (12 m) (included) 240’ (73 m) (maximum recommended)

Note: Maximum displayable wind decreases as the length of cable increases. At 140’ (42 m) of cable, the maximum wind speed displayed is 135 mph (60 m/s); at 240’ (73 m), the maximum wind speed displayed is 100 mph (34 m/s).

Wind Speed Sensor	Solid state magnetic sensor
Wind Direction Sensor	Wind vane with potentiometer
Rain Collector Type	Tipping bucket, 0.01" per tip (0.2 mm with metric rain adapter), 33.2 in^2 (214 cm^2) collection area
Temperature Sensor Type	PN Junction Silicon Diode
Relative Humidity Sensor Type	Film capacitor element
Housing Material	UV-resistant ABS, ASA plastic

ISS Dimensions (not including anemometer or bird spikes):

DAVIS® Davis Instruments 3465 Diablo Ave., Hayward, CA 94545-2778 USA
(510) 732-9229 • FAX (510) 670-0589 • sales@davisnet.com • www.davisnet.com

Vantage Pro2 with Standard Rad Shield	14.0" x 9.4" x 14.5" (356 mm x 239 mm x 368 mm)
Vantage Pro2 with Fan-Asprated Rad Shield	20.8" x 9.4" x 16.0" (528 mm x 239 mm x 406 mm)
Vantage Pro2 Plus with Standard Rad Shield	14.3" x 9.7" x 14.5" (363 mm x 246 mm x 368 mm)
Vantage Pro2 Plus with Fan-Aspirated Rad Shield	21.1" x 9.7" x 16.0" (536 mm x 246 mm x 406 mm)

Console

(Incluces product number 6312)

Console Operating Temperature	+32° to +140°F (0° to +60°C)
Non-Operating (Storage) Temperature	+14° to +158°F (-10° to +70°C)
Current Draw	0.9 mA average, 30 mA peak, (add 120 mA for display lamps, add 0.125 mA for each optional wireless transmitter received by the console) at 4 - 6 VDC
AC Power Adapter	5 VDC, 300 mA, regulated
Batteries	3 C-cells
Battery Life	up to 9 months
Connectors	Modular RJ-11
Housing Material	UV-resistant ABS plastic
Console Display Type	LCD Transflective
Display Backlight	LEDs
Console Dimensions	
Console with antenna down (L x H x D)	10.625" x 6.125" x 1.625" (270 mm x 156 mm x 41 mm)
Console with antenna extended up (L x H x D)	10.625" x 9.625" x 1.625" (270 mm x 245 mm x 41 mm)
Display (L x H)	5.94" x 3.375" (151 mm x 86 mm)
Weight (with batteries)	1.88 lbs. (.85 kg)

Data Displayed on Console

Data display categories are listed with General first, then in alphabetical order.

General

Historical Data	Includes the past 24 values listed unless otherwise noted; all can be cleared and all totals reset
Daily Data	Includes the earliest time of occurrence of highs and lows; period begins/ends at 12:00 am
Monthly Data	Period begins/ends at 12:00 am on the first of the month
Yearly Data	Period begins/ends at 12:00 am on the first of January unless otherwise noted
Current Display Data	Current display data describes the current reading for each weather variable. In most cases, the variable lists the most recently updated reading or calculation. Some current variable displays can be adjusted so there is an offset for the reading
Current Graph Data	Current graph data appears in the right-most column in the console graph and represents the latest value within the last period on the graph; totals can be set or reset. Display intervals vary. Examples include: Instant, 15-min., and Hourly Reading; Daily, Monthly, High and Low
Graph Time Interval	1 min., 10 min., 15 min., 1 hour, 1 day, 1 month, 1 year (user-selectable, availability depends upon variable selected)
Graph Time Span	24 Intervals + Current Interval (see Graph Intervals to determine time span)
Graph Variable Span (Vertical Scale)	Automatic (varies depending upon data range); Maximum and Minimum value in range appear in ticker
Alarm Indication	Alarms sound for only 2 minutes (time alarm is always 1 minute) if operating on battery power. Alarm message is displayed in ticker as long as threshold is met or exceeded. Alarms can be silenced (but not cleared) by pressing the DONE key.
Transmission Interval	Varies with transmitter ID code from 2.25 seconds (#1=shortest), to 3 seconds (#8=longest)
Update Interval	Varies with sensor - see individual sensor specs

Barometric Pressure

Resolution and Units	0.01" Hg, 0.1 mm Hg, 0.1 hPa/mb (user-selectable)

Range	16.00" to 32.50" Hg, 410 to 820 mm Hg, 540 to 1100 hPa/mb
Elevation Range	-999' to +15,000' (-600 m to 4570 m) (Note that console screen limits entry of lower elevation to -999' when using feet as elevation unit.)
Uncorrected Reading Accuracy	±0.03" Hg (±0.8 mm Hg, ±1.0 hPa/mb) (at room temperature)
Sea-Level Reduction Equation Used	United States Method employed prior to use of current "R Factor" method
Equation Source	Smithsonian Meteorological Tables
Equation Accuracy	±0.01" Hg (±0.3 mm Hg, ±0.3 hPa/mb)
Elevation Accuracy Required	±10' (3m) to meet equation accuracy specification
Overall Accuracy	±0.03" Hg (±0.8 mm Hg, ±1.0 hPa/mb)
Trend (change in 3 hours)	Change 0.06" (2 hPa/mb,1.5 mm Hg) = Rapidly Change 0.02" (0.7hPa/mb, 0.5 mm Hg)= Slowly
Trend Indication	5 position arrow: Rising (rapidly or slowly), Steady, or Falling (rapidly or slowly)
Update Interval	1 minute or when console BAR key is pressed twice
Current Display	Instant
Current Graph Data	Instant, 15-min., and Hourly Reading; Daily, Monthly, High and Low
Historical Graph Data	15-min. and Hourly Reading; Daily, Monthly Highs and Lows
Alarms	High Threshold from Current Trend for Storm Clearing (Rising Trend Low Threshold from Current Trend for Storm Warning (Falling Trend)
Range for Rising and Falling Trend Alarms	0.01 to 0.25" Hg (0.1 to 6.4 mm Hg, 0.1 to 8.5 hPa/mb)

Clock

Resolution	1 minute
Units	Time: 12 or 24 hour format (user-selectable)
Date	US or International format (user-selectable)
Accuracy	±8 seconds/month
Adjustments	Time: Automatic Daylight Savings Time (for users in North America and Europe that observe it in AUTO mode, MANUAL setting available for all other areas) Date: Automatic Leap Year
Alarms	Once per day at set time when active

Dewpoint (calculated)

Resolution and Units	1°F or 1°C (user-selectable) °C is converted from °F rounded to the nearest 1°C
Range	-105° to +130°F (-76° to +54°C)
Accuracy	±3°F (±1.5°C) (typical)
Update Interval	10 to 12 seconds
Source	World Meteorological Organization (WMO)
Equation Used	WMO Equation with respect to saturation of moist air over water
Variables Used	Instant Outside Temperature and Instant Outside Relative Humidity
Current Display Data	Instant Calculation
Current Graph Data	Instant Calculation; Daily, Monthly High and Low
Historical Graph Data	Hourly Calculations; Daily, Monthly Highs and Lows
Alarms	High and Low Threshold from Instant Calculation

Evapotranspiration (calculated, requires solar radiation sensor)

Resolution and Units	0.01" or 0.1 mm (user-selectable)
Range	Daily to 32.67" (832.1 mm); Monthly & Yearly to 199.99" (1999.9 mm)
Accuracy	Greater of 0.01" (0.25 mm) or ±5%, Reference: side-by-side comparison against a CIMIS ET weather station
Update Interval	1 hour
Calculation and Source	Modified Penman Equation as implemented by CIMIS (California Irrigation Management Information System) including Net Radiation calculation
Current Display Data	Latest Hourly Total Calculation
Current Graph Data	Latest Hourly Total Calculation, Daily, Monthly, Yearly Total
Historical Graph Data	Hourly, Daily, Monthly, Yearly Totals

Alarm	High Threshold from Latest Daily Total Calculation

Forecast

Variables Used	Barometric Reading & Trend, Wind Speed & Direction, Rainfall, Temperature, Humidity, Latitude & Longitude, Time of Year
Update Interval	1 hour
Display Format	Icons on top center of display; detailed message in ticker at bottom
Variables Predicted	Sky Condition, Precipitation, Temperature Changes, Wind Direction and Speed

Heat Index (calculated)

Resolution and Units	1°F or 1°C (user-selectable) °C is converted from °F rounded to the nearest 1°C
Range	-40° to +165°F (-40° to +74°C)
Accuracy	±3°F (±1.5°C) (typical)
Update Interval	10 to 12 seconds
Source	United States National Weather Service (NWS)/NOAA
Formulation Used	Steadman (1979) modified by US NWS/NOAA and Davis Instruments to increase range of use
Variables Used	Instant Outside Temperature and Instant Outside Relative Humidity
Current Display Data	Instant Calculation
Current Graph Data	Instant Calculation; Daily, Monthly High
Historical Graph Data	Hourly Calculations; Daily, Monthly Highs
Alarm	High Threshold from Instant Calculation

Humidity

Inside Relative Humidity (sensor located in console)

Resolution and Units	1%
Range	1 to 100% RH
Accuracy	±3% (0 to 90% RH), ±4% (90 to 100% RH)
Update Interval	1 minute
Current Display Data	Instant (user-adjustable offset available)
Current Graph Data	Instant; Hourly Reading; Daily, Monthly High and Low
Historical Graph Data	Hourly Readings; Daily, Monthly Highs and Lows
Alarms	High and Low Threshold from Instant Reading

Outside Relative Humidity (sensor located in ISS)

Resolution and Units	1%
Range	1 to 100% RH
Accuracy	±3% (0 to 90% RH), ±4% (90 to 100% RH)
Temperature Coefficient	0.03% per °F (0.05% per °C), reference 68°F (20°C)
Drift	±0.5% per year
Update Interval	50 seconds to 1 minute
Current Display Data	Instant (user-adjustable offset available)
Current Graph Data	Instant; Hourly Reading; Daily, Monthly High and Low
Historical Graph Data	Hourly Readings; Daily, Monthly Highs and Lows
Alarms	High and Low Threshold from Instant Reading

Extra Outside Relative Humidity (sensor located inside Temperature/Humidity Station)

Resolution and Units	1%
Range	1 to 100% RH
Accuracy	±3% (0 to 90% RH), ±4% (90 to 100% RH)
Temperature Coefficient	0.03% per °F (0.05% per °C), reference 68°F (20°C)
Drift	±0.5% per year
Update Interval	50 seconds to 1 minute
Current Display Data	Instant Reading (user adjustable)
Alarms	High and Low Threshold from Instant Reading

Leaf Wetness (requires leaf wetness sensor)

Resolution	1
Range	0 to 15
Dry/Wet Threshold	User-selectable
Accuracy	±0.5
Update Interval	46 to 54 seconds
Current Graph Data	Instant Reading; Daily High and Low; Monthly High
Historical Graph Data	Hourly Readings; Daily Highs and Lows; Monthly Highs
Alarms	High and Low Thresholds from Instant Reading

Moon Phase

Console Resolution	1/8 (12.5%) of a lunar cycle, 1/4 (25%) of lighted face on console
WeatherLink Resolution	0.09% of a lunar cycle, 0.18% of lighted face maximum (depends on screen resolution)
Range	New Moon, Waxing Crescent, First Quarter, Waxing Gibbous, Full Moon, Waning Gibbous, Last Quarter, Waning Crescent
Accuracy	±38 minutes

Rainfall

Resolution and Units	0.01" or 0.2 mm (user-selectable) (1 mm at totals ≥ 2000 mm)
Daily/Storm Rainfall Range	0 to 99.99" (0 to 999.8 mm)
Monthly/Yearly/Total Rainfall Range	0 to 199.99" (0 to 6553 mm)
Accuracy	For rain rates up to 4"/hr (100 mm/hr): ±4% of total or ± one tip of the bucket (0.01"/0.2mm), whichever is greater.
Update Interval	20 to 24 seconds
Storm Determination Method	0.02" (0.5 mm) begins a storm event, 24 hours without further accumulation ends a storm event
Current Display Data	Totals for Past 15-min
Current Graph Data	Totals for Past 15-min, Past 24-hour, Daily, Monthly, Yearly (start date user-selectable) and Storm (with begin date); Umbrella is displayed when 15-minute total exceeds zero
Historical Graph Data	Totals for 15-min, Daily, Monthly, Yearly (start date user-selectable) and Storm (with begin and end dates)
Alarms	High Threshold from Latest Flash Flood (15-min. total, default is 0.50", 12.7 mm), 24-Hour Total, Storm Total,
Range for Rain Alarms	0 to 99.99" (0 to 999.7 mm)

Rain Rate

Resolution and Units	0.01" or 0.1 mm (user-selectable) at typical rates (see Fig. 2 and 3)
Range	0, 0.04"/hr (1 mm/hr) to 96"/hr (0 to 2438 mm/hr)
Accuracy	±5% for rates less than 5" per hour (127 mm/hr)
Update Interval	20 to 24 seconds
Calculation Method	Measures time between successive tips of tipping bucket. Elapsed time greater than 15 minutes or only one tip of the rain collector constitutes a rain rate of zero.
Current Display Data	Instant
Current Graph Data	Instant and 1-min. Reading; Hourly, Daily, Monthly and Yearly High
Historical Graph Data	1-min Reading; Hourly, Daily, Monthly and Yearly Highs
Alarm	High Threshold from Instant Reading

Soil Moisture (requires soil moisture sensor)

Resolution	1 cb
Range	0 to 200 cb
Update Interval	77 to 90 seconds
Current Graph Data	Instant Reading; Daily and Monthly High and Low

Historical Graph Data . . . . . Hourly Readings; Daily and Monthly Highs and Lows
Alarms . . . . . High and Low Thresholds from Instant Reading

Solar Radiation (requires solar radiation sensor)

Resolution and Units . . . . . 1 W/m^2
Range . . . . . 0 to 1800 W/m^2
Accuracy . . . . . ±5% of full scale (Reference: Eppley PSP at 1000 W/m^2)
Drift . . . . . up to ±2% per year
Cosine Response . . . . . ±3% for angle of incidence from 0° to 75°
Temperature Coefficient . . . . . -0.067% per °F (-0.12% per °C); reference temperature = 77°F (25 °C)
Update Interval . . . . . 50 seconds to 1 minute (5 minutes when dark)
Current Graph Data . . . . . Instant Reading and Hourly Average; Daily, Monthly High
Historical Graph Data . . . . . Hourly Average, Daily, Monthly Highs
Alarm . . . . . High Threshold from Instant Reading

Sunrise and Sunset

Resolution . . . . . 1 minute
Accuracy . . . . . ±1 minute
Reference . . . . . United States Naval Observatory

Temperature

Inside Temperature (sensor located in console)

Resolution and Units . . . . . Current Data: 0.1°F or 1°F or 0.1°C or 1°C (user-selectable) °C is converted from °F rounded to the nearest 1°C
Historical Data and Alarms: 1°F or 1°C (user-selectable)
Range . . . . . +32° to +140°F (0° to +60°C)
Sensor Accuracy . . . . . ±1°F (±0.5°C), (see Fig. 1)
Update Interval . . . . . 1 minute
Current Display Data . . . . . Instant (user-adjustable offset available)
Current Graph Data . . . . . Instant Reading; Daily and Monthly High and Low
Historical Graph Data . . . . . Hourly Readings; Daily and Monthly Highs and Lows
Alarms . . . . . High and Low Thresholds from Instant Reading

Outside Temperature (sensor located in ISS)

