


Sustainable Soesterkwartier

Recommendations for the development of a sustainable eco-town in the Soesterkwartier, Amersfoort

Municipality of Amersfoort

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Wageningen University.

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Abstract

The municipality of Amersfoort want to construct an endurable and sustainable eco-town in the Soesterkwartier neighbourhood, by taking future climate change into account. The impact of climate change at the location of the proposed eco-town was studied by literature review. Studies from the KNMI and Klimaateffectatlas (eng: Climate effect atlas) show that increasing temperatures will change the precipitation pattern. All the scenarios generally show a trend with wetter winters, and most of the scenarios drier summers. Summers will be drier with less frequency of rainfall but the intensity of the rainfall is expected to increase. The intensity of rainfall is expected to increase in both summer and winter. This aggravates the problems related to excess surface runoff and high level of groundwater. These deductions from the climate study were taken into account to formulate recommendations for the proposed eco-town. These recommendations are based on five criteria including: 1. Expected climate effects, 2. Sustainability, 3. User friendliness, 4. Social aspects and 5. Costs.

Four categories of recommendations are given. Climate is the first category and recommendations such as vegetated roofs, retention basin, and permeable roads to address the issues of increased runoff in the future were made. Sustainability recommendations include the drum composting, reuse of grey water and rainwater for toilet flushing, permeable roads, intelligent architecture, water and energy saving and thermal storage (KWO). Recommendation for enhancing the 'green feeling' in an urban setting, include green areas, community gardens, creepers and noise barriers. For social interaction community gardens, green parks, car sharing, appraisals of Wagenwerkplaats to a trendy hangout place are some of the recommendations for making the proposed eco-town a hotspot for sustainable living.

Keywords Climate change, precipitation, groundwater, runoff, eco-town, sustainability, retention basin, rainwater harvesting, community garden, permeable road, solar energy and car sharing.

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Preface

This report has been prepared for the Academic Consultancy Training course (YMC60809) of the Wageningen University. We like to take this opportunity to thank the commissioner Heino Abrahams from the municipality of Amersfoort, experts Hasse Goosen and Fokke de Jong, and the project coach Djura Prins for their sincere involvement in the project. We highly appreciate their devotion in guiding us, their valuable comments and ideas, and their cooperation during the entire course period and set-up of this report.

1. Introduction

The Dutch face a serious threat from climate change for the coming decades. Precipitation patterns are expected to change in the future, also affecting the groundwater and runoff. Climate change will threaten the safety of its inhabitants, the quality of life and the ecology. These climate effects call for more innovative measures than simply raising the height of the dykes or building storm surge barriers. The focus is more on living together and making use of the water rather than taming and controlling it. The required measures will have to go hand in hand with the state of the art technological solutions of the 21st Century.

Amersfoort, a large city in the Netherlands, has acknowledged the need to take future climate change into account in the further expansion and development of the city. Amersfoort is located in a valley – the Gelderse Vallei – which is surrounded by elevated areas, the Utrechtse Heuvelrug to the South-West and the Veluwe to the East (see Figure 1.1). The elevated areas play a major role within the hydrology of the area. Amersfoort is mainly influenced by the Utrechtse Heuvelrug, due to its proximity. A large part of the catchment within this valley unites near Amersfoort as the Eem River, which actually flows through the city. Still the Eem River is relatively small with an average discharge ranking from 4 m^3/s in dry periods to 70 m^3/s in wet periods (Bakel et al., 2008).

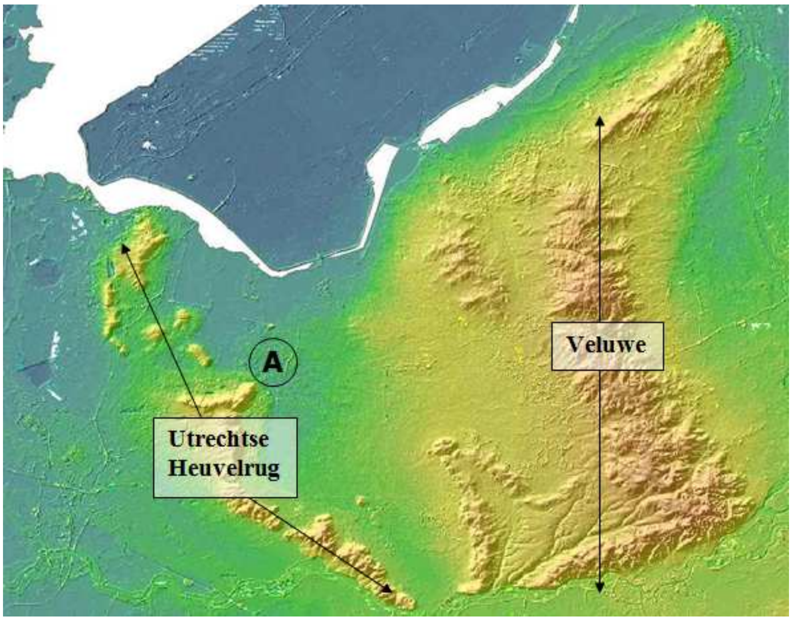

Figure 1.1: *Elevation map of the centre area in the Netherlands, including Amersfoort (A) and surrounding elevated areas (Utrechtste Heuvelrug and Veluwe). The valley between the elevated areas is known as the Gelderse Vallei (edited from Hurk et al., 2007).*

Amersfoort is one of the leading “green” cities in the Netherlands. The municipality of Amersfoort has plans to develop a new eco-town in the West end of the city. The eco-town is to be located between the existing Soesterkwartier neighbourhood and the railway station, which is near the city centre (Figure 1.2). This eco-town should be sustainable, endurable, and functional. The eco-town should not be seen as a separated ecological village, but allow for social interaction between the surrounding neighbourhoods and the new eco-town. The municipality is aware of climate change and wants to construct the eco-town in such a way that it can endure future climate effects. The purpose of this project is to provide recommendations to the municipality of Amersfoort to develope an attractive and sustainable eco-town in the Soesterkwartier neighbourhood. With a perspective towards the future, climate change is a major factor that has to be taken into account.

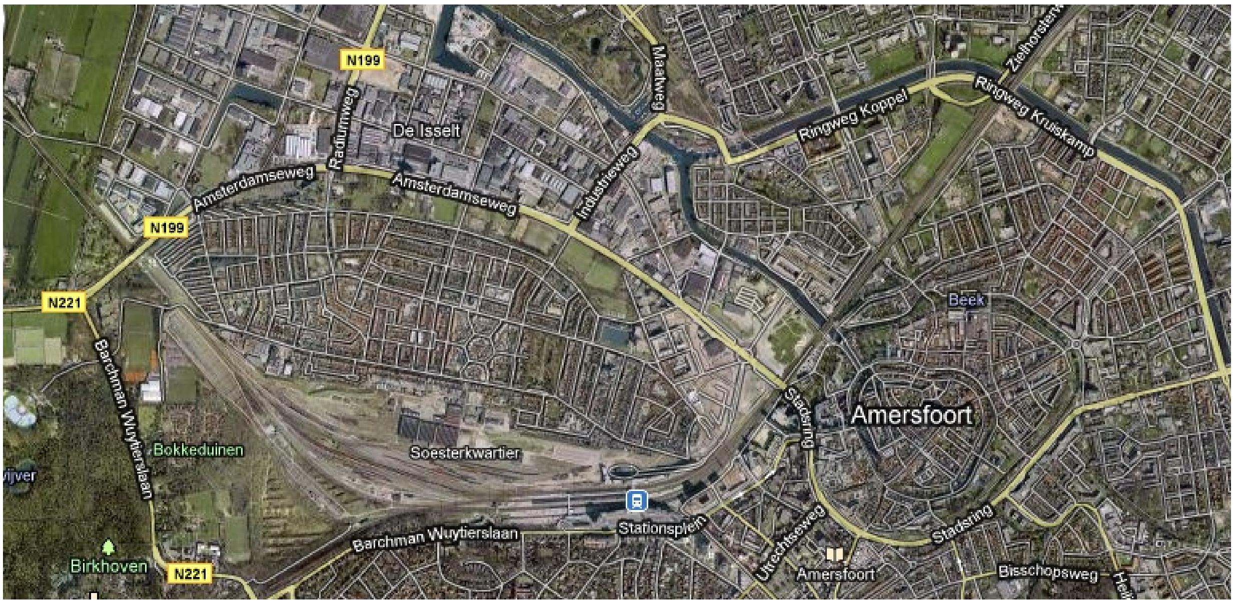

Figure 1.2: *Overview of the West part of Amersfoort, including the Soesterkwartier neighbourhood. The city centre is depicted on the right, and the train station is depicted directly to the South of the Soesterkwartier (Google Earth, 2010).*

The report will start with a description of the methodology that was used to gather the information for this report. Chapter 3 will estimate and describe how the climate in the Netherlands is likely to change. In this chapter the focus will eventually be on precipitation change. Precipitation change is important for whole of the Netherlands, but especially for the study area. From all this information the climate change effects on groundwater and runoff will be discussed in chapter 4. The eco-town is supposed to endure future changes in climate. Therefore chapter 5 will provide design options for the eco-town by taking climate change and its effects on groundwater and runoff into account. The eco-town is also intended to be sustainable and allow for social interaction with surrounding neighbourhoods. Therefore, chapter 5 will also describe design options that focus on sustainability and design options that are intended to increase the social interaction with the surrounding neighbourhoods. Finally, in chapter 6 the recommendations for the eco-town are provided.

2. Methodology

The findings of this report are based on literature review, brainstorming sessions, excursions and expert interviews. Throughout the project, relevant literature for the study area concerning climate change was collected. After it became clear for the project team what the expected climate effects would be for the study area, different design options were collected from scientific literature and websites . These findings were analyzed and discussed within the team. An excursion to the GWL-terrain in Amsterdam and a site-visit to Amersfoort were made to get a better insight about the possibilities and to get supporting information from the municipality itself, the study area and the inhabitants of the neighbourhood. Additionally, several meetings with the experts Hasse Goosen and Fokke de Jong were made for additional information or advice. During the nine weeks of the project, numerous team meetings were made in order to discuss findings, to brainstorm or to synchronize opinions . As a result, this report contains well thought recommendations for the development of a sustainable eco-town in the Soesterkwartier in Amersfoort.

3.Climate Change in the Netherlands

There are many indicators that show that the global climate is changing. One of the indicators is the observed increase in the global mean temperature during the 20th century (Figure 3.1). This increase is very likely to be related to increasing emissions of atmospheric green house gasses. CO2 is seen as the most important greenhouse gas within the climate system. The current atmospheric CO2 concentration is ~ 385 parts per million (ppm), which is more than 100 ppm higher than the pre-industrial value (Bresser et al., 2005). The increase in CO2 emissions are mostly the result of human activity and these emissions are still increasing. This increase has mainly been caused by the combustion of fossil fuels, the production of cement and large-scale deforestation.

The global mean temperature rise is not necessarily the same as the regional temperature rise in Western Europe, and the Netherlands in specific. During the 20th century the temperature rise in the Netherlands follows the rise in the global mean, but multiplied by a factor of 1.4 (Oldenborgh & Van Ulden, 2003) or 1.5 (Bresser et al., 2005). Since 1900 the mean temperature rose by about 0.8°C worldwide (Figure 3.1) and by about 1,2 °C in the Netherlands (Bresser et al., 2005; Bremer, 2006; Klein Tank & Lenderink, 2009), with an increase of ~0.5°C since 1975 (Bremer, 2006). This temperature rise in the Netherlands has not been a gradual process but has occurred mainly in the periods 1920–1945 and 1980–2000, with the years 1995, 1997, 1998, 2001, 2002 and 2003 being the warmest since 1860 (Bresser et al., 2005).

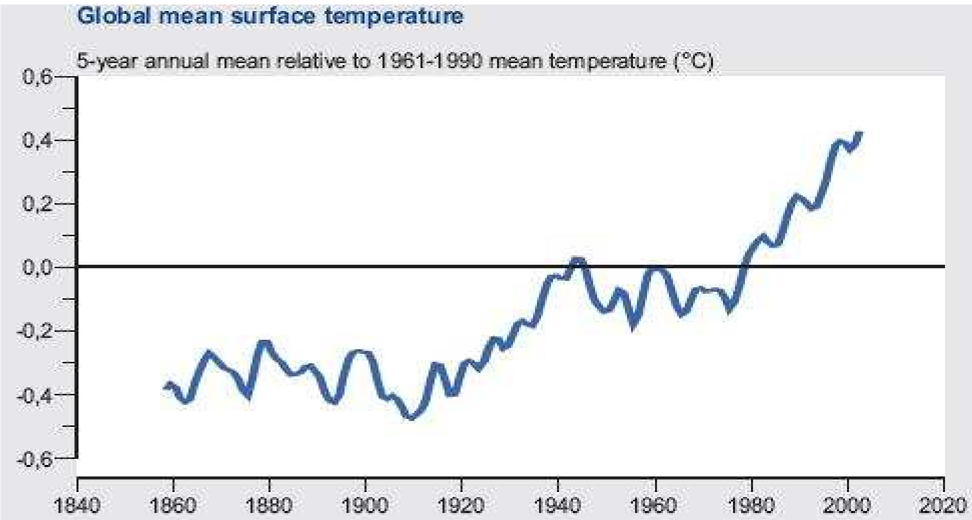

Figure 3.1: *The global mean temperature rise from 1860 to 2005. The global mean temperature has increased significantly (~0.8°C) during the 20th century. These measurements are from De Bilt, near Utrecht (Bresser et al., 2005).*

The difference between the global temperature rise and the temperature rise in the Netherlands is mainly caused by seasonal changes in the prevailing wind direction. The direction and strength of the wind determines the temperature variation from year to year and even from day to day. Generally in winter, an easterly wind originating over land masses brings cold air over the Netherlands, and a westerly wind originating over the sea brings mild sea air. In the summer, the reverse is true (Table 3.1) (Bresser et al., 2005) .

Western winds that transport air originating over the North-Sea typically contain a lot of moisture. Most of this moisture will eventually precipitate (i.e. rain out) over the Netherlands. In the Netherlands western winds typically prevail in winter, and eastern winds in summer (Bresser et al., 2005). The western winds are responsible for relatively mild and wet conditions, while the eastern winds are typically responsible for warm and dry conditions (Hurk et al., 2007). This means that in the Netherlands winters are relatively wet and cool compared to summers.

Table 3.1: *Typical air characteristics for the different seasons and the wind direction in the Netherlands. The *'s indicate the prevailing situations.*

	Western Wind	**Eastern Wind**
Winter	Mild, wet air *	Cold, dry air
Summer	Cool, wet air	Warm, dry air *

In particular, the late winter/early spring period has been noticeably warmer since the 1980s due to the increase in south-westerly winds (Bresser et al., 2005). It is still not clear whether this increase in 'warm' south-westerly winds in this season is of anthropogenic origin (Selten et al., 2004). Overall it is very likely that the temperature will further increase in the coming century.

For this project only climate change in the Netherlands – and Amersfoort in specific – is of importance. The KNMI (eng: Royal Dutch Meteorological Institute) has made an attempt to estimate the future climate within the Netherlands, with a focus on future precipitation patterns. In 3.1 these different scenarios for climate change in the Netherlands will be explained. In 3.2 the estimations for changes in precipitation will be discussed.

3.1 KNMI's Climate Scenarios

In 2006 the KNMI presented four different climate scenarios for the Netherlands (Hurk et al., 2006). A climate scenario is an estimation of the future climate in the Netherlands. Since estimations for the future are often uncertain there are several different scenarios, all with an equal probability. In 2009 the KNMI has presented a further elaboration on these climate scenarios, including new findings (Klein Tank & Lenderink, 2009).

The scenarios represent possible situations for 2050 relative to 1990, and a 30-year period is used to serve as climatology. Thus, the climate scenarios for 2050 describe the changes in the period 2036 – 2065 relative to the period 1976 – 2005. The four climate change scenarios are based on estimations by Global Climate Models (GCMs), Regional Climate Models (RCMs), and empirical/statistical downscaling using local observations in the Netherlands (Hurk et al., 2006).

The four climate scenarios are G, G+, W and W+ (Figure 3.2). The KNMI decided not to relate the climate scenarios to emission scenarios, but simply to the increase in global mean temperature by 2050 (relative to 1990). For the G and G+ scenarios the expected global temperature increase by 2050 is 1°, for the W and W+ scenarios 2°C. Hence, the G stands for the Dutch word “Gematigd” (eng: moderate) and W = “Warm” (Hurk et al., 2006).

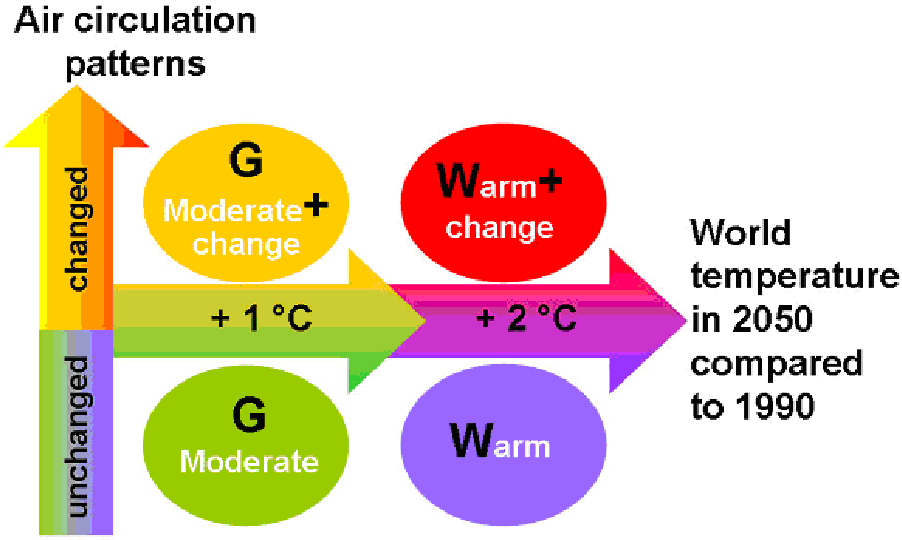

Figure 3.2: *The four KNMI climate scenarios. The G scenarios assume a global temperature rise of 1°C, while the W scenarios assume an increase of 2°C. The “+”scenarios assume a stronger air circulation (i.e. stronger eastern and western winds) (Hurk et al., 2006).*

The reason for choosing +1°C and +2°C as a basis for the climate scenarios is due to estimations by GCMs of the global mean temperature rise for the coming decades (Figure 3.3). This selection of models and emission scenarios are considered to reflect nearly the full range of realistic future temperature projections (Hurk et al., 2006).

The Dutch climate is tightly linked to the direction and strength of the mean atmospheric flow (Hurk et al., 2006; Hurk et al., 2007). Because of this importance the KNMI included the “+” scenarios which include the presence of a strong air circulation pattern, both during the winter and the summer season. In the Netherlands western winds prevail in winter and eastern winds in summer, which implies that the “+”-scenarios will typically estimate wetter winters and drier summers than the G and W scenarios.

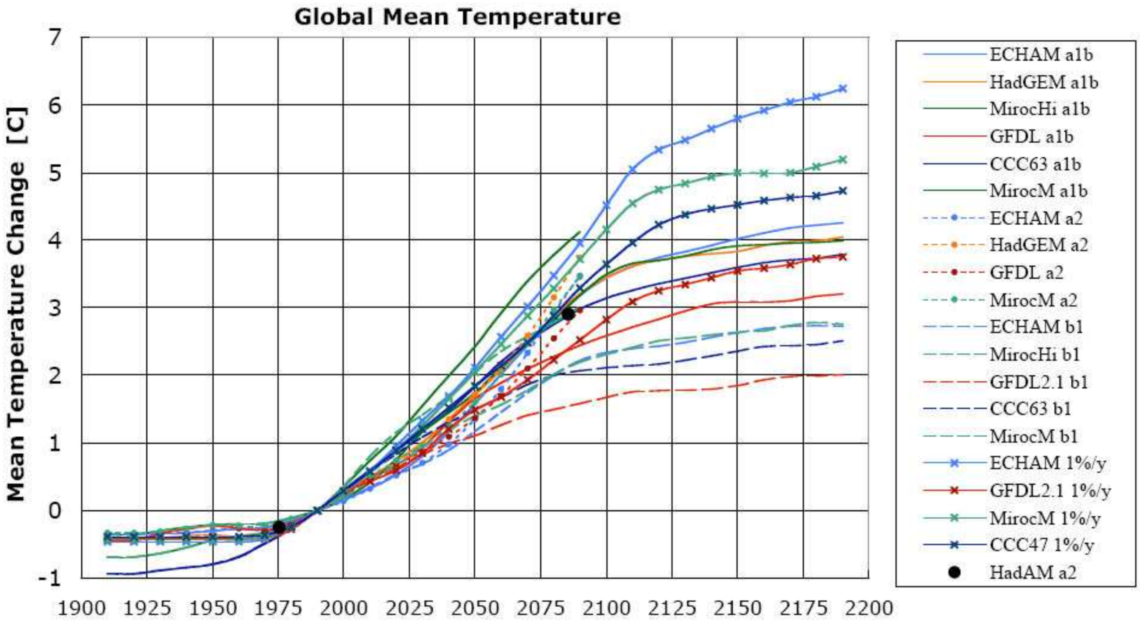

Figure 3.3: *Time series of global mean temperature change for a wide range of GCMs. The GCMs have estimated the global temperature rise for four different greenhouse gas emission scenarios (B1, A1B, A2, and a scenario with an increase of 1% CO2 per year), as noted behind each GCM. The global mean temperature rise is estimated to be roughly between 1°C and 2°C by 2050 (relative to 1990) (Hurk et al., 2006).*

One of the key features of climate change is the change in precipitation patterns. Precipitation plays an important role in the hydrological cycle, certainly in the Netherlands. Therefore future changes of precipitation in the Netherlands will be discussed next.

3.2 Precipitation Change

It is estimated that the wintertime precipitation will generally increase over most of Northern and Western Europe, and reduce over the Mediterranean. The summertime precipitation is estimated to decrease over Northern Europe, but is expected to decrease stronger in Southern Europe (Hurk et al., 2006). For the Netherlands the future change in summer precipitation – whether it decreases or actually increases – is not so clear. This uncertainty is mainly caused by the uncertainty in the future strength of eastern and western winds. In case of a weak (or no) change in air circulation (i.e. the G and W scenarios) the summer precipitation is estimated to increase, and in case of a strong air circulation change (i.e. the G+ and W+ scenarios) the summer precipitation is estimated to decrease.

The combined GCM/RCM approach only produces meaningful changes in temperature and precipitation. Many applications require a more complete description for future climate conditions. Therefore, where possible, additional information on spatial and temporal variability is added by a transformation of observations by Dutch weather stations. A summary of all estimated temperature and precipitation variables for the four different scenarios is given in Table 2.2 (Hurk et al., 2006).

Table 3.2: *Summary of regional changes corresponding to the KNMI'06 scenarios obtained by scaling GCM projections with RCM output for temperature and precipitation variables. All variables show changes by 2050 compared to 1990. The temperature related variables show estimated changes in Kelvin (K). The precipitation related variables show changes in amount of precipitation or frequency of occurrence by 2050, both in % (Hurk et al., 2006).*

Variable	G	G+	W	W+
summertime values				
mean temperature (K)	+0.9	+1.4	+1.7	+2.8
yearly warmest day (K)	+1.0	+1.9	+2.1	+3.8
mean precipitation (%)	+2.8	-9.5	+5.5	-19.0
wet day frequency (%)	-1.6	-9.6	-3.3	-19.3
precipitation on wet day (%)	+4.6	+0.1	+9.1	+0.3
10yr return level daily precipitation sum (%)	+13	+5	+27	+10
potential evaporation (%)	+3.4	+7.6	+6.8	+15.2
wintertime values				
mean temperature (K)	+0.9	+1.1	+1.8	+2.3
yearly coldest day (K)	+1.0	+1.5	+2.1	+2.9
mean precipitation (%)	+3.6	+7.0	+7.3	+14.2
wet day frequency (%)	+0.1	+0.9	+0.2	+1.9
precipitation on wet day (%)	+3.6	+6.0	+7.1	+12.1
10yr return level 10-day precipitation sum (%)	+4	+6	+8	+12
yearly maximum daily mean wind speed (%)	0	+2	-1	+4

From Table 3.2 the following characteristics of the estimated precipitation changes in the Netherlands can be recognized:

1. In the G and W scenarios the mean precipitation *increases* both in summer and winter.
2. In the G+ and W+ scenarios the mean precipitation *decreases* drastically in summer and *increases* drastically in winter.
3. The wet day frequency *decreases* in summer and *increases* in winter, for all scenarios. This decrease is more pronounced in the G+ and W+ scenarios.
4. The amount of precipitation on a wet day *increases* both in summer and winter for all scenarios. This increase is more pronounced in summer for the G and W scenarios, and more pronounced in winter for the G+ and W+ scenarios.

The difference between the first two points is caused by the difference in strength of eastern and western winds between the G/W and G+/W+ scenarios. In the "+"-scenarios the winds are stronger causing the mean precipitation on a wet day to increase more significantly in winter and decreases more significantly in summer. In general the "+"-scenarios show more extreme situations: dryer summers, and wetter winters. The fourth point implies that precipitation events (i.e. rainfall) will endure longer and/or will become more intense in the future.

An increase in rainfall intensity does not automatically imply that more extreme storms are expected in the Netherlands. The storm climate of the Netherlands is highly variable by nature. From one decennium to the next the differences are large. Heavy storms are also rare, which makes it difficult to establish a trend. Overall, the KNMI scenarios assume a small influence of climate change on the storm climate in the Netherlands (Klein Tank & Lenderink, 2009). Moreover, the number of extreme storms per year has actually decreased in the past decades (Figure 3.4).

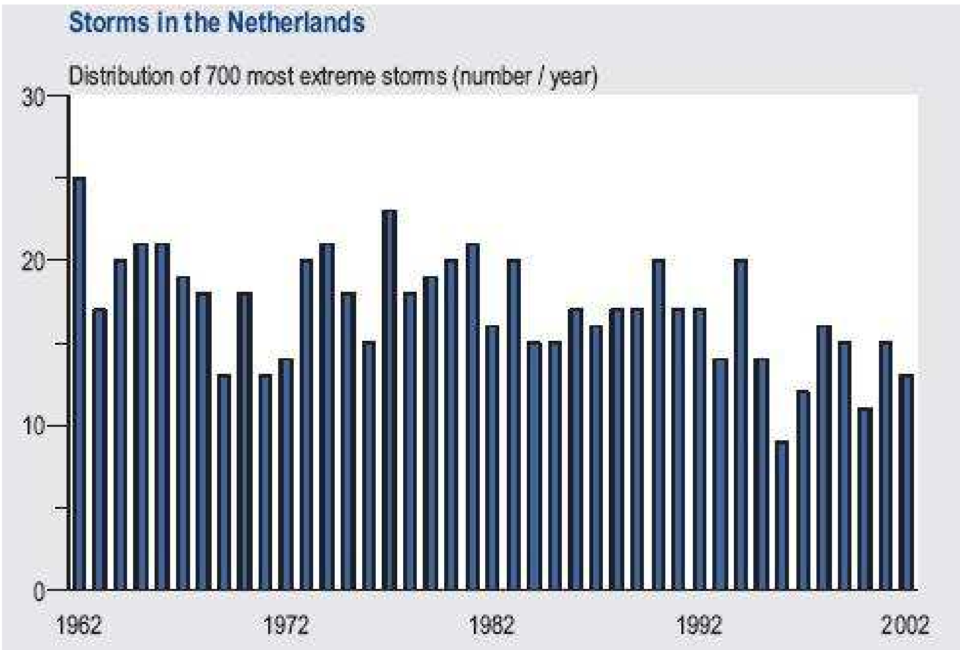

Figure 3.4: *Distribution of the 700 most extreme storms in the Netherlands over the past 41 years. There seems to be a slightly decreasing trend over the past decades (Bresser et al., 2005).*

The Soesterkwartier in Amersfoort is located within the area with the highest mean annual precipitation of the province of Utrecht (Figure 3.5). The location of Utrecht (city) and the Utrechtse Heuvelrug play a role in the presence of this precipitation maximum in the North-East of the province. Urban areas and elevated terrain lead to more convection which leads to the formation of clouds and the occurrence of precipitation. The prevailing South-Western winds cause the precipitation maximum to shift somewhat North-East, near Amersfoort (Bakel et al., 2008).