Resolution and Units . . . . . Current Data: 0.1°F or 1°F or 0.1°C or 1°C (user-selectable) nominal °C is converted from °F rounded to the nearest 1°C Historical Data and Alarms: 1°F or 1°C (user-selectable)
Range . . . . . -40° to +150°F (-40° to +65°C)
Sensor Accuracy . . . . . ±1°F (±0.5°C) above 20°F (-7°C), ±2°F (±1°C) under 20°F (-7°C) (see Fig. 1)
Radiation Induced Error (Passive Shield) . . . . . +4°F (2°C) at solar noon (insolation = 1040 W/m^2, avg. wind speed ≤ 2 mph (1 m/s)) (reference: RM Young Model 43408 Fan-Aspirated Radiation Shield)
Radiation Induced Error (Fan-Aspirated Shield) . . . . . +0.6°F (0.3°C) at solar noon (insolation = 1040 W/m^2, avg. wind speed ≤ 2 mph (1 m/s)) (reference: RM Young Model 43408 Fan-Aspirated Radiation Shield)
Update Interval . . . . . 10 to 12 seconds
Current Display Data . . . . . Instant (user-adjustable offset available)
Current Graph Data . . . . . Instant Reading; Daily, Monthly, Yearly High and Low
Historical Graph Data . . . . . Hourly Readings; Daily, Monthly, Yearly Highs and Lows
Alarms . . . . . High and Low Thresholds from Instant Reading

Extra Temperature Sensors or Probes

Resolution and Units . . . . . Current Data: 1°F or 1°C (user-selectable) °C is converted from °F rounded to the nearest 1°C
Historical Data and Alarms: 1°F or 1°C (user-selectable)
Range . . . . . -40° to +150°F (-40° to +65°C)
Sensor Accuracy . . . . . ±1°F (±0.5°C) above 20°F (-7°C), ±2°F (±1°C) under 20°F (-7°C) (see Fig. 1)
Update Interval . . . . . 10 to 12 seconds (77 to 90 seconds for Leaf Wetness/Temperature and Soil Moisture/Temperature Stations)
Current Display Data . . . . . Instant Reading (user-adjustable offset available)
Alarms . . . . . High and Low Thresholds from Instant Reading

Temperature Humidity Sun Wind Index (requires solar radiation sensor)

Resolution and Units	1°F or 1°C (user-selectable) °C is converted from °F rounded to the nearest 1°C
Range	-90° to +165°F (-68° to +74°C)
Accuracy	±4°F (±2°C) (typical)
Update Interval	10 to 12 seconds
Sources and Formulation Used	United States National Weather Service (NWS)/NOAA Steadman (1979) modified by US NWS/NOAA and Davis Instruments to increase range of use and allow for cold weather use
Variables Used	Instant Outside Temperature, Instant Outside Relative Humidity, 10-minute Average Wind Speed, 10-minute Average Solar Radiation
Formulation Description	Uses Heat Index as base temperature, affects of wind and solar radiation are either added or subtracted from this base to give an overall effective temperature
Current Graph Data	Instant and Hourly Calculation; Daily, Monthly High
Historical Graph Data	Hourly Calculation; Daily, Monthly Highs
Alarm	High Threshold from Instant Reading

Ultra Violet (UV) Radiation Dose (requires UV sensor)

Resolution and Units	0.1 MEDs to 19.9 MEDs; 1 MED above 19.9 MEDS
Range	0 to 199 MEDs
Accuracy	±5% of daily total
Drift	up to ±2% per year
Update Interval	50 seconds to 1 minute (5 minutes when dark)
Current Graph Data	Latest Daily Total (user resetable at any time from Current Screen)
Historical Graph Data	Hourly, Daily Totals (user reset from Current Screen does not affect these values)
Alarm	High Threshold from Daily Total
Alarm Range	0 to 19.9 MEDs

Ultra Violet (UV) Radiation Index (requires UV sensor)

Resolution and Units	0.1 Index
Range	0 to 16 Index
Accuracy	±5% of full scale (Reference: Yankee UVB-1 at UV index 10 (Extremely High))
Cosine Response	±4% FS (0° to 90° zenith angle)
Update Interval	50 seconds to 1 minute (5 minutes when dark)
Current Graph Data	Instant Reading and Hourly Average; Daily, Monthly High
Historical Graph Data	Hourly Average, Daily, Monthly Highs
Alarm	High Threshold from Instant Calculation

Wind

Wind Chill (Calculated)

Resolution and Units	1°F or 1°C (user-selectable) °C is converted from °F rounded to the nearest 1°C
Range	-110° to +135°F (-79° to +57°C)
Accuracy	±2°F (±1°C) (typical)
Update Interval	10 to 12 seconds
Source	United States National Weather Service (NWS)/NOAA
Equation Used	Osczevski (1995) (adopted by US NWS in 2001)
Variables Used	Instant Outside Temperature and 10-min. Avg. Wind Speed
Current Display Data	Instant Calculation
Current Graph Data	Instant Calculation; Hourly, Daily and Monthly Low
Historical Graph Data	Hourly, Daily and Monthly Lows
Alarm	Low Threshold from Instant Calculation

Wind Direction

Range	0 - 360°
Display Resolution	16 points (22.5°) on compass rose, 1° in numeric display
Accuracy	±3°
Update Interval	2.5 to 3 seconds

Current Display Data . . . . Instant (user-adjustable offset available)
Current Graph Data . . . . Instant; 10-min. Dominant; Hourly, Daily, Monthly Dominant
Historical Graph Data . . . . Past 6 10-min. Dominants on compass rose only; Hourly, Daily, Monthly Dominants

Wind Speed

Resolution and Units. . . . . 1 mph, 1 km/h, 0.4 m/s, or 1 knot (user-selectable). Measured in mph, other units are converted from mph and rounded to nearest 1 km/hr, 0.1 m/s, or 1 knot.
Range. . . . . 1 to 200 mph, 1 to 173 knots, 0.5 to 89 m/s, 1 to 322 km/h
Update Interval . . . . Instant Reading: 2.5 to 3 seconds, 10-minute Average: 1 minute
Accuracy . . . . ±2 mph (2 kts, 3 km/h, 1 m/s) or ±5%, whichever is greater
Maximum Cable Length . . . . 240’ (73 m) (See note on page 1)
Current Display Data . . . . Instant
Current Graph Data . . . . Instant; 10-minute and Hourly Average; Hourly High; Daily, Monthly and Yearly High with Direction of High
Historical Graph Data . . . . 10-min. and Hourly Averages; Hourly Highs; Daily, Monthly and Yearly Highs with Direction of Highs
Alarms . . . . High Thresholds from Instant Reading and 10-minute Average

Wireless Communications

Transmit/Receive Frequency

US Models . . . . 902 - 928 MHz FHSS,
EU Models . . . . 868.0 - 868.6 MHz FHSS
Japan Models . . . . 928.15 - 929.65 MHz FHSS
NZ Models . . . . 921 - 928 MHz FHSS
India Models . . . . 865.0 - 867.0 MHz FHSS

ID Codes Available. 8

Output Power

US Models . . . . 902 - 928 MHz FHSS: FCC-certified low power, less than 8 mW, no license required
EU Models . . . . 868.0 - 868.6 MHz FHSS. CE-certified, less than 8 mW, no license required.
Japan Models . . . . 928.15 - 929.65 MHz FHSS, less than 1 mW, no license required.
NZ Models . . . . 921- 928 MHz FHSS, less than 10mW, no license required.
India Models. . . . . 865.0 - 867.0 MHz, less than 10mW, no license required.

Range: All models except Japan

Line of Sight . . . . up to 1000 feet (300 m)
Through Walls . . . . 200 to 400 feet (60 to 120 m)

Range: Japan models

Line of Sight . . . . up to 300 feet (100 m)
Through Walls . . . . 50 to 200 feet (15 to 60m)

Sensor Inputs

RF Filtering. . . . . RC low-pass filter on each signal line

Sensor Charts

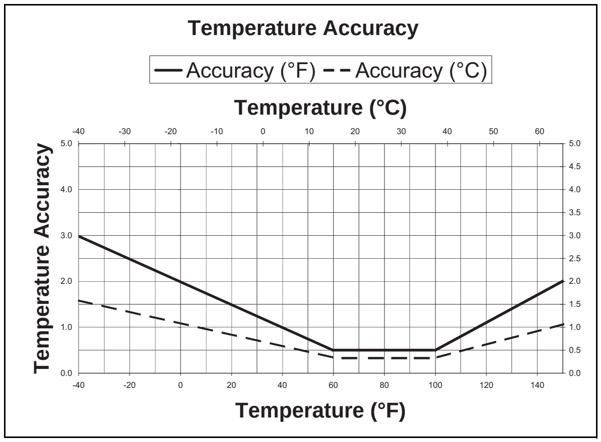


Figure 1. Temperature Accuracy

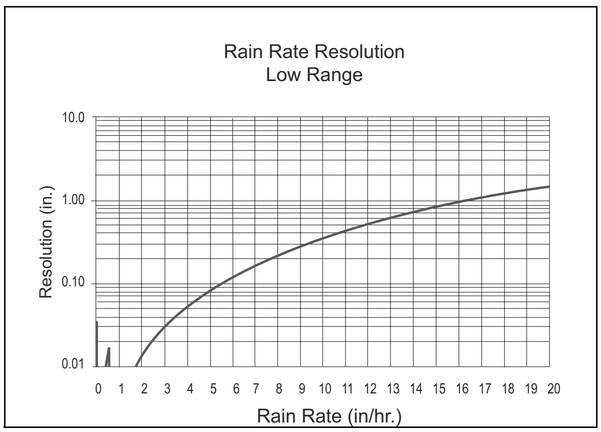


Figure 2. Low Range Rain Rate Resolution

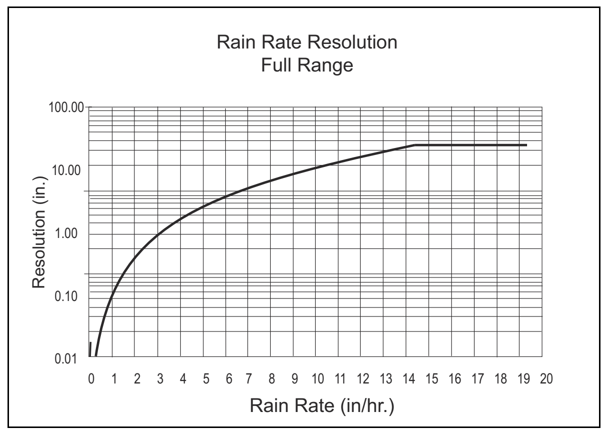


Figure 3. Full Range Rain Rate Resolution

Package Dimensions

Product #	Package Dimensions (Length x Width x Height)	Package Weight	UPC Codes
6152 6152EU 6152UK	17.50" x 10.4" x 16.0" (445 mm x 264 mm x 406 mm)	11 lbs. 13 oz. (5.4 kg)	011698 00229 0 011698 00347 1 011698 00348 8
6162 6162EU 6162UK		11 lbs. 15 oz. (5.4 kg)	011698 00306 8 011698 00307 5 001698 00308 2
6153 6153EU 6153UK	14.9 x 12.9" x 23.4" (378 mm x 327 mm x 594 mm)	16 lbs. 11 oz. (7.6 kg)	011698 00335 8 011698 00336 5 001698 00337 2
6163 6163EU 6163UK		17 lbs. 5 oz. (7.9 kg)	011698 00341 9 011698 00342 6 001698 00342 3
6322 6322OV	17.50" x 10.4" x 16.0" (445 mm x 264 mm x 406 mm)	9 lbs.. 1 oz. (4.1 kg)	011698 00776 9 011698 00778 3
6327 6327OV		11 lbs. 1 oz. (5.0 kg)	011698 00781 3 011698 00783 7
6323 6323OV	14.9" x 12.9" x 23.4" (378 mm x 327 mm x 594 mm	15 lbs. 15 oz. (7.2 kg)	011698 00779 0 011698 00780 6
6328 6328OV		16 lbs. 8 oz. (7.5 kg)	011698 00784 4 011698 00785 1
6312 6312EU 6312UK	12.6" x 9.3" x 2.5" (320 mm x 235 mm x 64 mm)	2 lbs. 10 oz. (1.2 kg)	011698 00724 0 011698 00766 0 011698 00767 7

Appendix 6: Tmrt Calculations

Appendix 6 - Tmrt Calculations

Measurement 1. Albert Hein door (shadow). From 12h50 to 13h10

GPS	53º12'54,26" N
	6º30'3,66" E

12h50	Tg = 27,8º	
	Ta = 23,9º	
	Va = 0,4 m/s	
1.	(27,8+ 273,15)^4	8203088380
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(27,8-23,9)	3,9
6.	4. x 5.	1004835634
7.	1. + 6.	9207924014
8.	7. ^1/4	309,770767
9.	7. - 273,15	**36,6207674**

12h51	Tg = 27,2º	
	Ta = 23,8º	
	Va = 0,4 m/s	
1.	(27,2+ 273,15)^4	8137866201
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(27,2-23,8)	3,4
6.	4. x 5.	876010553
7.	1. + 6.	9013876754
8.	7. ^1/4	308,125686
9.	7. - 273,15	**34,9756863**

Appendix 6 -Tmrt Calculations

12h52	Tg = 26,7º Ta = 23,7º Va = 0,4 m/s	
1.	(26,7+ 273,15)^4	8083812146
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(26,7-23,7)	3
6.	4. x 5.	772950488
7.	1. + 6.	8856762634
8.	7. ^1/4	306,774143
9.	7. - 273,15	**33,6241429**

12h53	Tg = 26,1º Ta = 23,6º Va = 0,0 m/s	
1.	(26,1+ 273,15)^4	8019303244
2.	(1,335 x (10^8)x (0,0^0,71))	0
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	0
5.	(26,1-23,6)	2,5
6.	4. x 5.	0
7.	1. + 6.	8019303244
8.	7. ^1/4	299,25
9.	7. - 273,15	**26,1**

Appendix 6 -Tmrt Calculations

12h54	Tg = 25,6º	
	Ta = 23,6º	
	Va = 0,4 m/s	
1.	(25,6+ 273,15)^4	7965841409
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(25,6-23,6)	2
6.	4. x 5.	515300325
7.	1. + 6.	8481141734
8.	7. ^1/4	303,468474
9.	7. - 273,15	**30,3184736**

12h55	Tg = 25,6º	
	Ta = 23,6º	
	Va = 0,4 m/s	
1.	(25,6+ 273,15)^4	7965841409
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(25,6-23,6)	2
6.	4. x 5.	515300325
7.	1. + 6.	8481141734
8.	7. ^1/4	303,468474
9.	7. - 273,15	**30,3184736**

Appendix 6 -Tmrt Calculations

12h56	Tg = 25,0º	
	Ta = 23,5º	
	Va = 0,4 m/s	
1.	(25,0+ 273,15)^4	7902040564
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(25,0-23,5)	1,5
6.	4. x 5.	386475244
7.	1. + 6.	8288515808
8.	7. ^1/4	301,730486
9.	7. - 273,15	**28,5804862**

12h57	Tg = 25,0º	
	Ta = 23,5º	
	Va = 0,4 m/s	
1.	(25,0+ 273,15)^4	7902040564
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(25,0-23,5)	1,5
6.	4. x 5.	386475244
7.	1. + 6.	8288515808
8.	7. ^1/4	301,730486
9.	7. - 273,15	**28,5804862**