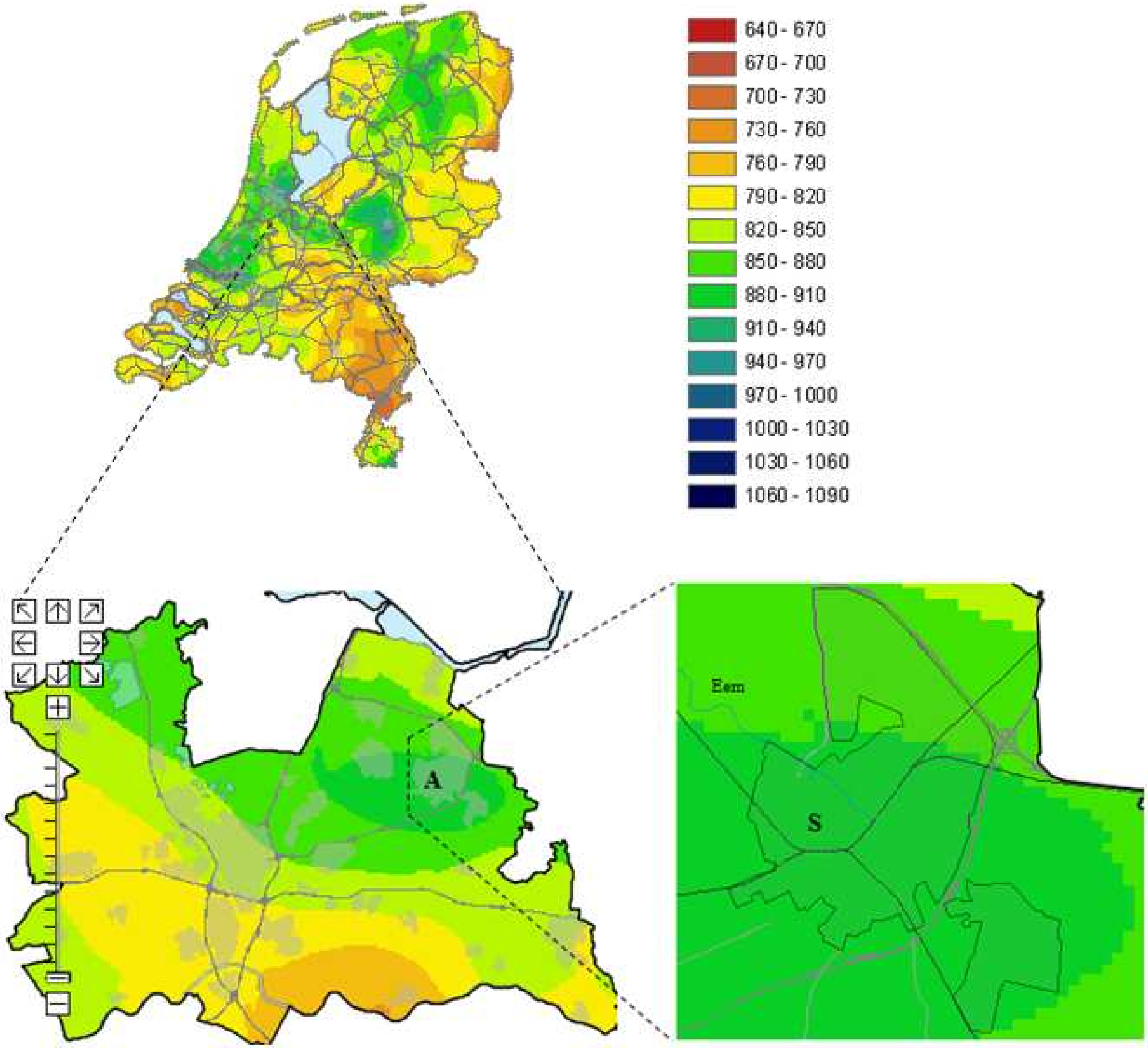

Figure 3.5: *Mean Annual Precipitation for the Netherlands (top) and the province of Utrecht (bottom left), zoomed in on Amersfoort (bottom right) including the Soesterkwartier neighbourhood. These data represent the situation around 1990 (mean of 1976-2005). It shows that Amersfoort lies within the area with the highest precipitation rate of the province Utrecht: 880-910 mm/year. A=Amersfoort, S=Soesterkwartier, values are in mm/year (edited from Klimaateffectatlas, 2010).*

In order to come up with relevant recommendations for the Soesterkwartier area it is useful to have information about possible future precipitation patterns. The KNMI and Alterra (Wageningen University) set up the so called climate effect atlas (dutch: klimaat effect atlas). From this online atlas it is possible to obtain estimations for future precipitation patterns for both summer and winter in specific areas of the Netherlands. Estimations can be made separately for each of KNMI climate scenarios.

Estimations have been made for the precipitation patterns and amounts for Amersfoort by the year 2050. In the Soesterkwartier the winter precipitation is expected to increase in all scenarios, and most extreme in the W+ scenario (Figure 3.6). The summer precipitation is expected to decrease in all scenarios except the W scenario where a slight increase is expected (Figure 3.7). The increase in winter and decrease in summer are more pronounced in the "+" scenarios.

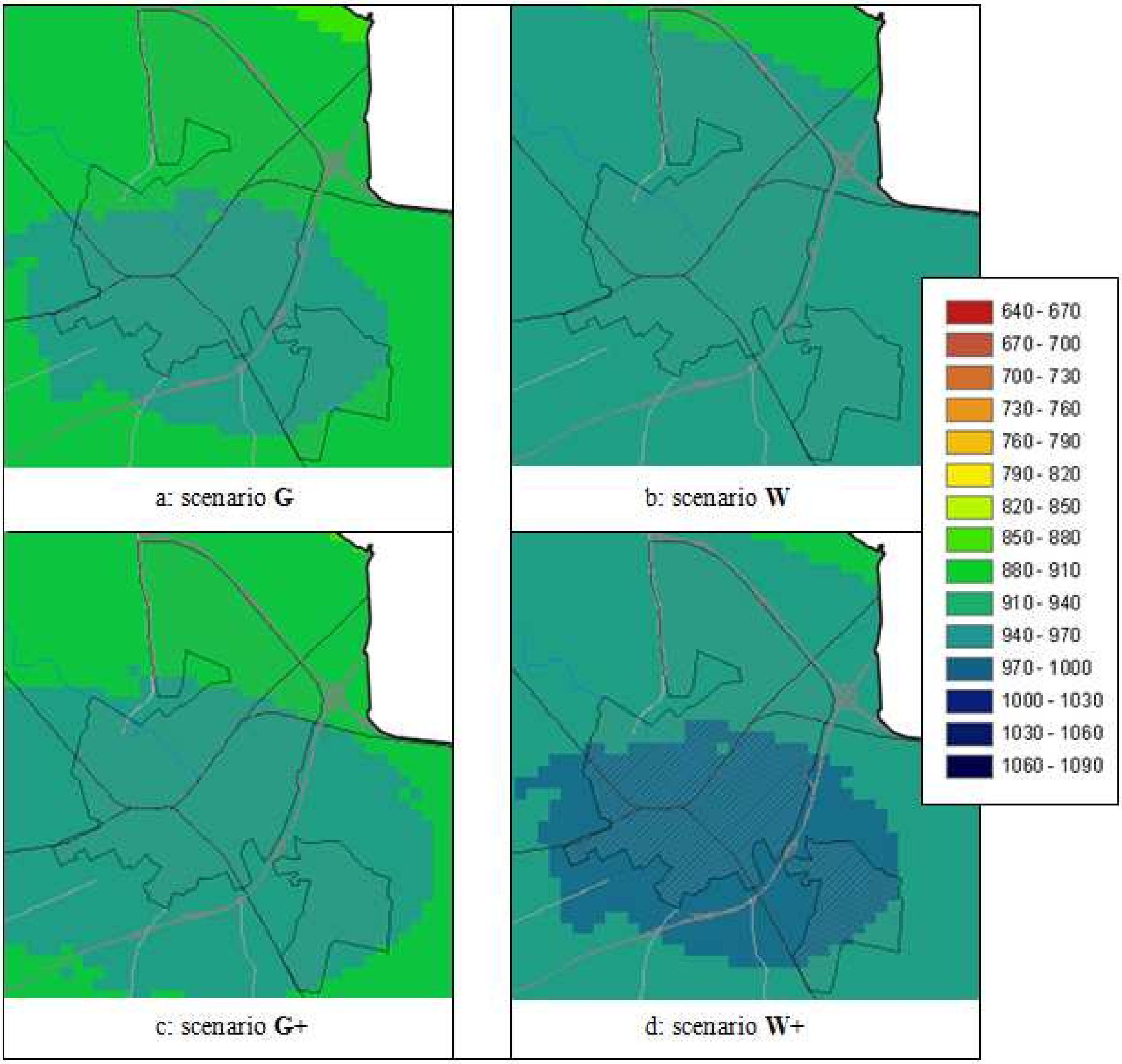

Figure 3.6: *Expected winter precipitation in Amersfoort, including the Soesterkwartier, by 2050. Estimations have been made for each KNMI climate scenario. Values are in mm/year (Klimaateffectatlas, 2010).*

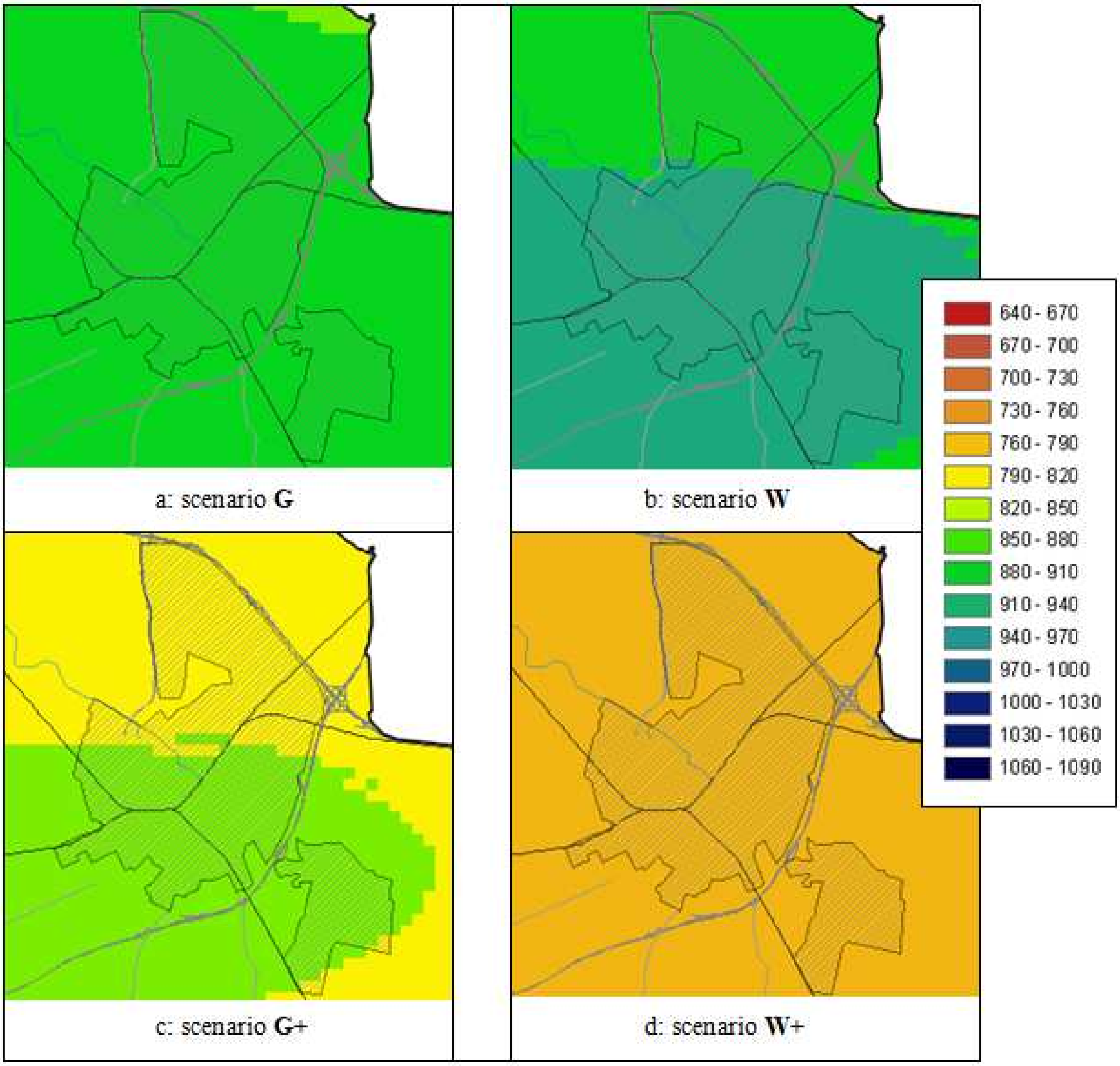

Figure 3.7: *Expected summer precipitation in Amersfoort, including the Soesterkwartier, by 2050. Estimations have been made for each KNMI climate scenario. Values are in mm/year (Klimaateffectatlas, 2010).*

Combining the estimations for winter and summer precipitation provide insight in the expected mean annual precipitation. In the Soesterkwartier the mean annual precipitation is expected to increase for the G and W scenarios, and remain the same or even decrease in the G+ and W+ scenarios (Figure 3.8). These results imply that the expected decrease in summer precipitation is more extreme than the increase in winter precipitation, in case of the “+”-scenarios. Similar estimations for the years 2020 and 2100 can be found in Annex I.