Appendix 6 -Tmrt Calculations

12h58	Tg = 24,4º	
	Ta = 23,6º	
	Va = 0,4 m/s	
1.	(24,4+ 273,15)^4	7838623739
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(24,4-23,6)	0,8
6.	4. x 5.	206120130
7.	1. + 6.	8044743869
8.	7. ^1/4	299,487055
9.	7. - 273,15	**26,3370551**

12h59	Tg = 24,4º	
	Ta = 23,6º	
	Va = 0,4 m/s	
1.	(24,4+ 273,15)^4	7838623739
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(24,4-23,6)	0,8
6.	4. x 5.	206120130
7.	1. + 6.	8044743869
8.	7. ^1/4	299,487055
9.	7. - 273,15	**26,3370551**

Appendix 6 -Tmrt Calculations

13h00	Tg = 24,4º Ta = 23,6º Va = 0,4 m/s	
1.	(24,4+ 273,15)^4	7838623739
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(24,4-23,6)	0,8
6.	4. x 5.	206120130
7.	1. + 6.	8044743869
8.	7. ^1/4	299,487055
9.	7. - 273,15	**26,3370551**

13h01	Tg = 23,9º Ta = 23,6º Va = 0,4 m/s	
1.	(23,9+ 273,15)^4	7786068619
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(23,9-23,6)	0,3
6.	4. x 5.	77295048,8
7.	1. + 6.	7863363668
8.	7. ^1/4	297,784501
9.	7. - 273,15	**24,6345013**

Appendix 6 -Tmrt Calculations

13h02	Tg = 23,9º	
	Ta = 23,6º	
	Va = 0,4 m/s	
1.	(23,9+ 273,15)^4	7786068619
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(23,9-23,6)	0,3
6.	4. x 5.	77295048,8
7.	1. + 6.	7863363668
8.	7. ^1/4	297,784501
9.	7. - 273,15	**24,6345013**

13h03	Tg = 23,9º	
	Ta = 23,5º	
	Va = 0,4 m/s	
1.	(23,9+ 273,15)^4	7786068619
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(23,9-23,5)	0,4
6.	4. x 5.	103060065
7.	1. + 6.	7889128684
8.	7. ^1/4	298,028132
9.	7. - 273,15	**24,8781315**

Appendix 6 -Tmrt Calculations

13h04	Tg = 23,9º	
	Ta = 23,6º	
	Va = 0,4 m/s	
1.	(23,9+ 273,15)^4	7786068619
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(23,9-23,6)	0,3
6.	4. x 5.	77295048,8
7.	1. + 6.	7863363668
8.	7. ^1/4	297,784501
9.	7. - 273,15	**24,6345013**

13h05	Tg = 23,9º	
	Ta = 23,6º	
	Va = 0,4 m/s	
1.	(23,9+ 273,15)^4	7786068619
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(23,9-23,6)	0,3
6.	4. x 5.	77295048,8
7.	1. + 6.	7863363668
8.	7. ^1/4	297,784501
9.	7. - 273,15	**24,6345013**

Appendix 6 -Tmrt Calculations

13h06	Tg = 23,9º	
	Ta = 23,6º	
	Va = 0,4 m/s	
1.	(23,9+ 273,15)^4	7786068619
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(23,9-23,6)	0,3
6.	4. x 5.	77295048,8
7.	1. + 6.	7863363668
8.	7. ^1/4	297,784501
9.	7. - 273,15	**24,6345013**

13h07	Tg = 23,9º	
	Ta = 23,5º	
	Va = 0,0 m/s	
1.	(23,9+ 273,15)^4	7786068619
2.	(1,335 x (10^8)x (0,0^0,71))	0
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	0
5.	(23,9-23,5)	0,4
6.	4. x 5.	0
7.	1. + 6.	7786068619
8.	7. ^1/4	297,05
9.	7. - 273,15	**23,9**

Appendix 6 -Tmrt Calculations

13h08	Tg = 23,9º	
	Ta = 23,5º	
	Va = 0,4 m/s	
1.	(23,9+ 273,15)^4	7786068619
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(23,9-23,5)	0,4
6.	4. x 5.	103060065
7.	1. + 6.	7889128684
8.	7. ^1/4	298,028132
9.	7. - 273,15	**24,8781315**

13h09	Tg = 23,9º	
	Ta = 23,6º	
	Va = 0,4 m/s	
1.	(23,9+ 273,15)^4	7786068619
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(23,9-23,6)	0,3
6.	4. x 5.	77295048,8
7.	1. + 6.	7863363668
8.	7. ^1/4	297,784501
9.	7. - 273,15	**24,6345013**

Appendix 6 -Tmrt Calculations

13h10	Tg = 23,9º Ta = 23,5º Va = 0,4 m/s	
1.	(23,9+ 273,15)^4	7786068619
2.	(1,335 x (10^8)x (0,4^0,71))	69653646,8
3.	(0,95 x 0,04)^0,4	0,27034195
4.	2./3.	257650163
5.	(23,9-23,5)	0,4
6.	4. x 5.	103060065
7.	1. + 6.	7889128684
8.	7. ^1/4	298,028132
9.	7. - 273,15	**24,8781315**

Average 21 mins	**25,69**
Average last 16 mins	**25,80**

Appendix 7: Questionnaires

Appendix 6 - Questionnaire

1	Albert Hein Door

1.	**General information:**	
a.	Time	13h00
b.	Location: coordinates, in the shade/sun, near weather station	Albert Hein - Shadow - Next to WS
c.	Name interviewer	J.Tipping
2.	**Persoonlijke Informatie**	
a.	Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b.	Gender	m / f
c.	Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d.	Activity level	sitting, standing, walking, running
e.	Home country/How long have you been in the NL?	The Netherlands
f.	Thermal history	
	i. For how long how are you at this specific location?	5 minutes
	ii. Where did you come from?	Groningen
	iii. Were you outdoors 5 minutes ago?	Ja
3.	**Thermal perception**	
a.	How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b.	What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c.	What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d.	What do you think of the humidity at this moment?	Damp/OK/Dry
4.	**Thermal comfort**	
a.	Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5.	**Thermische voorkeur**	
a.	How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

Appendix 6 - Questionnaire

1	Albert Hein Door

1.	**General information:**	
a.	Time	13h05
b.	Location: coordinates, in the shade/sun, near weather station	Albert Hein - Shadow - Next to WS
c.	Name interviewer	Alba Castellano
2.	**Persoonlijke Informatie**	
a.	Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b.	Gender	m / f
c.	Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d.	Activity level	sitting, standing, walking, running
e.	Home country/How long have you been in the NL?	40 years
f.	Thermal history	
	i. For how long how are you at this specific location?	1 minute
	ii. Where did you come from?	Groningen
	iii. Were you outdoors 5 minutes ago?	Ja
3.	**Thermal perception**	
a.	How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b.	What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c.	What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d.	What do you think of the humidity at this moment?	Damp/OK/Dry
4.	**Thermal comfort**	
a.	Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5.	**Thermische voorkeur**	
a.	How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

1	Albert Hein Door

1. General information:	
a. Time	13h05
b. Location: coordinates, in the shade/sun, near weather station	Albert Hein - Shadow - Next to WS
c. Name interviewer	Alba Castellano
2. Persoonlijke Informatie	
a. Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b. Gender	m / f
c. Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d. Activity level	sitting, standing, walking, running
e. Home country/How long have you been in the NL?	My whole life
f. Thermal history	
i. For how long how are you at this specific location?	1 minute
ii. Where did you come from?	Groningen
iii. Were you outdoors 5 minutes ago?	Ja
3. Thermal perception	
a. How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b. What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c. What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d. What do you think of the humidity at this moment?	Damp/OK/Dry
4. Thermal comfort	
a. Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5. Thermische voorkeur	
a. How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

------ *Appendix 6 - Questionnaire*

1	Albert Hein Door

1. General information:	
a. Time	13h09
b. Location: coordinates, in the shade/sun, near weather station	Albert Hein - Shadow - Next to WS
c. Name interviewer	J. Tipping
2. Persoonlijke Informatie	
a. Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b. Gender	m / f
c. Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d. Activity level	sitting, standing, walking, running
e. Home country/How long have you been in the NL?	21 years
f. Thermal history	
i. For how long how are you at this specific location?	5 minutes
ii. Where did you come from?	Hoogkerk
iii. Were you outdoors 5 minutes ago?	Ja
3. Thermal perception	
a. How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b. What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c. What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d. What do you think of the humidity at this moment?	Damp/OK/Dry
4. Thermal comfort	
a. Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5. Thermische voorkeur	
a. How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

Appendix 6 - Questionnaire

1	Albert Hein Door

1. General information:	
a. Time	13h12
b. Location: coordinates, in the shade/sun, near weather station	Albert Hein - Shadow - Next to WS
c. Name interviewer	J. Tipping
2. Persoonlijke Informatie	
a. Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b. Gender	m / f
c. Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d. Activity level	sitting, standing, walking, running
e. Home country/How long have you been in the NL?	The Netherlands
f. Thermal history	
i. For how long how are you at this specific location?	1 minute
ii. Where did you come from?	Zwembad
iii. Were you outdoors 5 minutes ago?	Ja
3. Thermal perception	
a. How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b. What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c. What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d. What do you think of the humidity at this moment?	Damp/OK/Dry
4. Thermal comfort	
a. Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5. Thermische voorkeur	
a. How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

1	Albert Hein Door

1.	**General information:**	
a.	Time	13h19
b.	Location: coordinates, in the shade/sun, near weather station	Albert Hein - Shadow - Next to WS
c.	Name interviewer	J. Tipping
2.	**Persoonlijke Informatie**	
a.	Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b.	Gender	m / f
c.	Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d.	Activity level	sitting, standing, walking, running
e.	Home country/How long have you been in the NL?	65
f.	Thermal history	
	i. For how long how are you at this specific location?	30 minutes
	ii. Where did you come from?	Holland
	iii. Were you outdoors 5 minutes ago?	Ja
3.	**Thermal perception**	
a.	How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b.	What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c.	What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d.	What do you think of the humidity at this moment?	Damp/OK/Dry
4.	**Thermal comfort**	
a.	Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5.	**Thermische voorkeur**	
a.	How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

1	Albert Hein Door

1. General information:	
a. Time	13h21
b. Location: coordinates, in the shade/sun, near weather station	Albert Hein - Shadow - Next to WS
c. Name interviewer	J. Tipping
2. Persoonlijke Informatie	
a. Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b. Gender	m / f
c. Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d. Activity level	sitting, standing, walking, running
e. Home country/How long have you been in the NL?	The Netherlands
f. Thermal history	
i. For how long how are you at this specific location?	5 minutes
ii. Where did you come from?	Hoogkerk
iii. Were you outdoors 5 minutes ago?	Ja
3. Thermal perception	
a. How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b. What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c. What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d. What do you think of the humidity at this moment?	Damp/OK/Dry
4. Thermal comfort	
a. Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5. Thermische voorkeur	
a. How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

------ *Appendix 6 - Questionnaire*

1	Albert Hein Door

1.	**General information:**	
a.	Time	13h34
b.	Location: coordinates, in the shade/sun, near weather station	Albert Hein - Shadow - Next to WS
c.	Name interviewer	J. Tipping
2.	**Persoonlijke Informatie**	
a.	Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b.	Gender	m / f
c.	Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d.	Activity level	sitting, standing, walking, running
e.	Home country/How long have you been in the NL?	60 years
f.	Thermal history	
	i. For how long how are you at this specific location?	10 minutes
	ii. Where did you come from?	Groningen
	iii. Were you outdoors 5 minutes ago?	Ja
3.	**Thermal perception**	
a.	How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b.	What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c.	What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d.	What do you think of the humidity at this moment?	Damp/OK/Dry
4.	**Thermal comfort**	
a.	Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5.	**Thermische voorkeur**	
a.	How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

Appendix 6 - Questionnaire

1	Albert Hein Door

1.	**General information:**	
a.	Time	13h40
b.	Location: coordinates, in the shade/sun, near weather station	Albert Hein - Shadow - Next to WS
c.	Name interviewer	J. Tipping
2.	**Persoonlijke Informatie**	
a.	Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b.	Gender	m / f
c.	Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d.	Activity level	sitting, standing, walking, running
e.	Home country/How long have you been in the NL?	
f.	Thermal history	
	i. For how long how are you at this specific location?	2 minutes
	ii. Where did you come from?	A.H. Winkel
	iii. Were you outdoors 5 minutes ago?	No
3.	**Thermal perception**	
a.	How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b.	What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c.	What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d.	What do you think of the humidity at this moment?	Damp/OK/Dry
4.	**Thermal comfort**	
a.	Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5.	**Thermische voorkeur**	
a.	How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

------ *Appendix 6 - Questionnaire*

1	Albert Hein Door

1.	**General information:**	
a.	Time	13h45
b.	Location: coordinates, in the shade/sun, near weather station	Albert Hein - Shadow - Next to WS
c.	Name interviewer	J. Tipping
2.	**Persoonlijke Informatie**	
a.	Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b.	Gender	m / f
c.	Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d.	Activity level	sitting, standing, walking, running (Bicycle)
e.	Home country/How long have you been in the NL?	The Netherlands
f.	Thermal history	
	i. For how long how are you at this specific location?	1 minute
	ii. Where did you come from?	Hoogkerk
	iii. Were you outdoors 5 minutes ago?	Ja
3.	**Thermal perception**	
a.	How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b.	What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c.	What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d.	What do you think of the humidity at this moment?	Damp/OK/Dry
4.	**Thermal comfort**	
a.	Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5.	**Thermische voorkeur**	
a.	How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

2	Parking alot

1.	**General information:**	
a.	Time	13h30
b.	Location: coordinates, in the shade/sun, near weather station	Parking alot - In front Sugar factory
c.	Name interviewer	Alba Castellano
2.	**Persoonlijke Informatie**	
a.	Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b.	Gender	m / f
c.	Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d.	Activity level	sitting, standing, walking, running
e.	Home country/How long have you been in the NL?	66 years
f.	Thermal history	
	i. For how long how are you at this specific location?	5 minutes
	ii. Where did you come from?	Hoogkerk
	iii. Were you outdoors 5 minutes ago?	Ja
3.	**Thermal perception**	
a.	How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b.	What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c.	What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d.	What do you think of the humidity at this moment?	Damp/OK/Dry
4.	**Thermal comfort**	
a.	Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5.	**Thermische voorkeur**	
a.	How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

2	Parking alot

1.	**General information:**	
a.	Time	13h30
b.	Location: coordinates, in the shade/sun, near weather station	Parking alot - In front Sugar factory
c.	Name interviewer	Alba Castellano
2.	**Persoonlijke Informatie**	
a.	Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b.	Gender	m / f
c.	Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d.	Activity level	sitting, standing, walking, running
e.	Home country/How long have you been in the NL?	72 years
f.	Thermal history	
	i. For how long how are you at this specific location?	5 minutes
	ii. Where did you come from?	Hoogkerk
	iii. Were you outdoors 5 minutes ago?	Ja
3.	**Thermal perception**	
a.	How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b.	What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c.	What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d.	What do you think of the humidity at this moment?	Damp/OK/Dry
4.	**Thermal comfort**	
a.	Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5.	**Thermische voorkeur**	
a.	How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

3	Famoda For Kids Door

1.	**General information:**	
a.	Time	14h00
b.	Location: coordinates, in the shade/sun, near weather station	Famoda For Kids door
c.	Name interviewer	Alba Castellano
2.	**Persoonlijke Informatie**	
a.	Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b.	Gender	m / f
c.	Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d.	Activity level	sitting, standing, walking, running
e.	Home country/How long have you been in the NL?	56 years
f.	Thermal history	
	i. For how long how are you at this specific location?	5 minutes
	ii. Where did you come from?	Groningen
	iii. Were you outdoors 5 minutes ago?	Ja
3.	**Thermal perception**	
a.	How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b.	What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c.	What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d.	What do you think of the humidity at this moment?	Damp/OK/Dry
4.	**Thermal comfort**	
a.	Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5.	**Thermische voorkeur**	
a.	How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