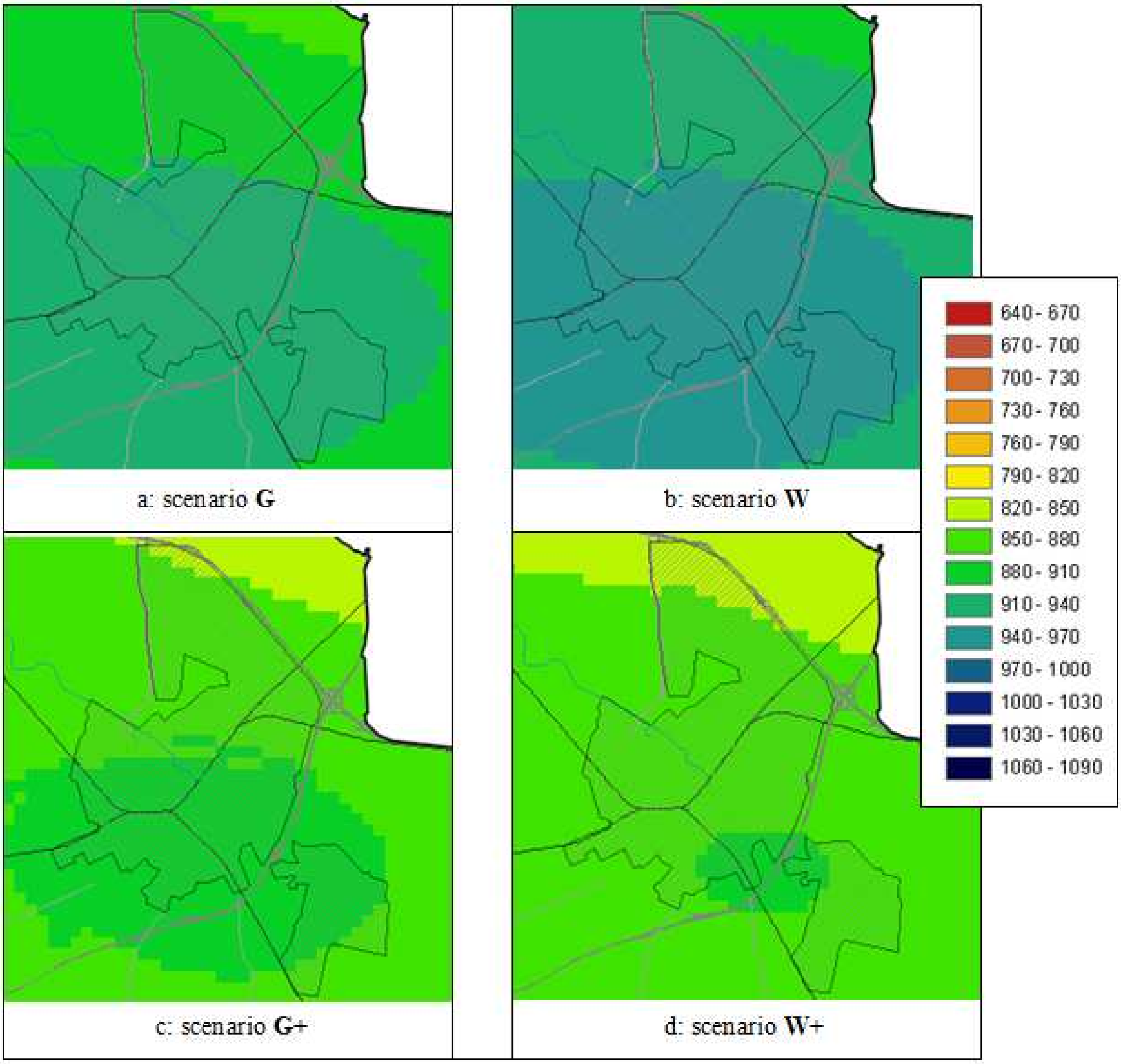

Figure 3.8: Estimation of the mean annual precipitation in Amersfoort by 2050. Estimations have been done for all four KNMI climate scenarios: G, G+, W, and W+. Values are in mm/year *(Klimaateffectatlas, 2010).*

In winter the rainy days are expected to become more intense and occur more often. In summer less rainy days are expected but the rain events are also expected to become more intense. The amount and intensity of precipitation have effect on the runoff and groundwater table. These effects will be discussed next, in 4.1 and 4.2, respectively.

4.The effects of climate change on the local hydrology

The estimated change in precipitation has a direct effect on the hydrological system in the study area. In this chapter the effects of climate change on groundwater and water quality will be discussed in 4.1, while 4.2 will analyse the effects on run-off and sewage. Although an ensemble of models are available to predict future changes in runoff and groundwater, none can give very precise predictions (Goderniaux et al., 2009).

4.1 Effects on groundwater and water quality

Groundwater is the water which is present beneath the Earth's surface. It can be either in the form of moisture in the soil pores or in the form of water in the lithographic fractures. In Amersfoort the groundwater is phreatic, which means that all the pore spaces are saturated with water (Wuite, 2006).

The groundwater in Amersfoort is relatively shallow and is influenced by several factors like precipitation, evaporation, soil structure, ground water extraction or drainage, and the presence of vegetated or concrete surfaces (Wuite, 2006). The groundwater level varies throughout the year. It is typically higher in winter than in summer. In the "+" scenarios this difference will become larger because in those cases more precipitation is expected in winter and less in summer. In winter the precipitation is expected to increase in all scenarios which can increase the groundwater level to problematic levels that cause water logging.

Evaporation generally lowers the groundwater level. Evaporation is expected to increase in all scenarios due to increasing temperatures (Klein Tank & Lenderink (2009). The evaporation will then increase most during summer in the "+" scenarios because the summers are expected to become both warmer and drier in those cases.

Another problem is that increasing amounts of groundwater are extracted to accommodate the increasing number of inhabitants in Amersfoort. The worry is that the groundwater is depleted faster than the natural processes can recharge the aquifers, especially during the summer. Infiltration or seepage of precipitation is a major source for groundwater recharge. Concrete surfaces (e.g. buildings) and asphalt prevent precipitation from infiltrating the Earth's surface.

The Soesterkwartier lies within the region where changes in groundwater level are expected (see Annex II; Bakel et al., 2008). It is expected that the average highest groundwater level (dutch: Gemiddeld Hoogste Grondwaterniveau or GHG) will slightly increase in the G and W scenarios, and slightly decrease in the G+ and W+ scenarios. The same trend is expected for the average lowest groundwater level (dutch: Gemiddeld Laagste Grondwaterniveau or GLG). The expectations are summarized in Table 4.1.

Table 4.1: *Effect of climate change on groundwater levels in the Soesterkwartier for all four climate scenarios. GHG = average highest groundwater level; GLG = average lowest groundwater level.*

	G	W	G+	W+
GHG	Increase	Increase	Decrease	Decrease
GLG	Increase	Increase	Decrease	Decrease

In this project the main focus will be on an estimated increase in groundwater levels. One of the main reasons for this is that the average groundwater level in Amersfoort is already relatively high, so a decrease would probably do little harm. Also a study by Hermans et al. (2008) estimates Amersfoort as one of the cities that could get flooded as a result of too high groundwater levels in the future (Figure 4.1). Therefore, the eventual recommendations for the Soesterkwartier will mainly be based on an expected increase in groundwater level, rather than a decrease.

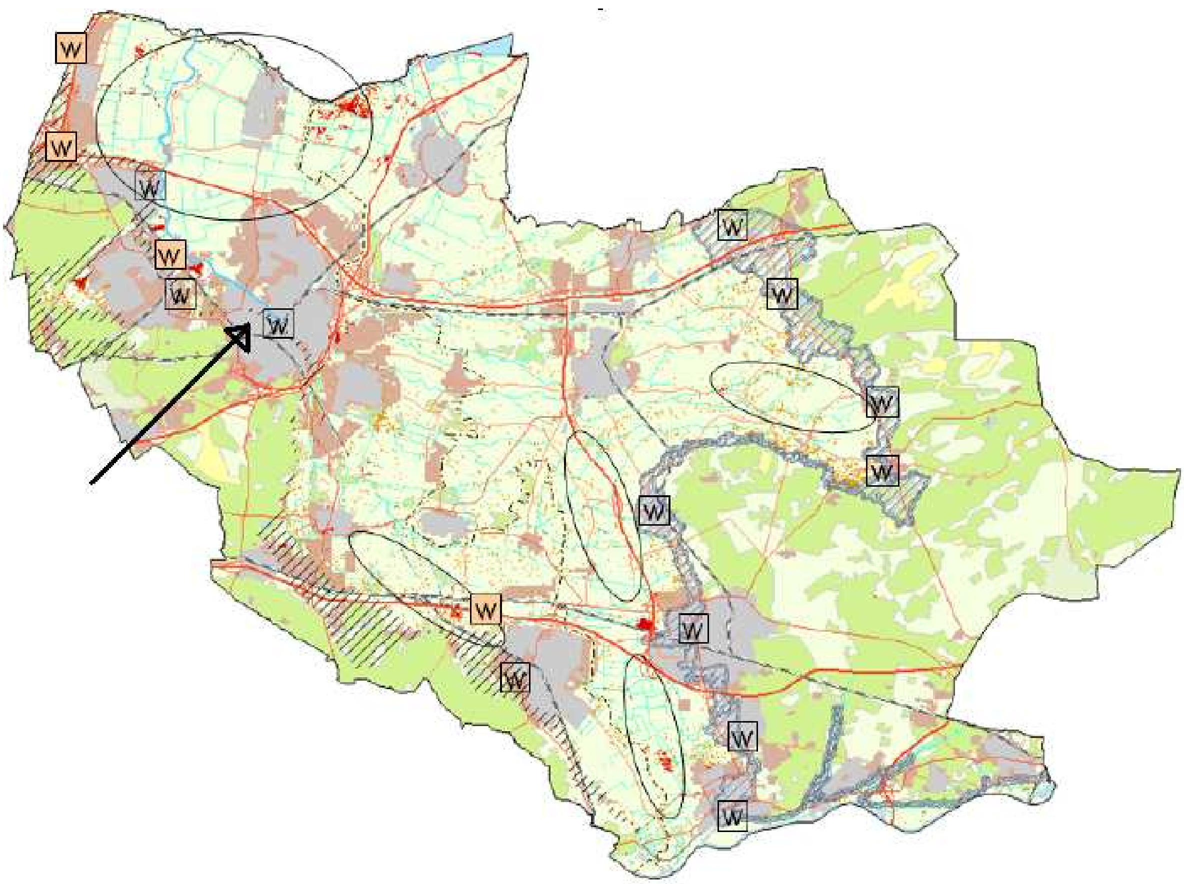

Figure 4.1: *A map of flood risks within the Gelderse Vallei. The arrow points to the location of the Soesterkwartier, Amersfoort. The symbol W indicates an estimated increase of flooding due to the ground water (Hermans et al., 2008).*

There are also several effects of climate change on the water quality. Infiltration of precipitation in urban areas can leach pollutants like heavy metals or fertilizers into the groundwater (Wuite, 2006). Possible sources of these pollutants are roads, buildings and fertilized crop fields. Considering the estimated changes in precipitation, leaching of pollutants is certainly expected to increase in winter in all four scenarios. For summer this is not so clear, because the amount of precipitation is estimated to increase for the G and W scenarios and decreases for the G+ and W+ scenarios. However, precipitation events are estimated to become generally more intense, which can also increase the seepage of pollutants.

Another effect is related to temperature rise and consequently the increase in water temperature, which create better living conditions for blue-algae (Bakel et al., 2008). The expected drier summers in the "+" scenarios cause stationary water to occur more frequently, which allow the blue-algae to flourish even better. Actually, stagnant water often reduces water quality in general by allowing accumulation of pollutants (Senhorst & Zwolsman, 2005). In case of an increase in blue-algae occurrence the effects for society are that (public) outdoor water pools will be closed more often, and they can cause stench. However, more intense precipitation events are expected in all scenarios, which can wash out the blue-algae.

Expanding cities, like Amersfoort, call for an integrated approach to combine water with urban areas. The eventual challenge in adapting to climate change is keeping society safe from environmental hazards, like water logging. Some challenges can be addressed by restoring natural processes and undertaking risk assessment (Hattum et al., 2008). The effects on the groundwater and water quality of the Soesterkwartier could be attained by attempting to take advantage of the estimated changes in future precipitation. Since an increase in winter precipitation is estimated, this surplus could be stored for use in drier periods. To avoid an increase in seepage of pollutants it is important to avoid the creation of flash floods (i.e. run-off, see 4.2), by actually improving the infiltration rate of the surface. Chapter 5 will eventually describe some design options that can deal with the effects of an increased groundwater level and a lack of infiltration capacity. But first the effects of climate change on run-off and sewage will be discussed.

4.2 Effects on run-off and sewage

Surface run-off is the flow of water that occurs when the Earths surface (e.g. soil or asphalt) is infiltrated to full capacity (i.e. saturation is reached), forcing excess water to flow over the surface. Urban infrastructure like roads, pavements, and buildings hinder or prevent infiltration and therefore stimulate the formation of run-off. The concentration of pollutants such as oil, heavy metals, toxins and organic substances is often very high on the surface of busy roads (Polkowska et al., 2005). This implies that runoff that is generated on roads or streets can cause soil or groundwater pollution. It is therefore important to direct the run-off from polluted streets directly into the sewage system.

Runoff can also result in (urban) flooding, especially in dense urban areas where run-off is created more easily (Davoudi et al, 2009). Run-off is also related to the sewage system because most of the urban run-off eventually enters the sewage system through street pits. The existing sewage system in the elder part of the Soesterkwartier is that of an old mixed system. The more recently dated neighborhoods (e.g. Schothorst, Nieuwland, and Kattenbroek) are designed with a modern separated sewage system (Wuite, 2006).

Climate change is likely to induce alteration in the amount of surface runoff in a specific area (Burlando and Renzo, 2002). An increase in precipitation intensity – as estimated for all KNMI scenarios – is likely to increase run-off because the surface is then given less time to infiltrate the rainwater. In case of the KNMI scenarios the amount of winter precipitation is expected to increase in all four scenarios, which is then likely to increase the formation of run-off because at some point water saturation will be reached. In the same way summer run-off is expected to increase in the G and W scenarios, and decrease in the G+ and W+ scenarios.

An increase in runoff can lead to a sudden nutrient flow to a water basin (e.g. a lake) (Jeppesen et al., 2009). An excess of nutrients in a stationary basin can cause an uninhibited increase of primary productivity (e.g. flourishment of algae). This process is known as eutrophication. Eutrophication leads to a decrease in the water quality as described before in 4.1.

Not all the run-off in the Soesterkwartier is necessarily of local origin. Amersfoort lies in the Gelderse Vallei – a valley – which is surrounded by elevated areas. A part of the run-off from elevated regions like the Utrechtse Heuvelrug and the Veluwe will flow through the drainage waters of the Gelderse Vallei towards the IJsselmeer, a large lake to the North of Amersfoort. One of these main drainage waters is the Eem River which flows through Amersfoort. The main problem for the Soesterkwartier related to regional run-off is expected to originate from the Utrechtse Heuvelrug.

An increase in runoff can also be problematic for the sewage system. The sewage can get overwhelmed by a sudden input of excess water (i.e. runoff), which can eventually cause the sewers to flood. The sewage system of the area surrounding the location of the eco town might be too old fashioned to deal with increases in run-off. This can be a potential threat for the future eco town.