Appendix 6 - Questionnaire

3	Famoda For Kids Door

1.	**General information:**	
a.	Time	14h00
b.	Location: coordinates, in the shade/sun, near weather station	Famoda For Kids door
c.	Name interviewer	Alba Castellano
2.	**Persoonlijke Informatie**	
a.	Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b.	Gender	m / f
c.	Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d.	Activity level	sitting, standing, walking, running
e.	Home country/How long have you been in the NL?	23 years
f.	Thermal history	
	i. For how long how are you at this specific location?	5 minutes
	ii. Where did you come from?	Go shopping
	iii. Were you outdoors 5 minutes ago?	Ja
3.	**Thermal perception**	
a.	How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b.	What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c.	What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d.	What do you think of the humidity at this moment?	Damp/OK/Dry
4.	**Thermal comfort**	
a.	Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5.	**Thermische voorkeur**	
a.	How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

3	Famoda For Kids Door

1.	**General information:**	
a.	Time	14h12
b.	Location: coordinates, in the shade/sun, near weather station	Famoda For Kids door
c.	Name interviewer	Alba Castellano
2.	**Persoonlijke Informatie**	
a.	Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b.	Gender	m / f
c.	Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d.	Activity level	sitting, standing, walking, running
e.	Home country/How long have you been in the NL?	28 years
f.	Thermal history	
	i. For how long how are you at this specific location?	5 minutes
	ii. Where did you come from?	Hoogkerk
	iii. Were you outdoors 5 minutes ago?	Ja
3.	**Thermal perception**	
a.	How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b.	What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c.	What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d.	What do you think of the humidity at this moment?	Damp/OK/Dry
4.	**Thermal comfort**	
a.	Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5.	**Thermische voorkeur**	
a.	How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

4	Tree water environment

1.	**General information:**	
a.	Time	14h17
b.	Location: coordinates, in the shade/sun, near weather station	Tree shadow water environment
c.	Name interviewer	Alba Castellano
2.	**Persoonlijke Informatie**	
a.	Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b.	Gender	m / f
c.	Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d.	Activity level	sitting, standing, walking, running (relaxing)
e.	Home country/How long have you been in the NL?	61 years
f.	Thermal history	
	i. For how long how are you at this specific location?	2hours 30 minutes
	ii. Where did you come from?	Groningen
	iii. Were you outdoors 5 minutes ago?	No
3.	**Thermal perception**	
a.	How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot (Nice)
b.	What do you think of the sun at this moment:	I prefer more/OK/Too much sun (Nice)
c.	What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind (Nice)
d.	What do you think of the humidity at this moment?	Damp/OK/Dry
4.	**Thermal comfort**	
a.	Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5.	**Thermische voorkeur**	
a.	How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

5	Tennis field

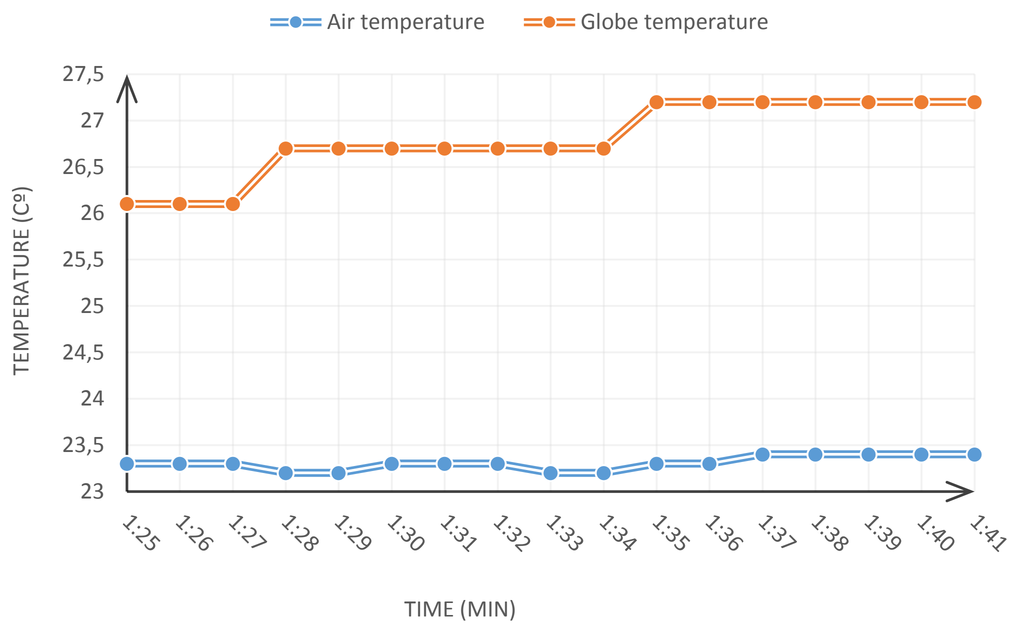
1.	**General information:**	
a.	Time	16h09
b.	Location: coordinates, in the shade/sun, near weather station	Tennis field
c.	Name interviewer	Alba Castellano
2.	**Persoonlijke Informatie**	
a.	Age	10-20, 20-30, 30-40, 40-50, 50-60, 60-70, 70+
b.	Gender	m / f
c.	Clothing	jacket, sweater, shirt, t-shirt / pants, short pants, skirt
d.	Activity level	sitting, standing, walking, running
e.	Home country/How long have you been in the NL?	Always
f.	Thermal history	
	i. For how long how are you at this specific location?	1 minute
	ii. Where did you come from?	Home
	iii. Were you outdoors 5 minutes ago?	Ja
3.	**Thermal perception**	
a.	How do you feel now?	Cold/Cool/Slightly cool/Neutral/Slightly warm/Warm/Hot
b.	What do you think of the sun at this moment:	I prefer more/OK/Too much sun
c.	What do you think of the wind at this moment?	Stale/Little wind/OK/windy/too much wind
d.	What do you think of the humidity at this moment?	Damp/OK/Dry
4.	**Thermal comfort**	
a.	Do you find this environment themally comfortable?	Comfortable/Slightly comfortable/Uncomfortable/Very uncomfortable
5.	**Thermische voorkeur**	
a.	How would you prefer it to be now?	Much cooler, Cooler, Slightly cooler, Equal, A little warmer, Much warmer.

Appendix 8: Graphs results

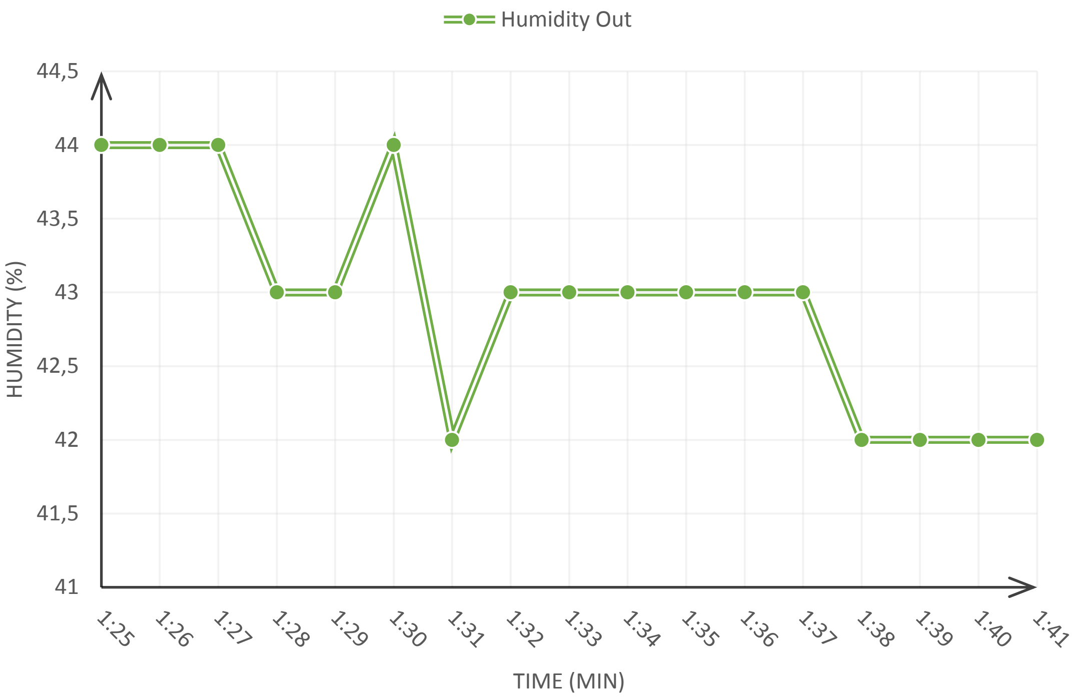
8.1.1.2. Measurement 2: Parking lot (17 minutes)

Date	Time	Air Temp.	Out Hum	Wind Speed	Hi Solar Rad.	Globe Temp.	Tmrt
05/11/2015	1:25 PM	23,3	44	4,0	786	26,1	55,87
05/11/2015	1:26 PM	23,3	44	4,0	788	26,1	55,87
05/11/2015	1:27 PM	23,3	44	3,6	796	26,1	53,98
05/11/2015	1:28 PM	23,2	43	5,4	824	26,7	69,64
05/11/2015	1:29 PM	23,2	43	3,1	830	26,7	57,43
05/11/2015	1:30 PM	23,3	44	3,6	738	26,7	59,55
05/11/2015	1:31 PM	23,3	42	4,5	738	26,7	64,31
05/11/2015	1:32 PM	23,3	43	4,9	849	26,7	66,27
05/11/2015	1:33 PM	23,2	43	4,5	821	26,7	65,24
05/11/2015	1:34 PM	23,2	43	4,9	849	26,7	67,24
05/11/2015	1:35 PM	23,3	43	3,1	863	27,2	60,80
05/11/2015	1:36 PM	23,3	43	4,0	842	27,2	66,39
05/11/2015	1:37 PM	23,4	43	4,0	838	27,2	65,54
05/11/2015	1:38 PM	23,4	42	4,5	838	27,2	68,33
05/11/2015	1:39 PM	23,4	42	4,9	838	27,2	70,44
05/11/2015	1:40 PM	23,4	42	6,3	849	27,2	77,22
05/11/2015	1:41 PM	23,4	42	5,4	849	27,2	72,97

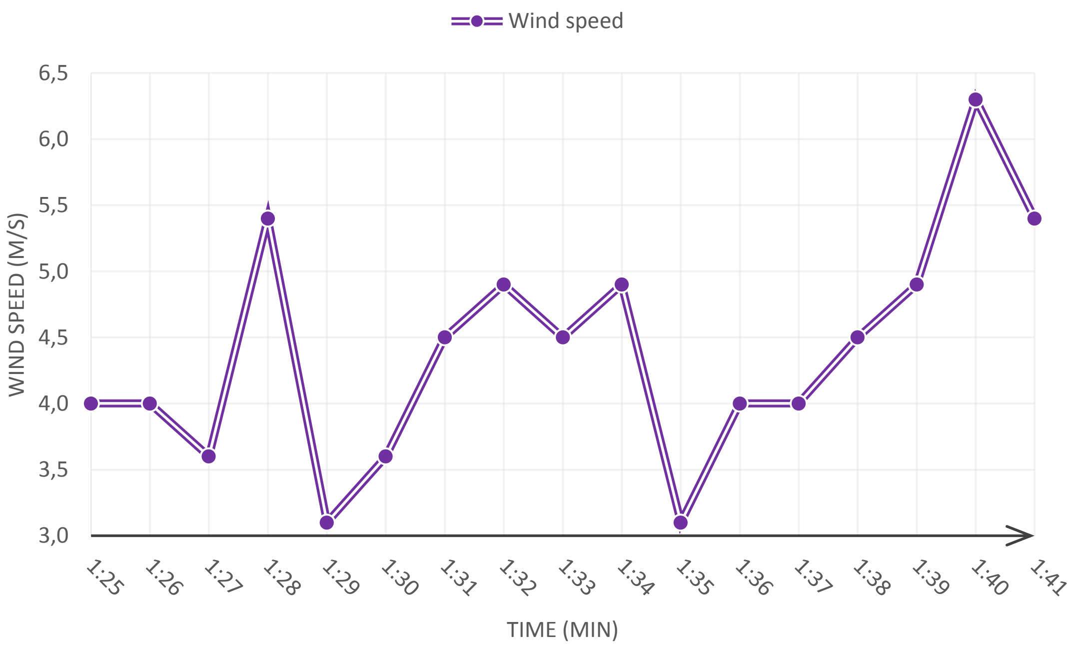
a) Air temperature and Globe temperature graph



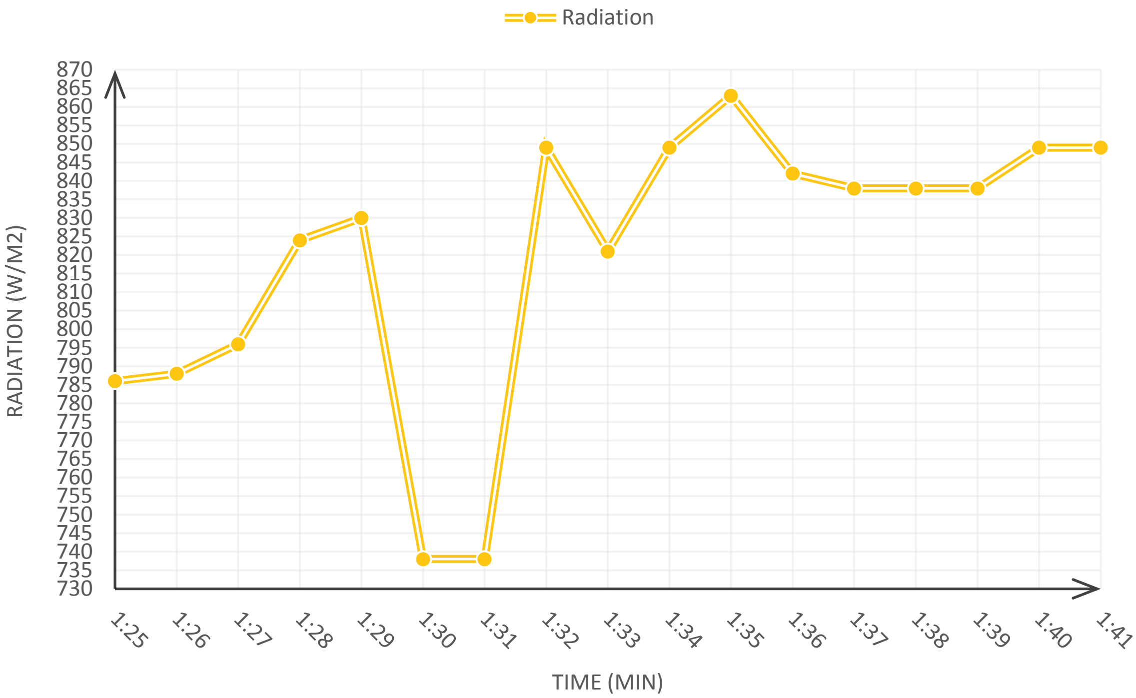
b) Humidity out graph



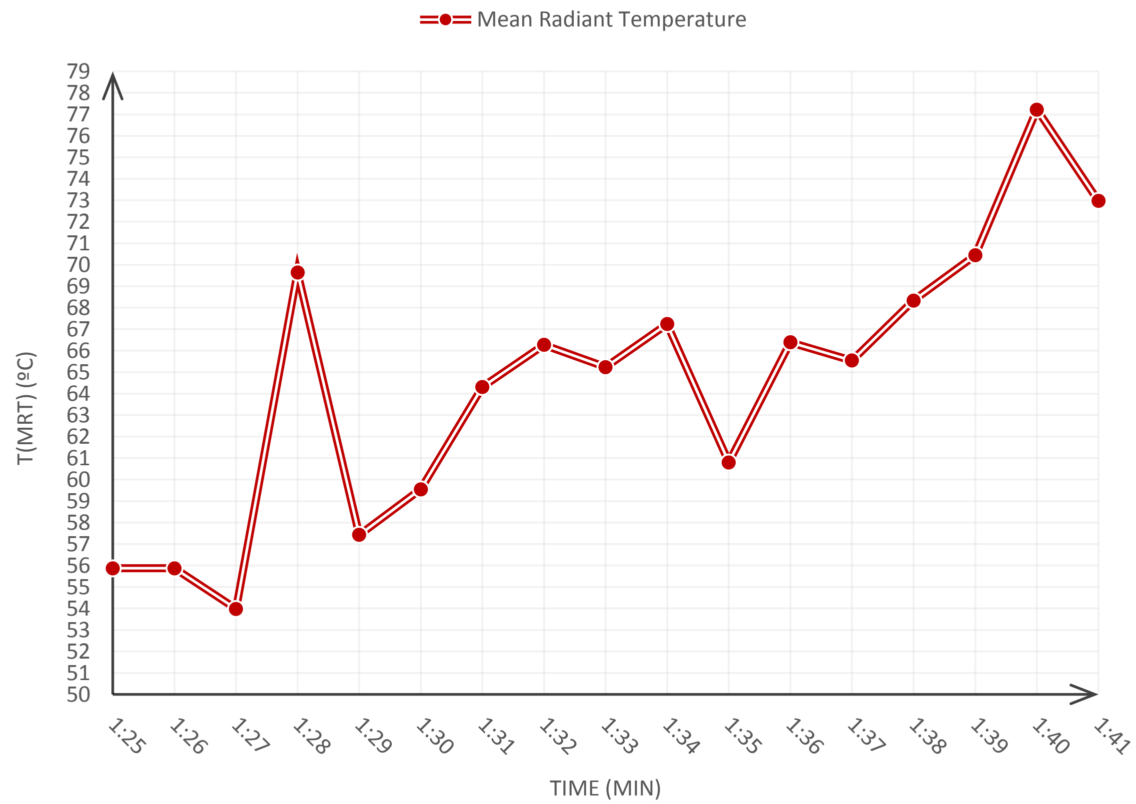
c) Wind Speed graph



d) High Solar Radiation graph



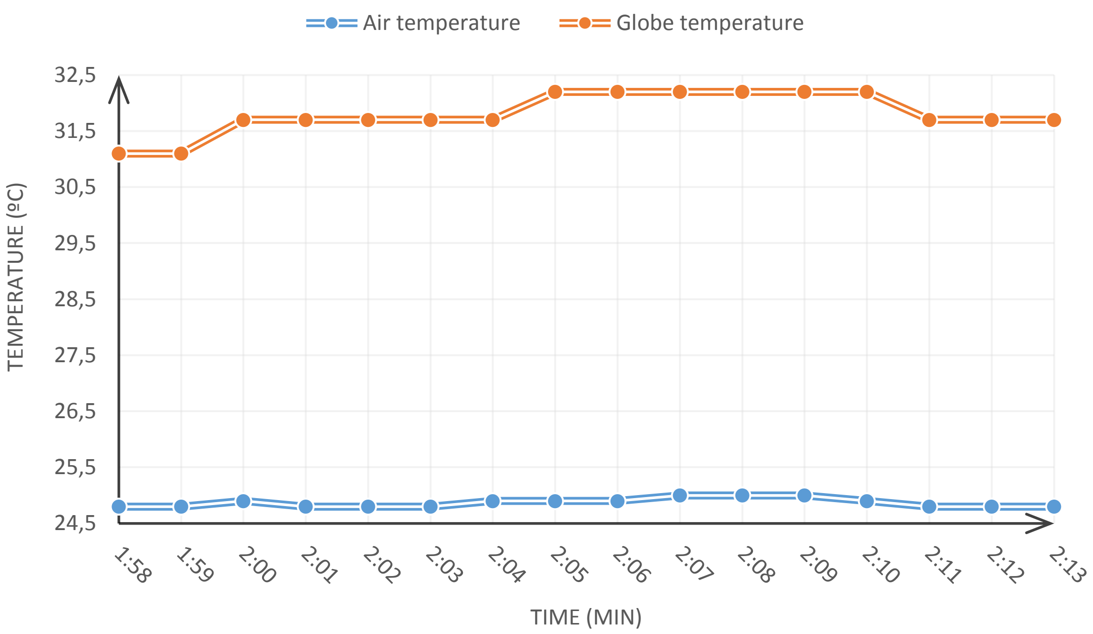
e) Mean Radiant Temperature graph



8.1.1.3. Measurement 3: "Famoda for Kids" (16 minutes)

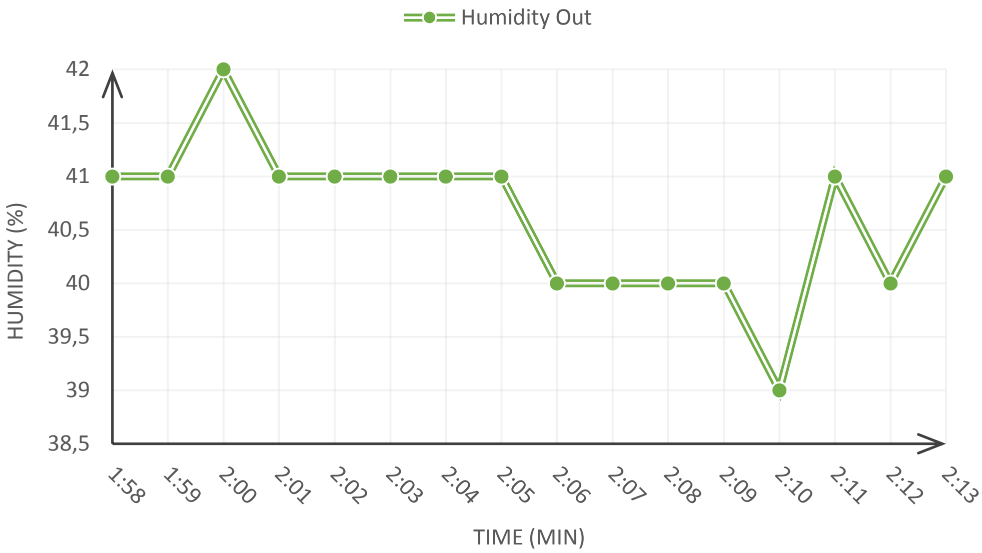
Date	Time	Air Temp.	Out Hum	Wind Speed	Hi Solar Rad.	Globe Temp.	Tmrt
05/11/2015	1:58 PM	24,8	41	0,4	779	31,1	44,58
05/11/2015	1:59 PM	24,8	41	0,9	802	31,1	54,01
05/11/2015	2:00 PM	24,9	42	1,3	814	31,7	62,43
05/11/2015	2:01 PM	24,8	41	1,3	789	31,7	62,82
05/11/2015	2:02 PM	24,8	41	1,8	798	31,7	69,65
05/11/2015	2:03 PM	24,8	41	0,9	788	31,7	56,43
05/11/2015	2:04 PM	24,9	41	0,4	795	31,7	46,11
05/11/2015	2:05 PM	24,9	41	0,4	816	32,2	47,52
05/11/2015	2:06 PM	24,9	40	0,9	789	32,2	58,09
05/11/2015	2:07 PM	25	40	0,9	810	32,2	57,77
05/11/2015	2:08 PM	25	40	1,3	779	32,2	64,36
05/11/2015	2:09 PM	25	40	1,8	768	32,2	71,38
05/11/2015	2:10 PM	24,9	39	1,3	765	32,2	64,75
05/11/2015	2:11 PM	24,8	41	0,9	788	31,7	56,43
05/11/2015	2:12 PM	24,8	40	0,9	788	31,7	56,43
05/11/2015	2:13 PM	24,8	41	0,9	784	31,7	56,43