It is important to look for design options that reduce or prevent the occurrence of both local and regional run-off. Other neighbourhoods of Amersfoort (e.g. Schothorst, Vathorst, and Kattenbroek) have already experienced runoff problems in the past during intense precipitation events, of which the cause was related to an inefficient drainage system (Zubair et al., 2009). The challenge will thus be to prevent the formation of local runoff and prepare the eco-town for a likely increase of regional runoff from surrounding elevated areas. To prevent the formation of runoff it is important to find ways to collect rainwater and increase the infiltration rate of the surface. To reduce the effects of run-off in general it is important to look for options to safely divert or collect any generated runoff.

In the next chapter a description will be given of relevant design options that are meant to mitigate or adapt to the previously described effects on the hydrological system.

5. Design options

Considering the results from the climate change study and the deduced effects on the study area, relevant design options were compiled. Thereby not only the climate impacts are addressed but also sustainability aspects, options that increase the ‘green feeling’ and the social interactions within the neighborhood

5.1. Climate effects

5.1.1. Vegetation roofs

The increasing urban infrastructure to accommodate the growing population reduces the natural (green) area of the earth. Reduction of the natural (green) earth surface with concrete structures aggravates the problems of storm water runoff and urban heat island effect as mentioned before (Liptan & Strecker, 2005). This problem can be addressed to some extent by having vegetation on the roofs (Figure 5.1).

Vegetation roofs built on light weight substrate with self- sustaining plants, native to the locality, has many advantages to the conventional roof. The benefits are as follows.

Green vegetation roofs slow down the rainwater discharge and create a lag time effect like in natural settings. The water retained enables evaporation and transpiration by the plants and substrate. This returns moisture back into the atmosphere instead of being discharged into the sewers together with the urban waste (Roofscapes, Inc., 2001).

The green vegetation filters the airborne particulate matter and provides clean air to some certain extent. Evapotranspiration from the vegetation lowers ambient temperatures and reduces urban heat island effect. Thereby excessive heat related health issues and mortalities are decreased (Curriero et al., 2002).

The modern concrete surfaces trap and radiate heat and thereby generate an urban heat island effect. Reducing this by planting vegetation allows for evapotranspirative cooling and shade, thereby reducing microclimate temperatures and improving living conditions in the urban environment (Dimoudi & Nikolopoulou, 2003).

Vegetated surfaces deflect high frequency sounds, and green roofs can attenuate low frequency noise by 40 decibels (Peck et al., 1999).

Figure 5.1: *Example of a vegetated roof (Apartmenttherapy, 2010)*

Additionally, the vegetation on the roof has an insulation effect. It keeps the building cooler and thereby less energy for air conditioning is required during the summer. In winter, less energy is used for heating. This energy saving results in reduced greenhouse gas emissions (Peck et al., 1999).
Green roofs protect the building material membranes from UV rays and moderate the thermal stress of temperature fluctuations, which can extend membrane life by a factor of two or three (Roofscapes Inc., 2001).
By installing vegetation roofs, costs are saved because energy is conserved, the lifespan of the materials is extended, storm water management fees are saved and public health is increased (Peck et al., 1999). Additionally, the green vegetation can create habitat and refuge for flora and fauna unique to the roof tops (Brenneisen, 2004).

There are two types of vegetated roofs: intensive or extensive. Intensive roof types are more or less a roof top garden for more social interaction. Since the layer is thick and thereby has a high weight, the intensive roof type has to conform to safety measures in order to address the requirements for the building stability. It also requires landscape maintenance, fertilizers, water reservoirs and irrigation (Peck & Kuhn, 2001). The other type of vegetation roof is the extensive type, which is much lighter. It requires low costs of installation and maintenance and does not need human attention constantly. It has a light weight veneer system. Light weight Veneer system is the term used to describe the extensive type of vegetated roofs which are normally inaccessible. Veneer types have thin drought tolerant plants such as colorful sedums, grasses, meadow flowers and mosses. Native species are more resilient and tolerant to the harsh conditions of the roof tops (Sutic, 2003).

The green roof has a number of layers depending on whether it is the intensive or extensive type. Typical layers for both types are depicted in figure 5.2.

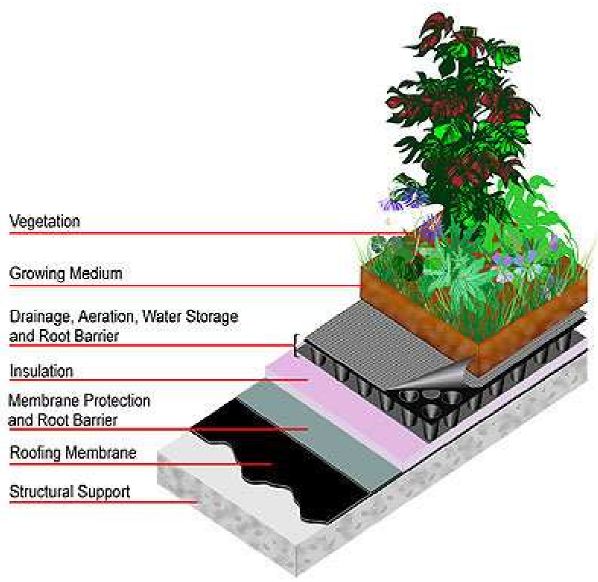

Figure 5.2: *Typical layers of the intensive and extensive roof type (Garmann/Miller, 2008)*

5.1.2. Runoff measures

Different kinds of measures are available to address the excess of surface water runoff. The options serve the purpose of capturing the water in order to prevent water flow through urban areas. The options are discussed as follows.

Infiltration basins

Infiltration basins (Figure 5.3) enable the collected surface runoff to percolate into the ground within 72 hours. This prevents mosquitoes from breeding and the basin from developing a bad odor as a result of decay, observed in stagnant water bodies. Infiltration basins also act as reservoirs for the polluted runoff and prevent it from entering the water stream directly. Vegetation in the basin facilitates the filtering of the polluted water and enhances the infiltration by maintaining the permeability of the soil. The water is purified to a certain extent by the natural process of filtering and also with the help of micro-organism. However, according to strict water quality controls, the water that infiltrates is not suitable for drinking and can contaminate the groundwater (EPA, 1999).

For the construction of an infiltration basin some important soil characteristic prerequisites are necessary, such as the permeability of the soil, low groundwater level and low sedimentation level. Other issues like maintenance and costs also need to be considered before the implementation (EPA, 1999).

Figure 5.3: *Example for an infiltration basin (Gardenvisit, 2008)*

Retention basin

The retention basin is an artificial lake and has permanent stationary water (Figure 5.4). The water level in the basin may vary during the seasons and is high during the rainy season. The runoff flows into the retention basin and remains in it, till the next heavy precipitation event displaces the amount of water that is evaporated (EPA, 1999). The retention basin is constructed at a lower elevation to collect the surface runoff by drainage (Semadeni, 2008).

On the one hand, the retention basin reduces the peak discharge and thus reduces the channel erosion that is caused by large discharges. On the other hand, it causes upstream channel erosion, which increases the sediment load in the basin. Fertilizers in residential areas can also enter the basin. Sedimentation takes place by gravitational settling, and helps with the removal of soluble and particulate pollutants. A vegetation buffer around the basin can already filter out some pollutants before entering the basin.

The load of sediments and the formation of algae due to the stationary water decrease the attractiveness of the water for recreation and the suitability for water supply (DCR Virginia, 1999). Therefore the basin demands maintenance for the removal of the sediment before it becomes to be more than 1/3 filled (DCR Virginia, 1999). The algae and water plants have to be taken out regularly, as well.

Unlike the infiltration basin, the retention basin experiences problems with bad smell, due to the standing water. To overcome this problem, the basin needs an extensive area. Some advise an area of 15 to 20 acres (DCR Virginia, 1999).

Figure 5.4: *Example of an retention basin at the campus of the Wageningen University (own picture)*

Constructed wetland

Wetlands are those areas which are inundated by surface water runoff or saturated by a high level of groundwater (Figure 5.5). The aquatic vegetation in the wetland is able to withstand water logged conditions and can even filter the water through biological processes. Wetlands have an important function for removing pollutant like nutrients, heavy metals and sediments from the water. This is done by physical, chemical and biological processes and breaks down 90% of the pollutants. Vegetation in the wetlands also slows down the speed of the runoff and can prevent erosion. Unlike the retention and infiltration basins, the vegetation in the wetlands has a shading effect and thereby promotes cooling of the water (Gelt, 1997).

The requirements for constructing the wetlands are a high level of groundwater or a continuous inflow of water (EPA, 1999). Wetlands can sustain as long as they are not overloaded with excessive flow of pollutants. If the pollution is higher than the natural process can handle, human intervention would be needed for cleaning up. In such situations a retention basin with pre-treatment provision would be more appropriate (EPA, 2010). The advantage of wetlands is the creation of a new habitat for wildlife and they also have recreational functions.

Figure 5.5: *Example of a constructed wetland (Trinity College Dublin, 2010)*

Urban creeks

Creeks are small artificial or natural canals, with a width of about 1m and a depth of about 0.2m, that drain through the city. Their main purpose is to collect runoff water, to prevent the city from flooding. There are many functions possible for an urban creek. It can be used for the collection of runoff to drain it into an infiltration or retention basin, constructed wetland or directly into the river. Additionally, it can serve as a connection between the runoff reservoirs (basins or wetlands) and the river to discharge the excess of water. To let the water flow, it needs a height difference.

A creek can also create a new habitat which attracts wildlife. This new landscape also induces a relaxing atmosphere and provides cooling during the summer. It also gives the people a sense of the management and use of water, and can be used for educational purposes. A bicycle or walking road next to the creek increases recreational opportunities, while a terrace of a bar or restaurant next to the creek serves as touristic attraction (Figure 5.6).

Figure 5.6: *Example of an urban creek with attached terrace of a café or restaurant (Wolf Creek Community Alliance, 2010)*

5.1.3. Permeable road material

In general it is recommended to limit the amount of hard, impermeable surfaces in the eco-town in order to limit the amount of runoff (Anink et al., 1996). This is especially the case when climate change is taken into account as runoff will increase according to several climate scenarios (see climate change part). By using more permeable solutions, rainwater can infiltrate easily and thereby prevent the formation of large amounts of runoff. As a result the use of asphalt should be prevented. The construction of an asphalt road is especially polluting as large amounts of NO_2 and SO_2 are emitted (Anink et al., 1996). As a result, concrete blocks or clay tiles which have more open spaces are much better choices when looking for a sustainable road material. An important advantage of these materials is that gaps between tiles are implemented, which let the water infiltrate. As can be seen in figure 5.7, this is ideal for parking spots and ordinary roads. However, because of the gaps between the tiles, it can pose some discomfort for cyclists and pedestrians. Wearing high heels for example can be a challenge on these pavements. Another disadvantage is that pollutants from the road (e.g. oil, rubber residues) are washed into the groundwater.

Figure 5.7: *Example of a permeable road (North Coast Stormwater Coalition, 2010)*

Other options for bike roads and pedestrians are semi-hard pavements such as sand or shell surfaces. These are sustainable and also give the eco-town a natural atmosphere. A disadvantage is the high maintenance cost, because they are mostly used for short and less frequent used pathways and as a result degenerate quickly (Anink et al., 1996). Wood-chippings (Figure 5.8) could be a good alternative for use on small and less frequently used paths in and to the communal gardens for example.

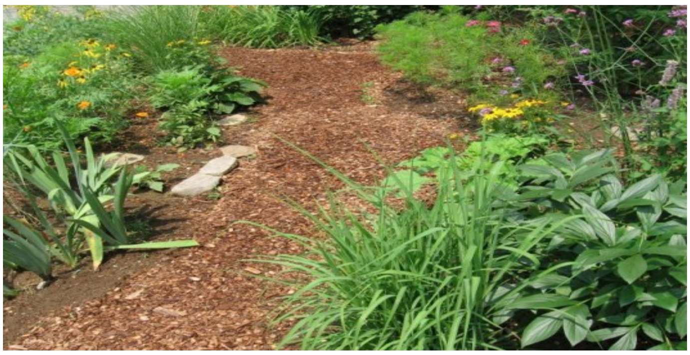

Figure 5.8: *Wooden chippings (Garden Web, 2008)*

5.2. Sustainability

5.2.1. Composting

The Dutch segregates and recycles a large percentage of its waste. Together with Germany, Swiss and Austria it is one of the leading countries in recycling and composting (BBC, 2005). These four countries are pioneers in the field of waste management. Even though the state of the art technology is in place some problems arise in the waste collection system. For instance the GWL in Amsterdam had very few trash cans around. As a result the team could observe that the trash was strewn all over the place and especially in the canal. Segregation of the waste was not practiced because it was not enforced by the authorities even though they had the infrastructure in place. These kind of loopholes need to be addressed to achieve higher percentage of recycling.

Bio-degradable waste constitutes a big portion of the domestic waste entering the landfills. Successful segregation of the waste at source is one of the most important steps for addressing this problem. Green waste (biodegradable) segregation from the domestic waste is one of the biggest challenges for sustainable waste management (Sykes et al., 2007). Composting, which has ecological and economic advantages, is one of the most important measures in order to achieve sustainable waste management. Composting can be done in two ways, either by traditional open composting or by drum composting.

The traditional method of open composting can be quite discomforting in a closed urban setting because of its characteristic pungent smell.

Bio-waste decomposed in open air produces a rancid odor which can be unpleasant in a housing facility. It can attract unwanted pests such as rats, flies and birds. Open air composting also emits microbes and endotoxins (endotoxins are poisonous toxins released when the walls of the bacteria are ruptured). Prolonged exposure to such emissions can be bad for health even though the concentrations are low.

Drum composting is a good alternative to solve the odor problem and treating the organic waste. Curing time for the compost is reduced from four months to four weeks. This method also reduces the release of microbes and endtoxins into the air (Tolvanen, et al., 1998).

Figure 5.9: *Example of drum compost (Stone harbor garden, 2010)*

Compost drums are light and can be moved from place to place (Figure 5.9). The drum can be secured with a lock and can prevent misuse by ignorant people, who trash compost drums with other waste. This kind of behavior is normally observed in urban areas. The drum composter is pest proof and is less susceptible to infestation from flies and rats.
The advantages of segregating and composting waste are manifold. Primarily, it will promote the image of the eco-town in Soesterkwartier and Amersfoort as a pioneer in environmental friendly and sustainable innovations. Secondly, the amount of waste entering the landfills will be reduced and the cost saving from reduced waste handling would trickle down to the households. The composted manure is organic and free. This diminishes the need of using synthetic fertilizer, which is bad for the environment.