a) Air temperature and Globe temperature graph

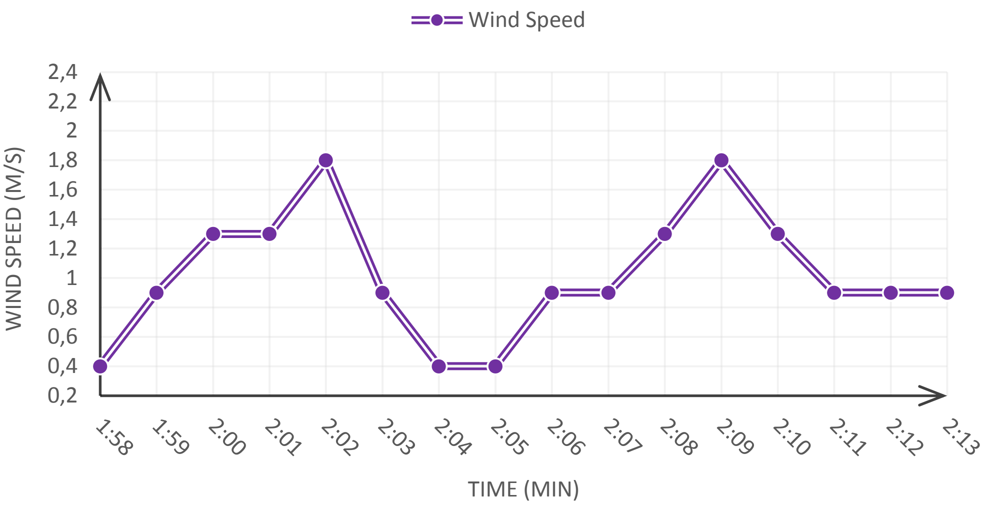


Appendix 8 – Graphs results

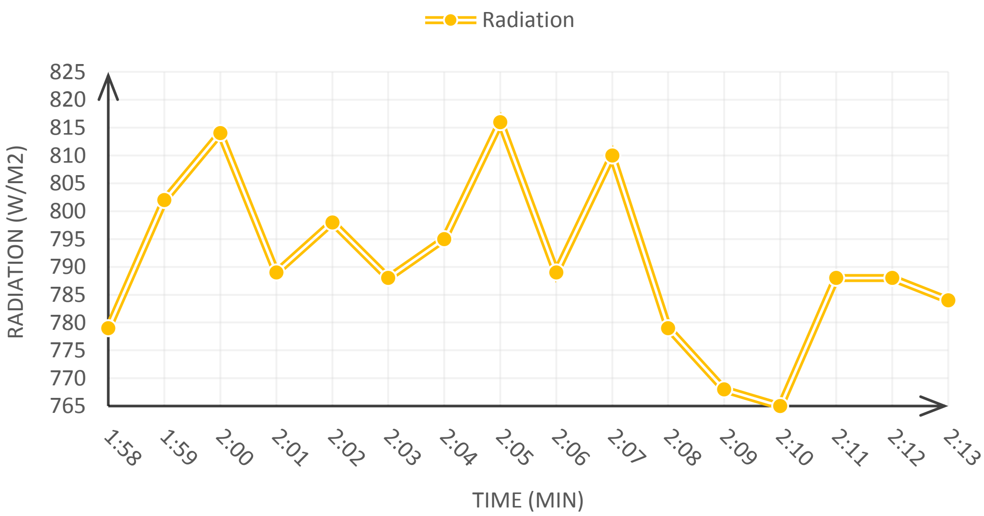
b) Humidity Out graph



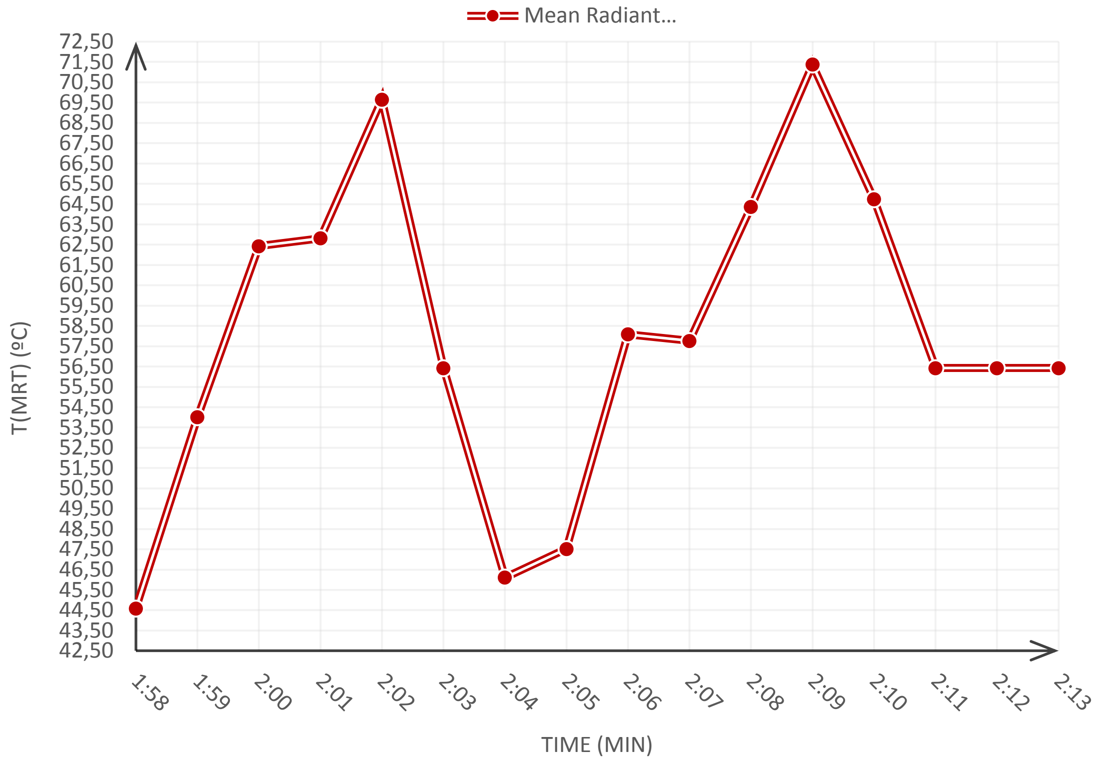
c) Wind Speed graph



d) High Solar Radiation graph



e) Mean Radiant Temperature graph

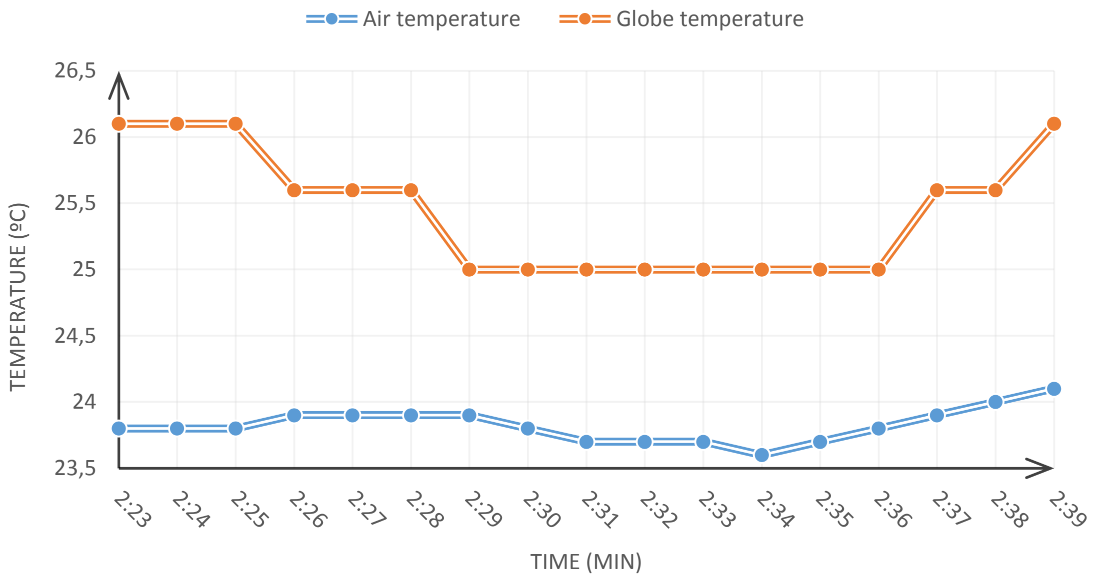


8.1.1.4. Measurement 4: Water environment (shade) (17 minutes)

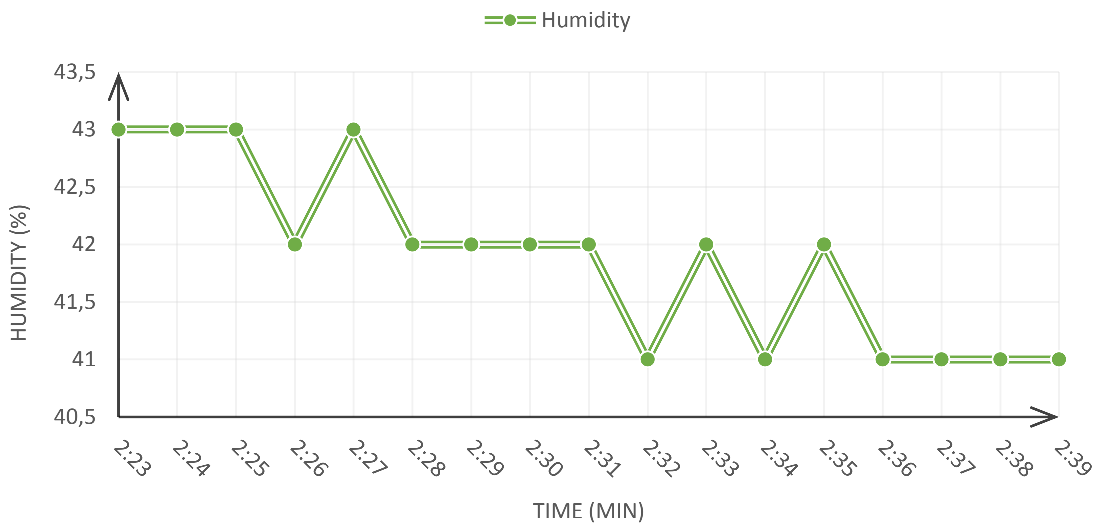
Date	Time	Temp Out	Out Hum	Wind Speed	Hi Solar Rad.	Temp 2nd	Tmrt
05/11/2015	2:23 PM	23,8	43	1,3	60	26,1	38,12
05/11/2015	2:24 PM	23,8	43	0,9	63	26,1	35,48
05/11/2015	2:25 PM	23,8	43	1,3	63	26,1	38,12
05/11/2015	2:26 PM	23,9	42	1,8	63	25,6	36,89
05/11/2015	2:27 PM	23,9	43	1,3	63	25,6	34,66
05/11/2015	2:28 PM	23,9	42	0,9	60	25,6	32,65
05/11/2015	2:29 PM	23,9	42	0,9	74	25	29,64
05/11/2015	2:30 PM	23,8	42	1,3	70	25	31,52
05/11/2015	2:31 PM	23,7	42	1,8	70	25	33,79
05/11/2015	2:32 PM	23,7	41	1,8	70	25	33,79
05/11/2015	2:33 PM	23,7	42	0,9	244	25	30,47
05/11/2015	2:34 PM	23,6	41	1,3	290	25	32,56
05/11/2015	2:35 PM	23,7	42	1,3	353	25	32,04
05/11/2015	2:36 PM	23,8	41	1,3	353	25	31,52
05/11/2015	2:37 PM	23,9	41	1,3	306	25,6	34,66
05/11/2015	2:38 PM	24	41	0,4	362	25,6	29,39
05/11/2015	2:39 PM	24,1	41	0,4	362	26,1	30,79

Appendix 8 – Graphs results

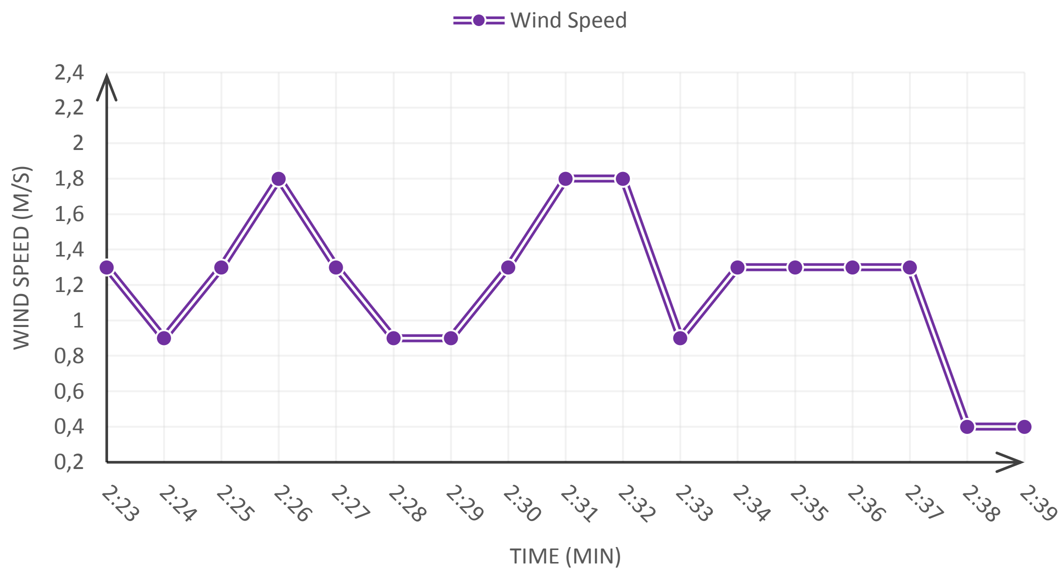
a) Air temperature and Globe temperature graph



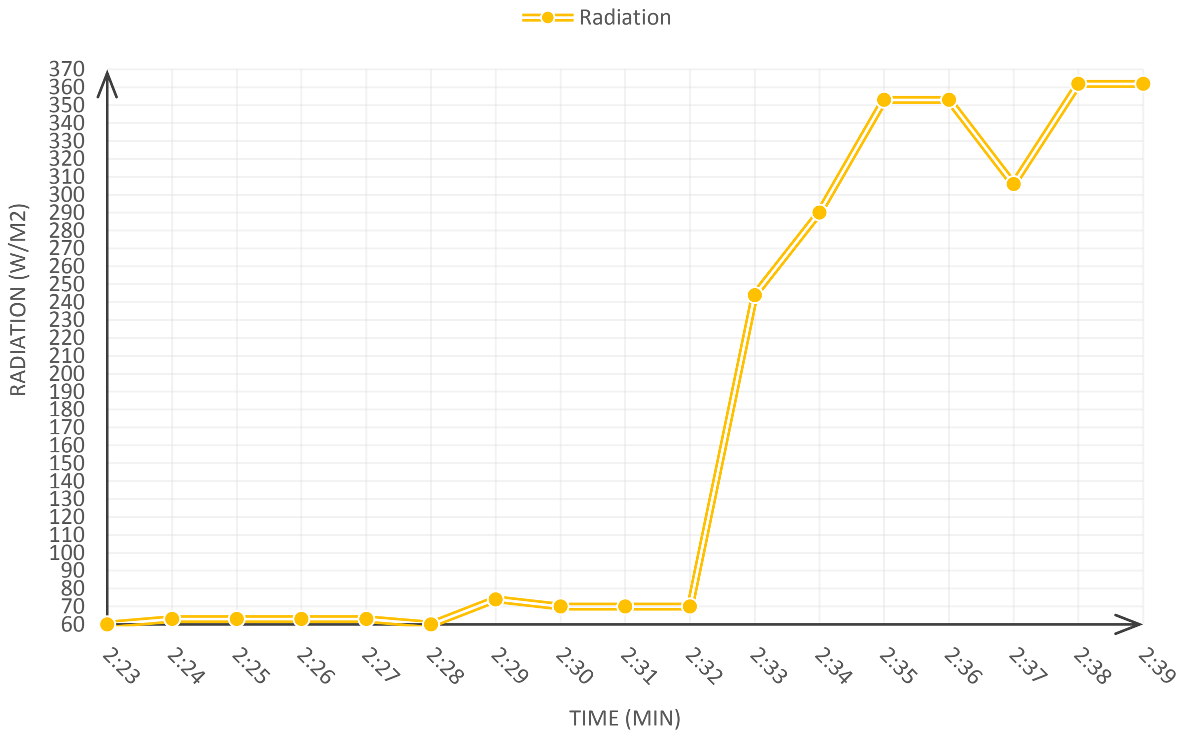
b) Humidity Out graph



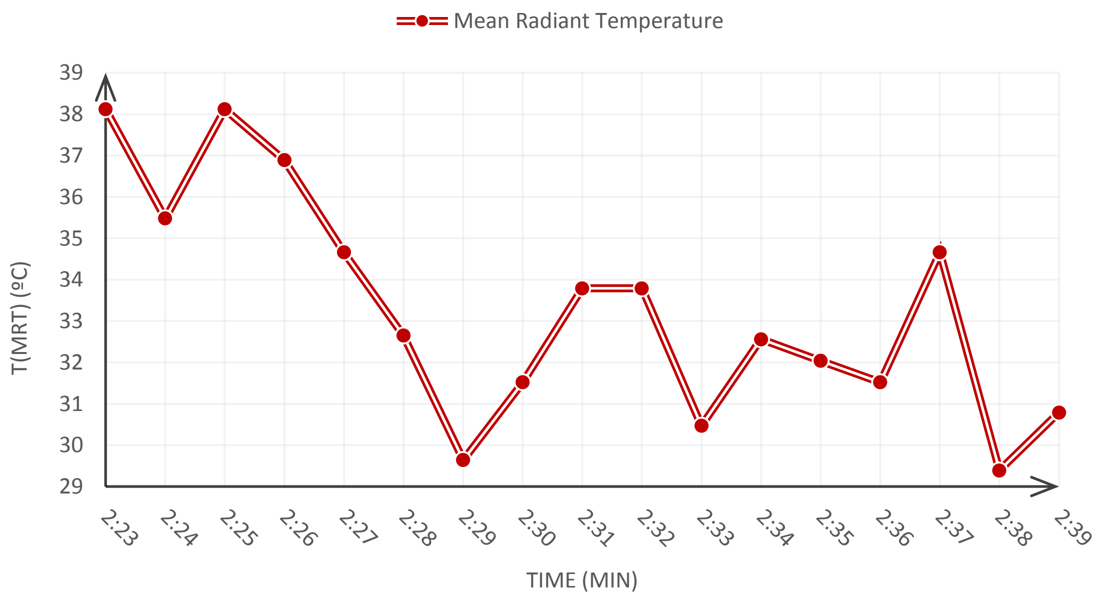
c) Wind speed graph



d) High Solar Radiation graph



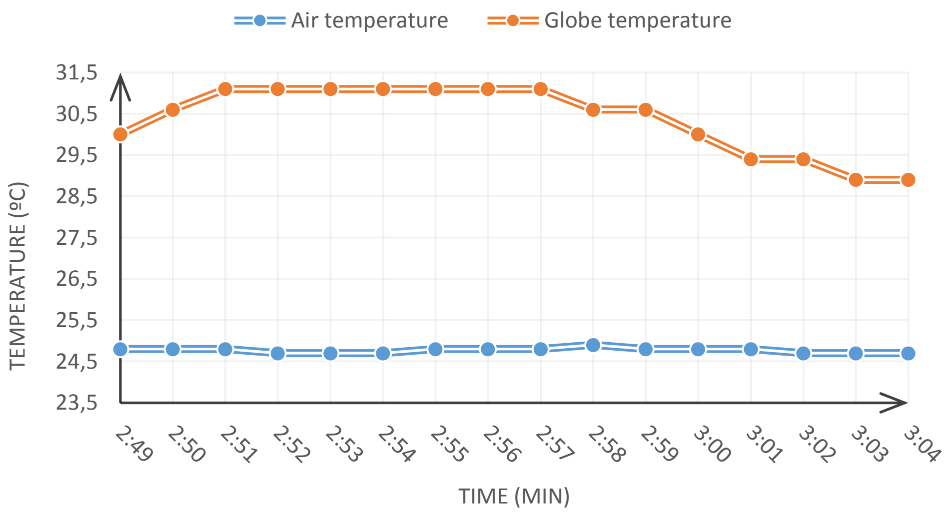
e) Mean Radiant Temperature graph



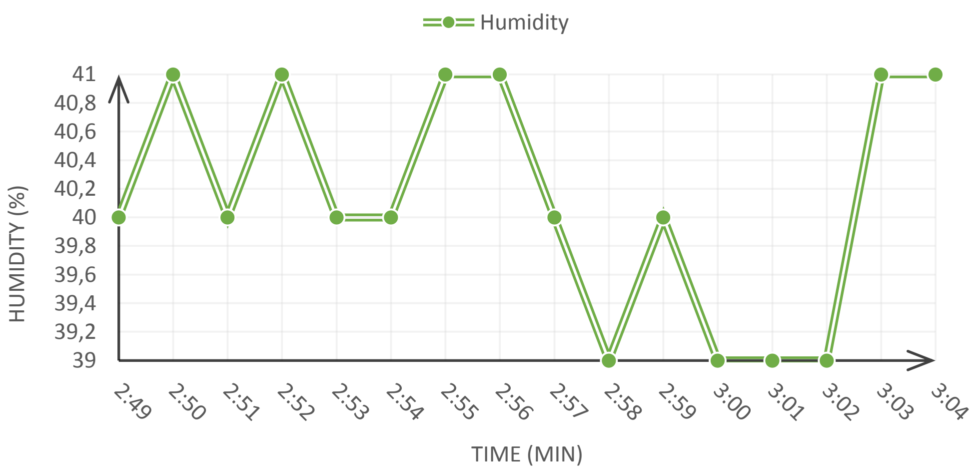
8.1.1.5. Measurement 5: Water environment (sunny) (16 minutes)

Date	Time	Air Temp.	Out Hum	Wind Speed	Hi Solar Rad.	Globe Temp.	Tmrt
05/11/2015	2:49 PM	24,8	40	0,4	798	30	41,37
05/11/2015	2:50 PM	24,8	41	1,3	803	30,6	57,57
05/11/2015	2:51 PM	24,8	40	2,7	802	31,1	76,03
05/11/2015	2:52 PM	24,7	41	1,3	819	31,1	60,39
05/11/2015	2:53 PM	24,7	40	2,7	810	31,1	76,62
05/11/2015	2:54 PM	24,7	40	4	819	31,1	80,07
05/11/2015	2:55 PM	24,8	41	1,8	805	31,1	66,39
05/11/2015	2:56 PM	24,8	41	1,3	800	31,1	59,99
05/11/2015	2:57 PM	24,8	40	2,2	803	31,1	70,92
05/11/2015	2:58 PM	24,9	39	1,3	798	30,6	57,16
05/11/2015	2:59 PM	24,8	40	0,9	803	30,6	52,36
05/11/2015	3:00 PM	24,8	39	1,3	805	30	54,6
05/11/2015	3:01 PM	24,8	39	1,8	791	29,4	56,62
05/11/2015	3:02 PM	24,7	39	1,3	786	29,4	51,98
05/11/2015	3:03 PM	24,7	41	1,8	772	28,9	54,12
05/11/2015	3:04 PM	24,7	41	1,3	751	28,9	49,38