In one of the studies done in Sweden, people were willing to spend more time on recycling and composting if the municipalities provide proper infrastructure for encouraging good environmental waste management. Economic incentives though important were a secondary factor in the people's choice to segregate and compost the bio degradable waste (Sterner, 1999). It can be assumed that good infrastructure needs to be in place to encourage waste segregation and composting.
Measures which contribute to solving the global waste management problem by practicing waste segregation can be one of the recommended options. This could promote the eco-town and Amersfoort's image as a pro active city for sustainability measures.

5.2.2. Toilet flushing

Use of rainwater

Instead of using potable water for the toilet flushing like it is usually done, it is also possible to use collected rainwater. There are mainly two different systems:

1. The first option is to collect the rainwater which lands on the roof directly and store it in an elevated water butt at an upper floor. In this simple system the rainwater runs along the guttering and flows down a pipe to the storage barrel. From there the water feeds the toilet cistern by gravity (Figure 5.10) (Renewable Energy UK, 2010). An additional pipe with mains water is needed that supplies the toilets with water when there is insufficient rain. Furthermore, a filter system should be included that filters big particles out of the rainwater (not shown in the figure).

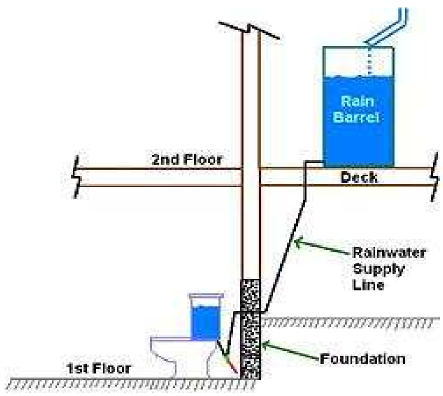

Figure 5.10: *Simple rainwater toilet flush system with elevated collection of the rainwater (Renewable Energy UK, 2010)*

2. The second option is a more complex system. It has to be established, if the toilet is high above ground level, or if there is no space for the water butt at an elevated level. This system uses a pump to bring the collected rainwater up to a header tank (Figure 5.11). From there it can feed toilet cisterns by gravity. Additionally, there should be a mains water inlet to the header tank for periods with insufficient rain. This pipe has to be at least 15cm above an overflow pipe (Renewable Energy UK, 2010). By this there is no risk of rainwater entering the mains water supply. The pump in the water butt at the ground level should be powerful enough to lift the water high enough to supply all toilets, but at the same time it should not use too much electricity. In order to turn the pump on and off according to the water level in the header tank, an electronic system has to be installed. The whole system should best be powered from renewable energy (Renewable Energy UK, 2010). Furthermore, a filter system should be included that filters big particles out of the rainwater.

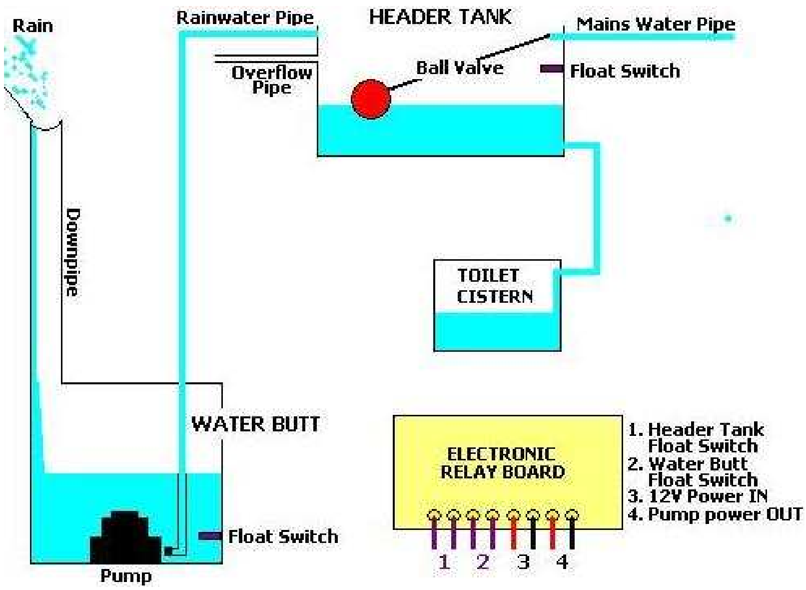

Figure 5.11: *Rainwater toilet flush system with pump (Renewable Energy UK, 2010)*

Typically 25% of the domestic water is flushed down the toilet. Installing a rainwater toilet flush system saves this expensively processed potable water (Renewable Energy UK, 2010). Thereby costs can be saved as the prices for drinking water are increasing (Albrechtsen, 2002).

As investigated by Zhang et al. (2009) in a model of a case study from Australia (Bix Hill, Melbourne), a rainwater harvesting system for a high rise building can reduce potable water use significantly, if an adequate storage capacity and roof area for the collection are available. Table 5.1 shows the results that can give an impression about the possible water savings in high rise buildings with different roof sizes.

Besides the water saving aspect that diminishes the uptake from groundwater, runoff is also reduced because the water is collected beforehand (Mikkelsen et al., 1999; Zhang et al., 2009). Additionally, the dependency on wastewater treatment plants and thereby energy use decreases (Zhang et al., 2009).

The collected rainwater can have a lower quality than potable water, because it is not used for human consumption. However, studies (e.g. Oesterholt, 2007) found out that there are no chemical toxicity effects expected from the use of rainwater in toilets. According to a study by Albrechtsen (2002) also the microbiological quality is approximately the same as in the toilets with drinking water flushing. In contrast to that, studies by Schets et al. (2010) indicate that the microbiological quality of collected rainwater is generally poor compared to drinking water quality and poses a health risk.

Table 5.1: *Model for high rise buildings: Tank size for storage capacity of two different roof sizes (rainwater collection area); saving of potable water per year (tank water use in ML/y); percentages of mains water and storm water discharge reduction compared to the reference scenario used in the study (no alternative water sources) (Zhang et al., 2009).*

	Rainwater collection area	
	600 m²	**900 m²**
Tank size (kL)	25	60
Tank water use (ML/y)	6.6	9.9
Mains water reduction (%)	6.9	10.4
Stormwater discharge reduction (%)	73.8	75.7

Oesterholt et al. (2007) even state that the biological stability of the water is insufficient and at least one biological filtration step (e.g. Rapid sand filtration) is recommended to improve the quality. By using rainwater, micro-organisms are introduced into the households that normally don't occur in the tap water. There may even be a risk for the occurrence of pathogens (Albrechtsen, 2002). Contamination can also occur through animal faeces and pollution on the roof from which the water is collected. Consequently, appropriated measures are crucial to reduce the possible health risk. The collection site and storage tanks have to be cleaned regularly and access for animals to the reservoirs has to be prevented (Schets et al., 2010). This might also help to reduce the smell that was in some cases reason for complaints (Albrechtsen, 2002). By diminishing this problem, the user acceptance may increase as well.

Besides this possible health risk, there is also a risk for contamination of the public drinking water by incorrect installations or leakages. This can happen because there always has to be a mains water pipe as backup for dry periods. This contamination would not only be a threat to the people using the rainwater toilet system, but also for the rest of the population in the area that is supplied with the drinking water (Albrechtsen, 2002). Since the Netherlands is one of the few countries that does not have disinfection in the water system (Smeets et al., 2009), the risk for such a contamination is more problematic (Albrechtsen, 2002). It has to be assured that the installations are correct and that regular controls are undertaken, also in the single houses, in order to avoid such incidents. However, this can lead to high costs as there is always technical knowledge and costs needed to maintain the system (Mikkelsen et al., 1999; Gelsenwasser AG, 2006).

Another disadvantage is the dependency on the rainfall. If the rainfall in summer is decreasing, like scenarios predict (see climate change chapter), there might be insufficient water for the toilet flushing. More intense precipitation events cannot change this because large volume of storage tanks would be required. It might even increase the health risk as Schets et al. (2010) found out that the microbiological quality of the collected rainwater decreases with high rainfall intensity. Since this is predicted for the area around Amersfoort (see climate change part) there might be even a higher health risk, if rainwater is used for toilet flushing.

Several studies come to the conclusion that the health risks, the low environmental benefit and the economic costs of the current installed systems outweigh the benefits (Gelsenwasser AG, 2006; Oesterholt, 2007). Consequently, improvements of the system are needed.

Use of grey water for toilet flushing

The use of grey water is an alternative to systems that flush toilets with collected rainwater or drinking water (Figure 5.12 a and b). Grey water is low-polluted wastewater generated from domestic activities like bathing, showering and laundry (Nolde, 2005). Sometimes it also includes water from dishwashing. Excluded is always the soiled water from toilet flushing.

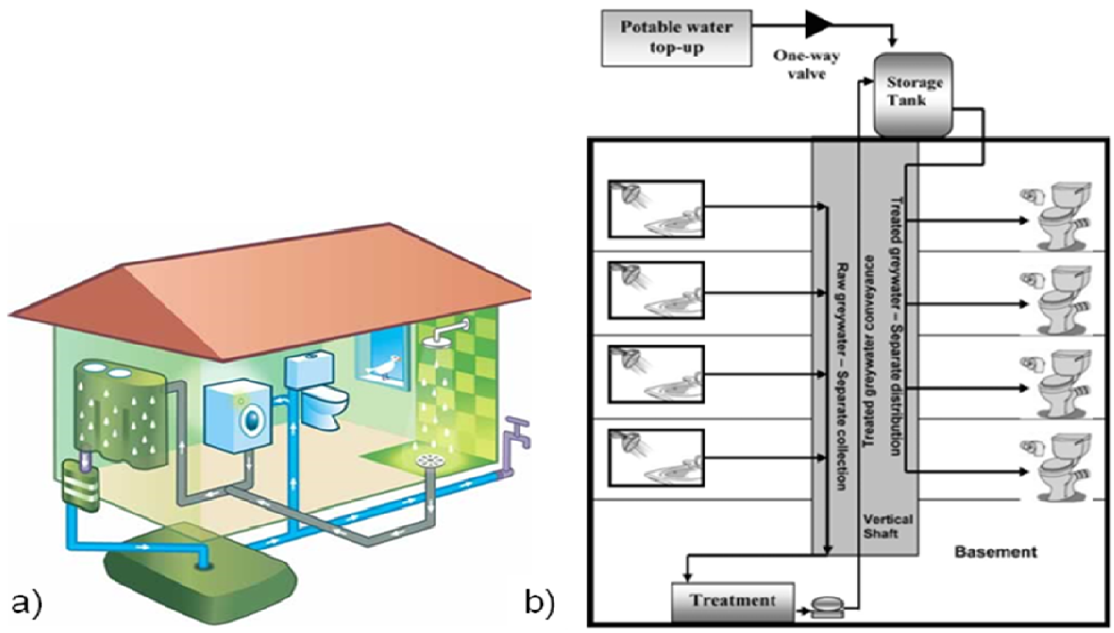

Figure 5.12: *a) Grey water system in single household (Spec-Net Building Index, 2010); b) Grey water system in a multi-storey building (Friedler & Hadari, 2006)*

Different investigations of the water quality and the related health risk show that the recycled water can have a low microbiological quality (Albrechtsen, 2002). Simple systems where the recycled water was not treated at all or only treated with electrochemical disinfection did not meet the required water quality. They were often reason for complaints about smell and hence rejected by the users (Albrechtsen, 2002; Nolde, 2005). Systems with a single treatment step followed by UV-disinfection were not of the required standard, either (Nolde, 2005). These systems are often installed in apartment buildings and collect the water from many households. That is why also disease-carrying persons may be included. They may excrete pathogenic agents which can be introduced into the collection system and pose a risk to the other inhabitants (Albrechtsen, 2002).
As it can be a problem in systems with rainwater for toilet flushing, also the systems that use grey water can lead to contaminations of the drinking water, if installations are done in an incorrect way or maintenance does not work properly. That is because both systems need an additional inlet for mains water, if there is not enough water collected. Consequently, a proper maintenance is certainly needed, which can be costly (Albrechtsen, 2002).

In order to avoid the above mentioned health risks, the treatment systems were improved and investigations show that personal hygiene products, household-cleaning chemicals and even faeces and pathogenic bacteria can be filtered out (Nolde, 1999). Systems in multiple households have proven their effectiveness for years already (Nolde, 2005).
There are mainly two different ways of treatment which are shown in figure 5.13. The rotating biological contactors (RBC) are preferentially installed in buildings in high densely populated areas because they are compact. The specific area requirement is only about 0.1m² per person (Nolde, 2005). According to investigations, the alternative treatment system (plant-covered soil filter) fulfills the hygiene requirements which are in accordance with the EU-Guidelines for Bathing Waters (Nolde, 2005).
Since treatment systems with fewer stages showed their unreliability, these extensive systems are essential in order to avoid health risks. Furthermore, they promote the public acceptance for grey water recycling (Nolde, 2005).
Another advantage of these improved systems is that additional chemical disinfectants, such as chlorine, do not have to be added to the treated water. This increases the environmental tolerance for the use of grey water (Nolde, 2005).

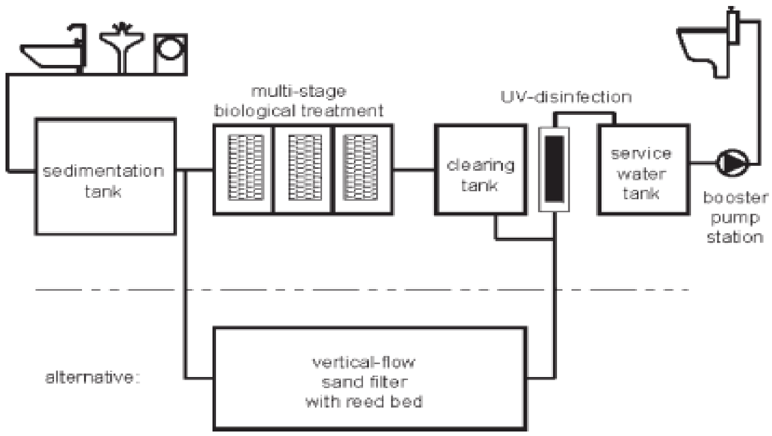

Figure 5.13: *Recommended concepts for grey water treatment. In the upper part the rotating biological contactors (RBC) multi-stage system can be seen and below the alternative plant-covered soil filter (Nolde, 2005).*

Besides the use of grey water for the toilet flushing it can also be used for floor cleaning, gardening, landscape irrigation and even for washing machines. Investigations show that there is no difference to the use of drinking water. From the economical point of view it is even better to include more applications than only toilet flushing (Nolde, 2005).
The economical aspect of the reuse of grey water is still controversial. Nolde (2005) for instance states that the installation of grey water recycling systems at the single household level is usually cheaper than a centralized system for the use in multiple households. In contrast, Friedler and Hadari (2006) argue that the costs (investment, operation and maintenance costs) for the cheaper RBC treatment system (see above) are reduced with increasing number of flats. The economic feasibility further depends on water price and sewage charge (Friedler & Hadari, 2006)
An advantage compared to the use of rainwater is that grey water collection has not to deal with natural variability of precipitation. The water is always available. Furthermore, the system does not depend on the size of the roof in order to collect enough water and the storage tank can be small. According to Dixon et al. (1999) it only needs a size of 0.15-0,2m².
To conclude, with a minor cost increase a reliable and safe system can be implemented that saves drinking water and creates an environmental friendly image (Friedler & Hadari, 2006).

5.2.3. Water and energy saving installations

In this power and resource intensive environment, it may be a good idea to make people aware of how much resources they use. In the eco-town several measures or solutions can be implemented to make the resource use lower than in other neighborhoods. Pressure on natural resources such as oil, gas, and fresh water is likely to increase in the future. As a result it is likely that their prices will rise. There are several simple instruments which make the inhabitants aware of their consumption and will eventually make sure that the resource use in the eco-town is lower than in other neighborhoods.

A possible first option is the installation of a visible power, energy or water meter so that people get acquainted with what they consume. A water meter in the shower for instance, could show how much water is used and its estimated costs. The same can be done with the power meter, which is normally hidden in the basement or meter cupboard and nobody is aware of it. A display in the living room which shows the amount of energy consumed would inform the inhabitants and also make them more aware of how much they use. An advantage of such displays is that they do not need changed behavior of the user, but inform and create awareness.

Several energy saving measures are available, of which most are common nowadays in the Netherlands. One of them is the installation of motion or heat detecting sensors which automatically switch lights on or off when you enter or leave a room. Another interesting recent technology is the inclusion of LED (Light Emitting Diode) lighting instead of the traditional compact fluorescent lamp. The main advantage of using LED lighting is their lower energy use. Moreover, LEDs do not require mercury and lead, which is still needed for the production of compact fluorescent lamps (Steigerwald et al., 2002). The disadvantage however is that the quality of light and distribution is not so good compared to a fluorescent lamp (Steigerwald et al., 2002). But the development is rapid as they are even included in

TVs and laptops nowadays. It could be that these drawbacks have disappeared within a few years. LEDs are an interesting development to follow for the coming years.

For the bathroom there are water saving showerheads which are easy to implement. For the toilet there is the common two- button system which uses one button for a small flush and a large for a big flush. Most flushes require only a small flush, so in this way a lot of water can be saved. These are all small measures, but when they are combined they can certainly lower resource use. More importantly, they can convince users to use fewer resources.

5.2.4. Intelligent architecture

Intelligent architecture refers in our case to options that make a building more sustainable and less energy consuming. The focus is put on the use of natural lighting and heating, and on insulation.

Lighting

Using natural daylight is the most sustainable and cheapest way of lighting as it is a free renewable resource. Buildings should be designed in a way that allows natural daylight to reach as many rooms as possible. This can be done by having many rooms with windows on the south side. Thereby the inner temperature regulation has to be maintained. In the best case the incoming light is further reflected to other rooms by careful placement of windows, skylights, light shafts and atriums (Sustainable Build, 2010). This concept is known as Day-lighting design and can lead to great energy use reductions (Patterson & Connery, 1997). Sunlight transportation is another new emerging technology where the sunlight is collected on roof panels and transported via fibre optic cables into the building (Sustainable Build, 2010).

Heating

Heating is another sector where energy can be saved. Besides the light, the energy from the sun can be used as well. In the Passive Solar design the heat of the sun is used to regulate the temperature in the building (Sustainable Build, 2010). Therefore, no additional energy source is needed and it is relatively easily implemented in any design styles. Moreover, the construction is not more expensive as it relies only on specific placement of the windows and the use of traditional building materials. The materials should have a high volumetric heat capacity to store the solar energy to a high degree (thermal mass). Materials with concrete and solid masonry can best be applied for floor and walls. Furthermore, south-facing windows and insulated roofs are prerequisite for the Passive Solar concept. The sunlight enters the room through the window and falls on the floor that absorbs and stores the heat. Additional storage is provided by the internal walls (CCAA, 2003).

An advantage of the system is that it has a function in both winter and summer, with a heating (winter) and cooling (summer) cycle:

In winter the sun stands low compared to the summer and can enter the room via the window. The heat is stored in the elements and is only released when the air temperature drops below that of the thermal mass (Figure 5.14) (CCAA, 2003).

When the outside temperature increases in summer, the inside air temperature is modified by the floor and the walls that absorb the heat from the air. Furthermore, cross-ventilation is provided by opening the windows. The sunlight cannot enter the room as it stands too high. However, additional shading over the windows should be configured to avoid access (Figure 5.15) (CCAA, 2003).

Consequently, it is needed to understand the position of the sun in order to locate the building and windows properly. Also the size and type of the windows is important. Additionally, other location factors have to be included into the planning like possible shading by vegetation and other buildings (Sustainable Build, 2010).

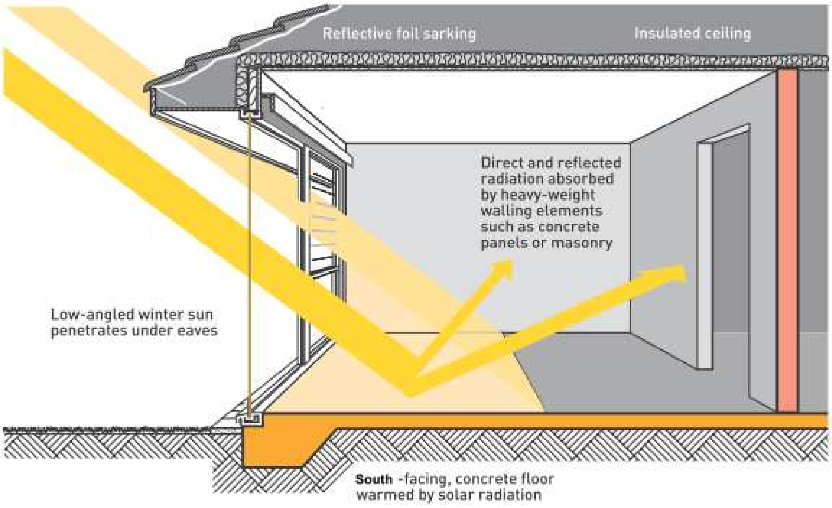

Figure 5.14: *Direct gain-heating cycle for the winter. The sun stands low and can enter through the window (CCAA, 2003).*

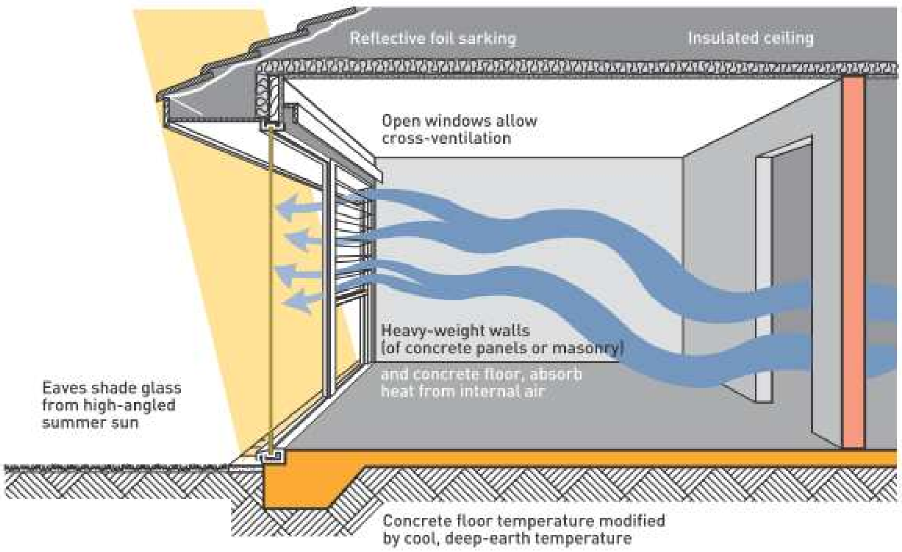

Figure 5.15: *Direct gain-cooling cycle for the summer. The sun stands high and cannot enter through the window (CCAA, 2003)*

Insulation

To make sure that the eco-town is sustainable, the building materials have to be as natural and durable as possible. It is highly recommended to make use of locally available materials in order to prevent large transportation costs and emissions (Anink et al., 1996). Another attractive option is to recycle or reuse available materials. To combine both, it could be an idea to reuse some of the steel or wood from the current existing railway tracks or depot. This also makes sure that the eco-town blends in with the existing Wagenwerkplaats and the Soesterkwartier neighborhood.

The inclusion of wood gives the eco-town an ecological attitude. By making use of certified wood (i.e. Forest Stewardship Council, FSC), you make sure that this wood is cultivated and managed ecologically and does not pose a threat to the sustainability of the eco-town. Sustainable hardwood is preferred for the outside use as this does not need regular maintenance and has a long lifetime. An alternative could be cheaper sustainable softwood, but this implies more painting and maintenance (Anink et al., 1996).

Most new houses in the Netherlands have already a high standard of insulation. This will not be different in the eco-town in the Soesterkwartier. Additional to the insulation properties, the sustainability of the materials is also important for the Soesterkwartier. Natural materials such as mineral wool are preferred above existing foamed glass insulation or polystyrene (plastic) as they are more sustainable. The use of cork or cellulose is also an attractive option, because it is a renewable material which does not use a lot of energy for the production (Anink et al., 1996).

To create a sustainable building it is not only important to place the windows correctly, like mentioned above, but also to use the right frames and glazing. This is because most of the energy in buildings flows in and out through the windows. Consequently, good insulated windows are essential. The same counts for doors with glass in it.

There are different types of window frames, which all have advantages and disadvantages. Wooden frames for example need regular maintenance (painting) to prevent damage from weathering. However, they are a good insulator and thereby energy efficient. Additionally, the wood can be from a certified sustainable supplier (FSC). Fiberglass frames, which are also energy efficient and expensive, have the advantage of being low-maintenance. In contrast to these types of frames aluminum frames are cheap and do not need a lot of maintenance. At the same time they are not really energy efficient as they conduct heat easily (Sustainable Build, 2010).

The most sustainable type of frame in relation to insulation might be that one made of Polyvinyl chloride (PVC). They are cheap, energy efficient and low-maintenance (Sustainable Build, 2010). Since the material is not really sustainable, the use of recycled PVC could be considered.

Beside the right choice for the frame material, the type of glazing is essential as well. Windows should at least have two panes of glass to be energy efficient (double paned or insulated windows, see figure 5.16). In between the panes is space filled with low conductance gasses, like argon or krypton, which slows down the heat transfer and also serves as noise insulation (Sustainable Build, 2010).

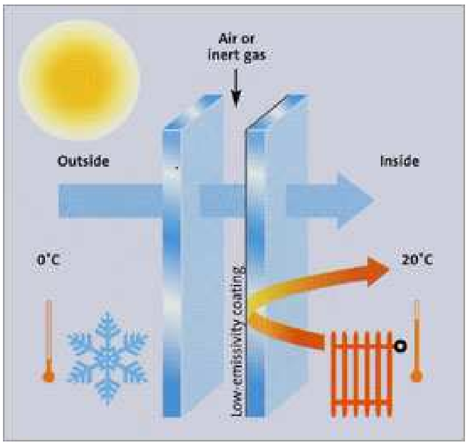

Figure 5.16: *Double glazed unit (Chipping Norton Glass, 2006)*

The windows have an even better insulation when the glazing is coated with thin layers of metal or metallic oxides, so called low-emittance coating. This layer slows down the heat transfer even more and thereby achieves better energy efficiency.
It is also important to pay attention to the spacers between the panes of glass as they also can have high conductivity, like for example aluminum spacers. These types of spacers should be avoided (Sustainable Build, 2010).

5.2.5. Thermal storage (Koude- en warmteopslag, KWO / WKO)

An interesting option that could be implemented in the eco-town is thermal storage, or KWO (Koude- en warmteopslag) in Dutch. This system uses thermal heat from the soil or groundwater to cool / heat the building depending on the demand. There exist two types: An open and a closed system. In an open system, groundwater is pumped up to cool or heat the building (Figure 5.17). After use it is released back again into the aquifer. A problem with this system is that in some regions of the Netherlands it is forbidden as the aquifers are protected by law (RIVM, 2010).

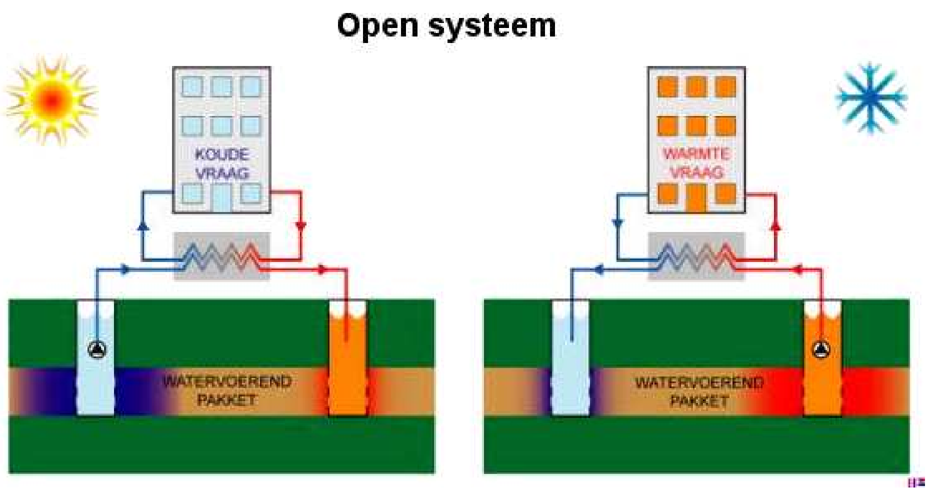

Figure 5.17: *Groundwater based KWO (RIVM, 2010)*

The soil heat exchanger is a closed system and works on the principle of soil heat (Figure 5.18). In the soil several containers with a coolant (mostly antifreeze) are installed. In summer, the soil is colder than the environment and thereby cools down the coolant in the containers. As a result, this colder fluid can be used to cool the building. During winter the soil is warmer than the environment and the fluid inside the containers can be used for heating. An advantage is that this system is closed and does not require the presence of groundwater in order to function properly. A drawback is that the efficiency is lower, and there are also concerns that too many buildings, which are close to each other, use it. This lowers the temperature difference of the soil as it is heated or cooled by other buildings. As a result the efficiency becomes lower, in some cases too low to be economically viable (RIVM, 2010). Another drawback for WKO is that it is an expensive system, and as a result it will take some time before it can earn itself back.