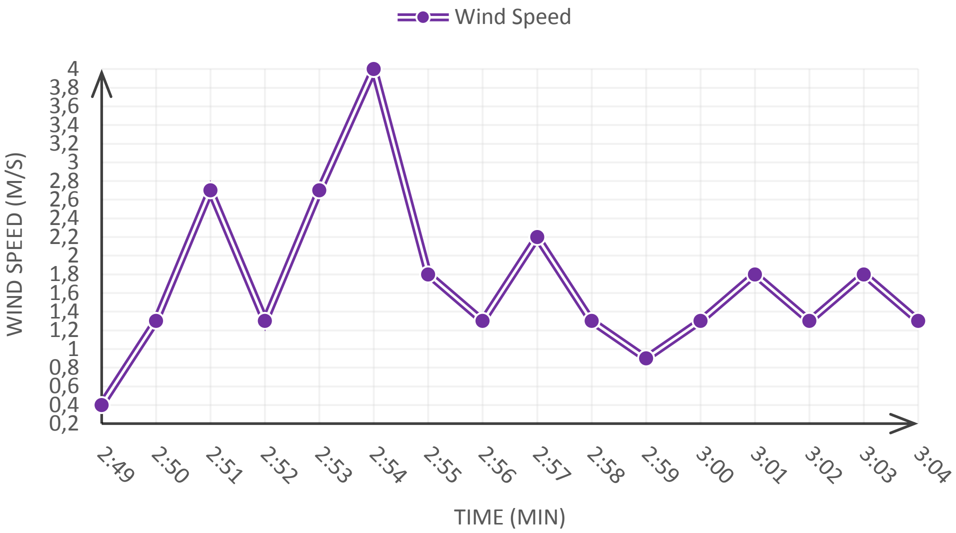
a) Air temperature and Globe temperature



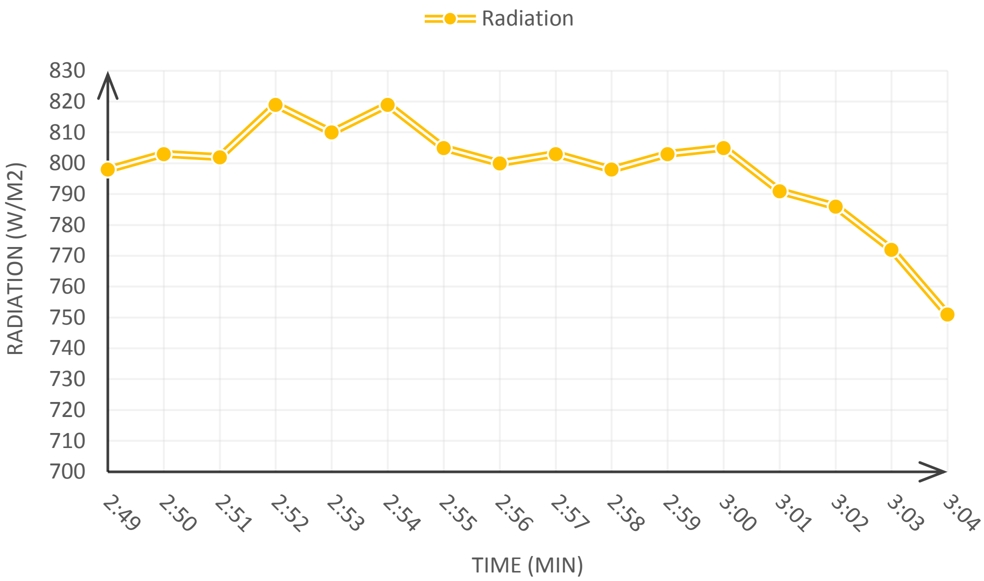
b) Humidity Out graph



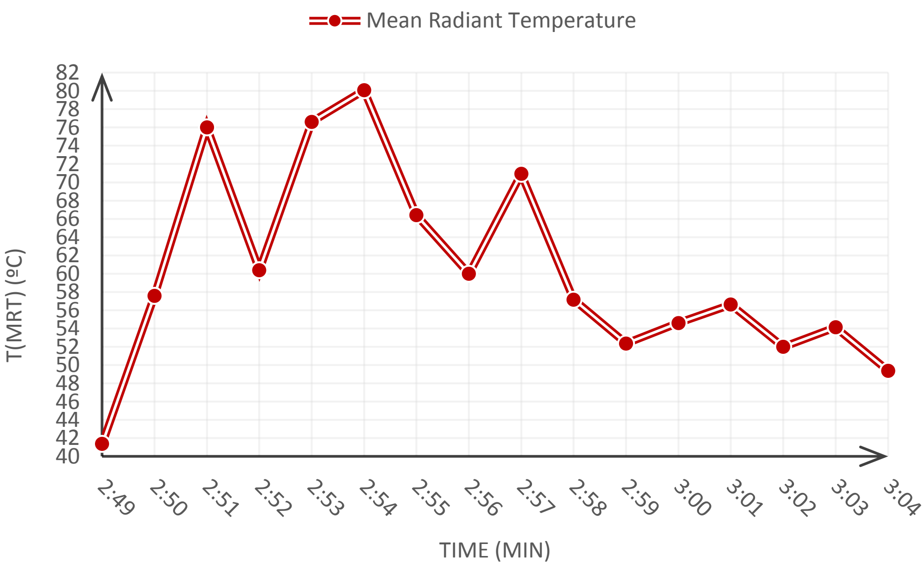
c) Wind speed graph



d) High Solar Radiation graph



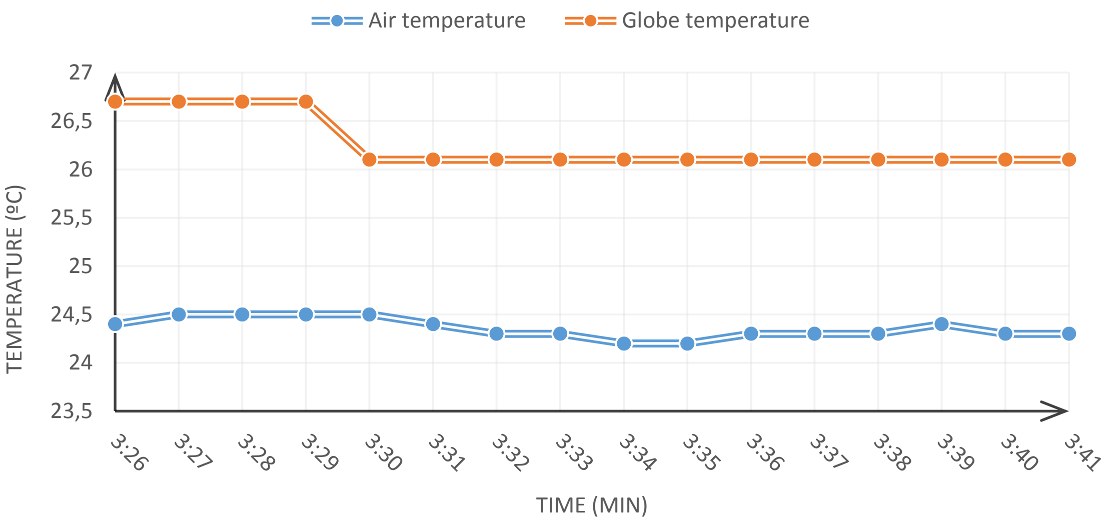
e) Mean Radiant Temperature graph



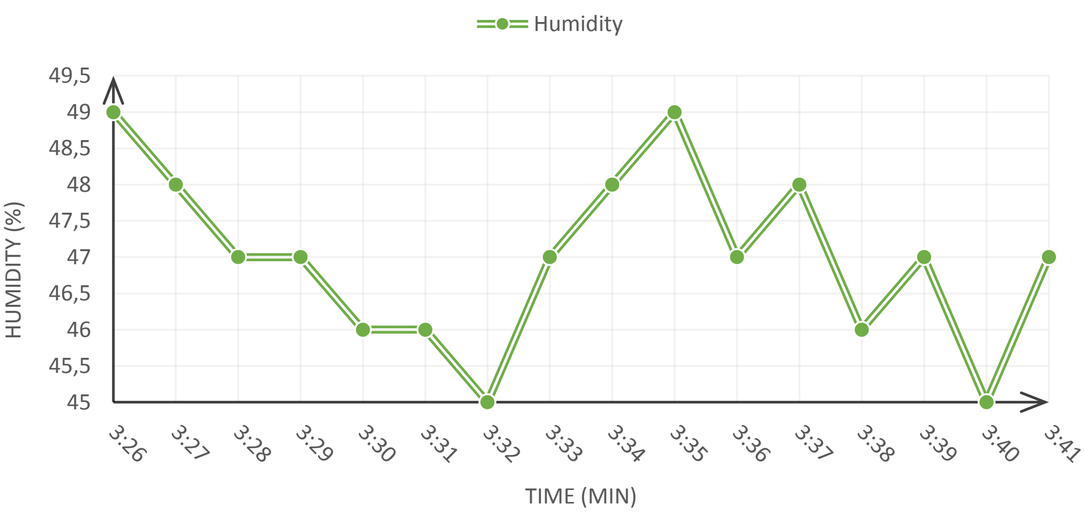
8.1.1.6. Measurement 6: Suikerbuurt green area (16 minutes)

Time	Air Temp.	Out Hum	Wind Speed	Hi Solar Rad.	Globe Temp.	Tmrt
3:26 PM	24,4	49	0,4	90	26,7	32,05
3:27 PM	24,5	48	0,4	90	26,7	31,82
3:28 PM	24,5	47	0,9	102	26,7	35,64
3:29 PM	24,5	47	1,3	97	26,7	38,16
3:30 PM	24,5	46	1,3	91	26,1	34,61
3:31 PM	24,4	46	1,3	91	26,1	35,12
3:32 PM	24,3	45	0,4	91	26,1	30,33
3:33 PM	24,3	47	0,4	54	26,1	30,33
3:34 PM	24,2	48	0,4	98	26,1	30,56
3:35 PM	24,2	49	0,4	172	26,1	30,56
3:36 PM	24,3	47	0,4	97	26,1	30,33
3:37 PM	24,3	48	0,9	153	26,1	33,51
3:38 PM	24,3	46	1,3	114	26,1	35,62
3:39 PM	24,4	47	0,9	95	26,1	33,12
3:40 PM	24,3	45	1,3	90	26,1	35,62
3:41 PM	24,3	47	0,4	104	26,1	30,33

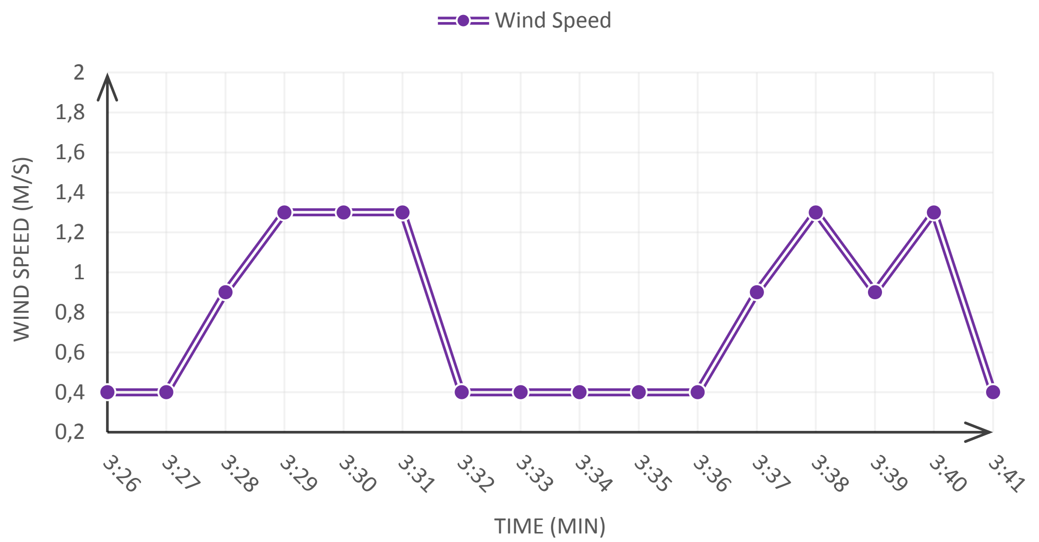
a) Air temperature and Globe temperature graph



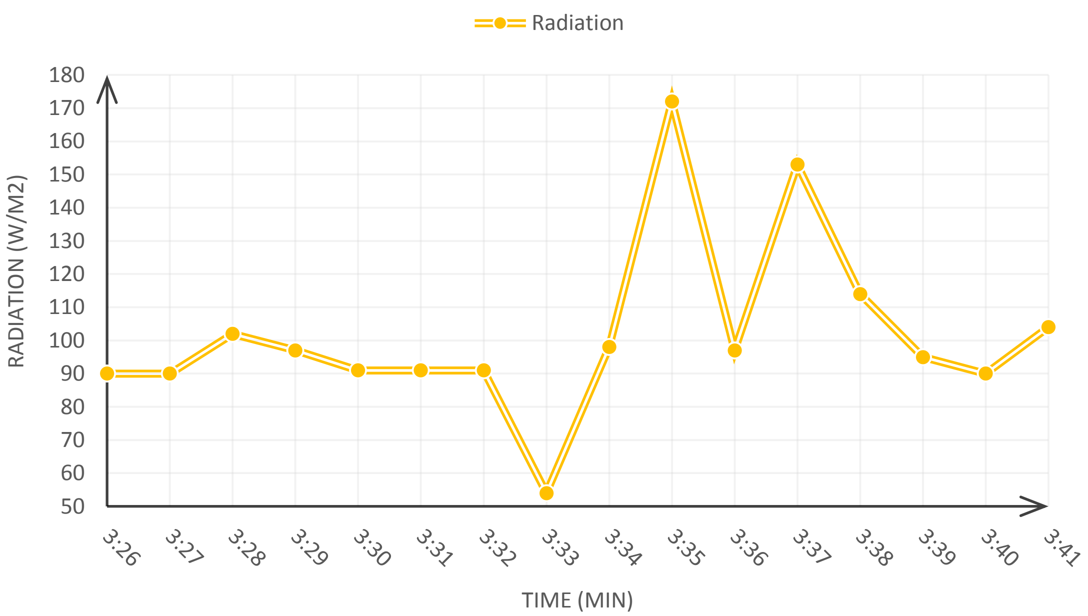
b) Humidity Out graph



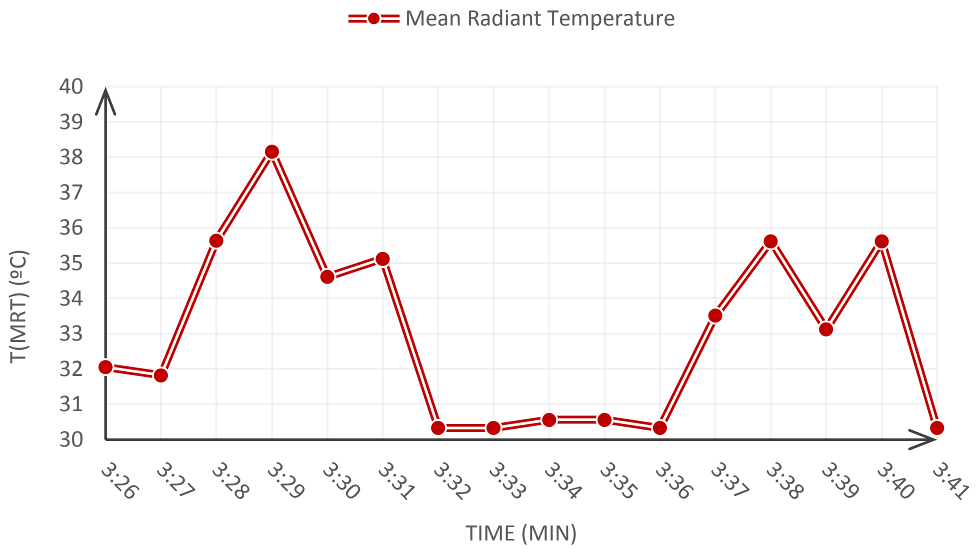
c) Wind speed graph



d) High Solar Radiation graph



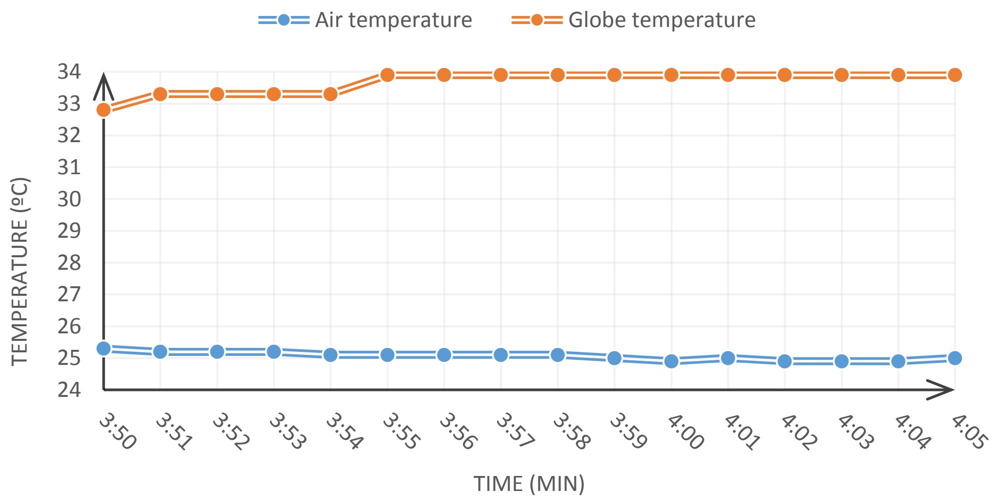
e) Mean Radiant Temperature graph



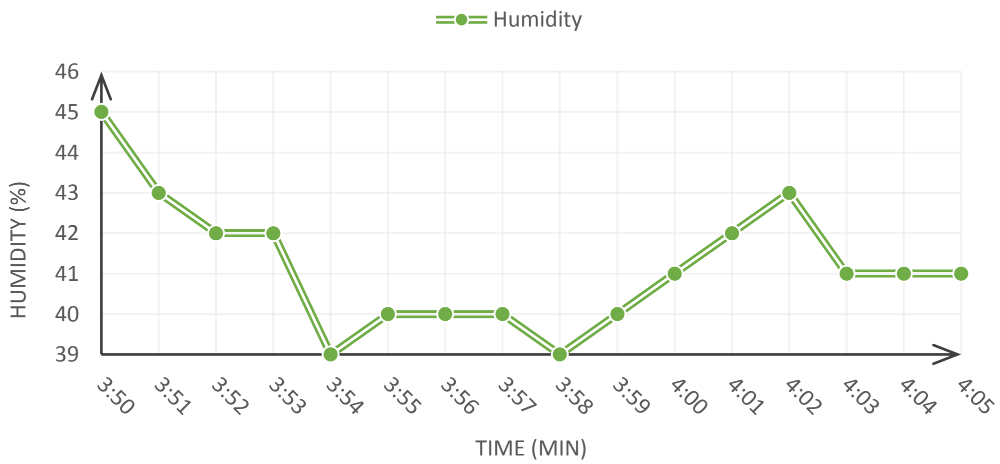
8.1.1.7. Measurement 7: Tennis field (16 minutes)

Date	Time	Temp Out	Out Hum	Wind Speed	Hi Solar Rad.	Temp 2nd	Tmrt
05/11/2015	3:50 PM	25,3	45	0,4	728	32,8	48,43
05/11/2015	3:51 PM	25,2	43	1,3	708	33,3	68,58
05/11/2015	3:52 PM	25,2	42	0,9	642	33,3	61,43
05/11/2015	3:53 PM	25,2	42	0,9	703	33,3	61,43
05/11/2015	3:54 PM	25,1	39	0,4	659	33,3	50,2
05/11/2015	3:55 PM	25,1	40	0,9	671	33,9	64
05/11/2015	3:56 PM	25,1	40	0,9	689	33,9	64
05/11/2015	3:57 PM	25,1	40	0,9	703	33,9	64
05/11/2015	3:58 PM	25,1	39	1,3	700	33,9	71,59
05/11/2015	3:59 PM	25	40	0,9	693	33,9	64,3
05/11/2015	4:00 PM	24,9	41	0,4	677	33,9	52,22
05/11/2015	4:01 PM	25	42	0,9	675	33,9	64,3
05/11/2015	4:02 PM	24,9	43	0,9	636	33,9	64,6
05/11/2015	4:03 PM	24,9	41	0,9	684	33,9	64,6
05/11/2015	4:04 PM	24,9	41	0,9	673	33,9	64,6
05/11/2015	4:05 PM	25	41	0,4	687	33,9	52,03

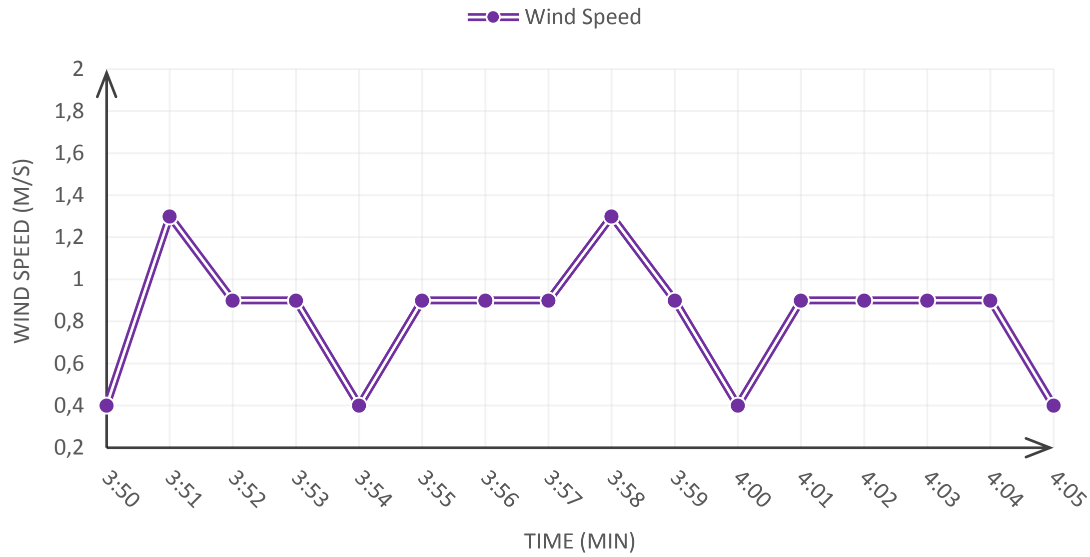
a) Air temperature and Globe temperature graph



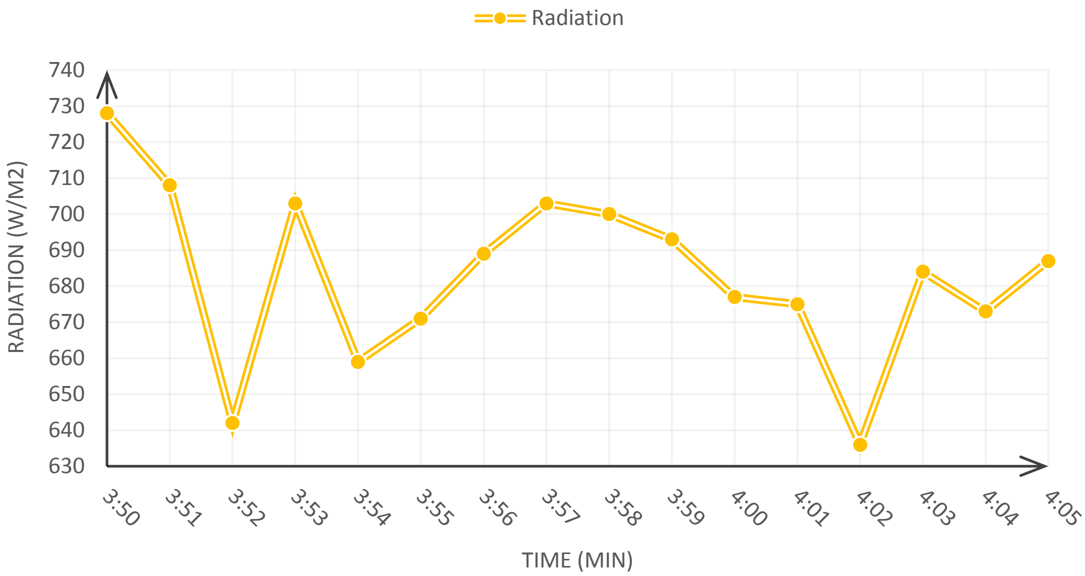
b) Humidity Out graph



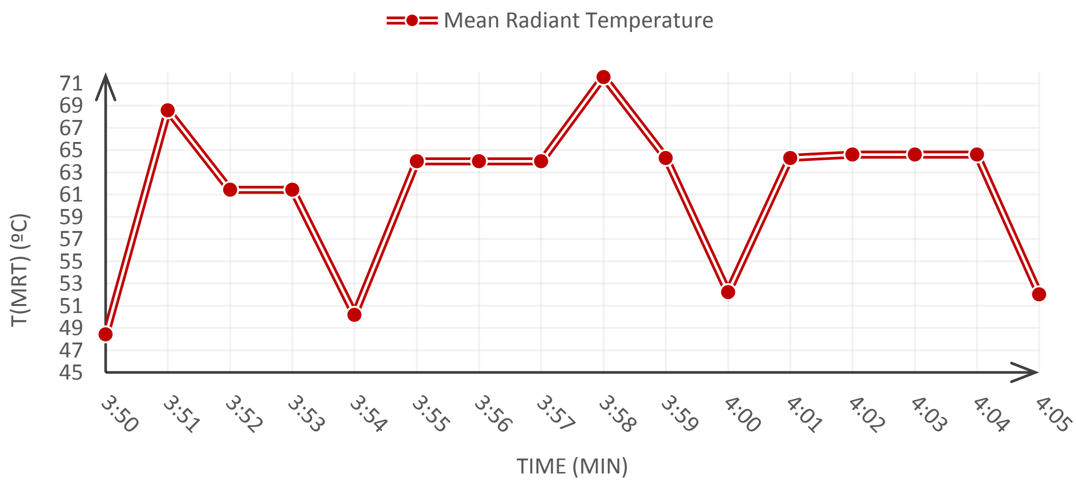
c) Wind speed graph



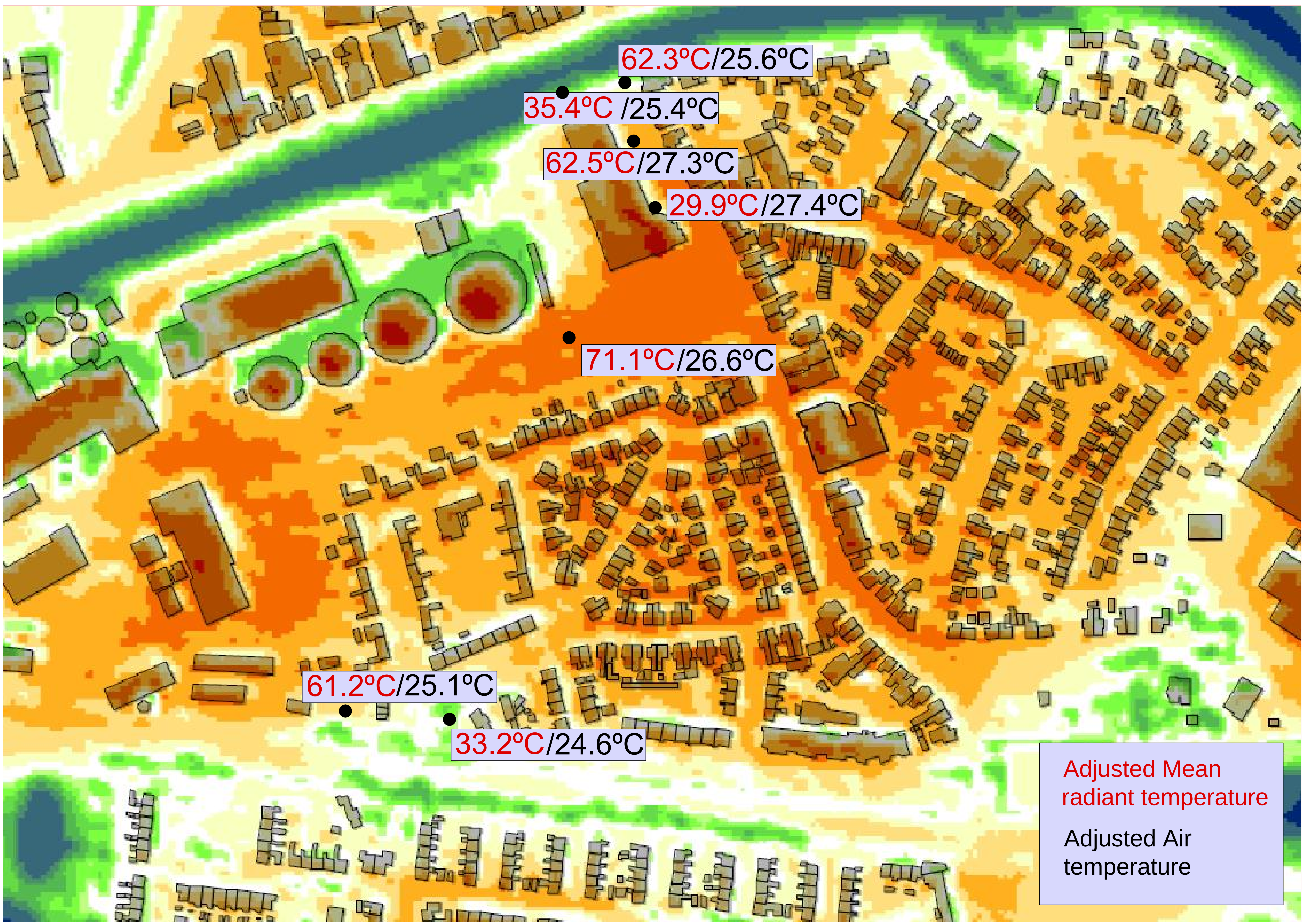
d) High Solar Radiation graph



e) Mean Radian Temperature



Appendix 9: Heat map with adjusted temperatures


62.3ºC/25.6ºC
35.4ºC /25.4ºC
62.5ºC/27.3ºC
29.9ºC/27.4ºC
71.1ºC/26.6ºC
61.2ºC/25.1ºC
33.2ºC/24.6ºC
Adjusted Mean radiant temperature
Adjusted Air temperature