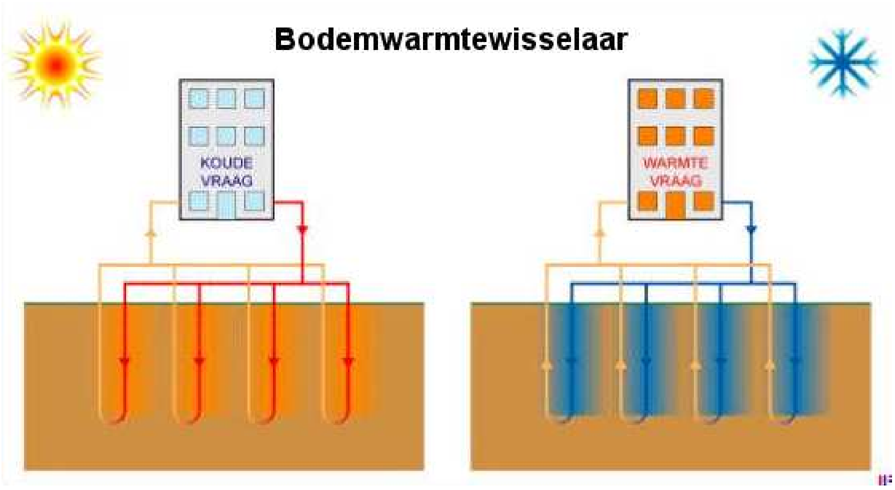

Figure 5.18: *Soil based KWO (RIVM, 2010)*

As turns out from the Klimaatactieplan 2009-2011 from the municipality of Amersfoort, KWO / WKO are already mentioned several times. Moreover, it becomes clear from this document that the municipality has several plans to use this system. It is therefore likely that for new building projects like the Soesterkwartier, a soil based KWO will be implemented. It would be most efficient to include KWO / WKO in larger buildings, as they have a larger surface and can thereby provide more room for the coolant containers. This increases their size and as a result their capacity. Also the transportation-lines will be shorter which results in a higher efficiency.

5.2.6. Solar Energy

Solar energy can be transformed into electricity and heat. The devices that use solar energy are heat boilers (i.e. solar collectors) and photovoltaics (Figure 5.19 a and b).

In the solar boiler a black metal plate is included, which captures the sunlight and heat. A glass plate on top of the metal plate prevents the heat to escape. The heat is conducted to a frame with tubes to heat the liquid in between the tubes. The liquid is attached to the cold tap

water, which is then heated and used for bath and shower and sometimes even for floor heating (Energiesparen, 2010).
Photovoltaics are solar cells made of silicium, combined in photovoltaic panels. The construction consists of a positively and negatively charged side, and power is generated by sunlight. The larger the panel, the more stream it can generate. The energy is transformed into electricity, for direct use. At moments with few sunlight available (night, dark days), it is still possible to get electricity from the net (Energiesparen, 2010).
Solar energy saves costs, because less electricity from the grid is needed. To have large benefits, the roof has to capture enough sunlight, free from shadow of buildings and trees. The solar boiler needs enough space on the roof (1m^2 for every 40-60 liters of boiler content). The solar panels have to be installed in an angle of 20°-60°relative to northeast or southwest. People can measure the energy they generate on a meter, which stimulates the awareness of the energy use. It gives satisfaction to people to generate their own energy (Energiesparen, 2010).
Solar energy is expensive, but the costs can be reduced by subsidies from the government. Compared to Belgium and Germany, the subsidies for solar panels in the Netherlands are not easy to obtain (Zonnestroompanelen in Nederlands, 2010).
Another disadvantage of solar panels is the variability of the intensity of the sunlight. When the intensity of sunlight is small, electricity has to be taken again from the grid. On the other hand, the system is overloaded at days with high intensity of sunlight and little use of electricity (hot summer days) and the system turns off. It asks a lot of time and energy to put the system again on. In winter, the snow remains on the solar panels and prevents the panels from capturing the sunlight.
Photovoltaics are usually put on the roofs of houses and larger buildings, but they can also be installed on street lights. They switch on and off automatically with sunset and sunrise, respectively. On dark and cloudy days the system keeps working for three days, so the energy can be stored (Oksolar, 2010).

Figure 5.19: *a) Solar Boiler (i.e. solar collector) (Zonne collector, 2010); b) Photovoltaics (To201's blog, 2009)*

5.3. ‘Green’ feeling

5.3.1. Green areas

Parks and green areas are an essential part of sustainable urban planning as they provide services from social to environmental aspects. They serve as a variation from the “concrete jungle” to which most of the inhabitants of a city are accustomed (University of Cincinnati, 1999). The vegetation in the green spaces reduces not only the noise from the city but it also promotes a good micro-climate regulation, such as cooling in summer (Saito et al., 1990/91; Bolund & Hunhammer, 1999). Additionally, the air quality is improved as pollution and particles are filtered by the plants, especially by trees. The best way to increase the air quality is a mix of coniferous and deciduous trees (Bolund & Hunhammer, 1999).
The social interaction between the inhabitants of the neighborhood is especially promoted by installing an attractive green space. A park has a high recreational value and can increase the physical and psychological well-being of urban citizens (Bolund & Hunhammer, 1999).
There are many possible options that can be applied in order to increase social interaction, like picnic shelters that form a semi-private space in a public setting, pavilions to provide shaded places, barbecue facilities and benches at several spots in the area such as in figure 5.20 a and b. Sports facilities like presented in the part about “Activities for children” can be included as well. The vegetation can be planted in a way that increases the scenic beauty and give a feeling of a bigger size. By planting trees with large canopies not only shade is created but also birds and other animals are attracted to this area. Thereby the biodiversity in the neighborhood can be increased. If fruit trees are used, there can also be a learning effect, when the species are indicated with signs.

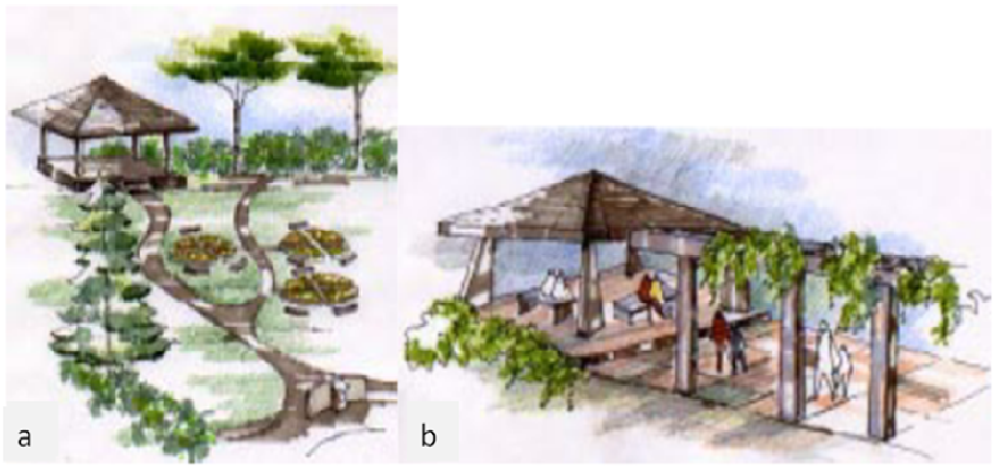

Figure 5.20 *a and b: Examples of a design for a green area, here with pavillions (University of Cincinnati, 1999)*

Besides these social benefits, green areas also have several environmental advantages. Water regulation is in this case a really important effect. The high percentage of pervious surfaces increases the infiltration of runoff and heavy precipitation water. Additionally, the vegetation takes up water and releases it again to the air via evapotranspiration.

Basins and creeks can be incorporated in the design of the area and reduce the effects of runoff even further (Figure 5.21). They can enhance the scenic beauty and might also be used as fish ponds.

Figure 5.21: *Example of a green area with a basin (Geograph 2010)*

Other services provided by green areas are CO_2 sequestration and thereby lowering the greenhouse effect; by planting grass and other vegetation the soil is protected from erosion, which is increased by strong runoff and precipitation events (Bolund & Hunhammer, 1999).
During the planning of the green area, the installation and maintenance have to be taken into account. If several spaces at different locations are planned, the maintenance can be facilitate by connecting the parks with footways and narrow green spaces. This also enables animals to migrate (University of Cincinnati, 1999).

In the new eco-town in the Soesterkwartier there might be a green area or public park. Hence, the social and environmental advantages of such a vegetated area are used. The most important service will thereby be the reduction of the runoff. An idea is to shape the area like a belt to connect the station with the leisure area in the west. Thereby the location will have different impacts. If the belt is located at the northern part of the Wagenwerkplaats, social interactions between the new inhabitants and current of the Soeserkwartier is promoted. However, to address the hydrological aspect, it would be better to place the belt in the south of the Wagenwerkplaats in order to directly reduce the runoff that comes from the elevated forest area in the west. In this case the social interaction might be diminished, though. If the southern location is picked, connections of the green area to the Soesterkwartier could be created by establishing several bike lanes and footways. Furthermore, it might be necessary to construct noise protection because of the proximity to the railway.
If the green belt is designed in an appealing way with many bike lanes, footways and connections to the historical buildings, this can stimulate tourism as well.

5.3.2. Individual and community gardens

A garden is a planned space, usually outdoors, set aside for the cultivation of vegetables and plants. Gardens mostly contain a mixture of vegetables and flowers. They may have high hedges or trees at the front side to protect the crops from passersby and to provide privacy.

Individual gardens

An individual garden is located outside the house or ground floor of an apartment and is owned by individuals. It has different advantages such as providing a safe outdoor place as an alternative to the apartment. Parents find a garden good for their offspring: a site where they are safe and can be around with the nature. An individual garden is a place to relax, living with nature and grow vegetables and flowers. This is especially applicable for those who do not have another nature place to go or who do not like to go out.
Moreover, gardens enhance the use of collected rainwater. The collected water can be used to irrigate the vegetables and other kinds of plants. Thereby potable water is saved.

Community gardens

In order to create social interactions between the inhabitants of apartment complexes, community gardens can be established. These can be used for growing of vegetables, flowers and other plants (Figure 5.22). They can be for rent and are mainly for the people who do not own an individual garden.
The advantages of having community gardens can be seen from two different points of view as there are social and environmental ones. During cultivating and sustaining the gardens, the gardeners develop a common goal and have immediate contact with each other (Schmelzkopf, 1995). This increases social interaction of the inhabitants. Through their work in the garden, such as treating the soil and being concerned about frosts, drought, soil fertility, and rainfall, they also have an immediate contact with the environment. Moreover, the gardeners get the chance to have fresh vegetables from known source. A benefit of community gardens for the whole neighbourhood is an increase in the aesthetic value.
Besides these social advantages, there are also environmental ones. Community gardens encourage composting and the use of biodegradable waste. Thereby the use of environmentally unfriendly or water polluting synthetic fertilizers is avoided. Furthermore, the gardens can reduce the effects of runoff by infiltrating the rainwater. With the planted vegetation a good microclimate can be maintained by releasing oxygen and filtering the air. Like in the individual gardens, collected rainwater can be used for the irrigation of the community gardens.
Even if the above mentioned advantages of having a community garden dominate over the demerits, it still may have some disadvantages, such as management related issues. One is that the spots have to be monitored and maintained if they are not in use, but also if they are in use. Around the spots taller plants are needed in order to protect the growing plants from passerby and to provide privacy. In some cases there was controversy about whether or not it was safe to grow and eat vegetables because of soil contamination by lead and other heavy metals in the rubble of demolished buildings (Schmelzkopf, 1995). In such a case it is important to manage and produce the vegetables with a great care to be free from contamination.

Figure 5.22: *Example at GWL terrain in Amsterdam for a community garden with small spots for growing of vegetables and other plants (own picture).*

5.3.3. Wall plants

In order to green up the neighborhood, plants can be planted to grow up the walls if buildings (Figure 5.23 a and b). Plants on the outside of walls add a very effective additional insulating layer for keeping heat in, thus reducing overall heating bill, but it also has a cooling effect. The vegetation provides nesting place for birds and other wildlife. Wall plants can be an effective way of covering up an unattractive wall. The green spots give buildings an idyllic character and can purify the air in urban environments (Kobæk et al., 2005). Furthermore, runoff is slowed down, incoming noise is reduced, and the greenhouse effect is decreased.

Figure 5.23 *a and b: Example for an apartment building with creepers, a) GWL terrain, Amsterdam (own picture); b) other example (Fassaden Grün, 2010)*

Since creepers grow fast, measures are needed in order to prevent them from excessive growth and covering windows, roof eaves, etc. (Kobæk et al., 2005). If the eco-town wants to implement wall plants like ivy, regular maintenance like pruning of the plants is required. The condition of the wall also has to be inspected regularly. These measures may need labor and cost expenses. It may be difficult to remove the plants if required and can cause damages to the walls.

5.3.4. Noise reduction

The Soesterkwartier is to be built close to the railway station, which is a significant source of noise. The railway station is located in the South of the Soesterkwartier. To reduce noise from the railway station and busy roads there are mainly two options:

1. Build a noise reducing wall
2. Build wide (apartment) buildings close to the noise source

The differences between the two are numerous. One major advantage of placing buildings for noise reduction is that it creates living space at the same time, while the function of a wall is solely to reduce the noise. However, a noise reducing wall requires less space than a line of buildings with the same length. Disadvantage of noise reducing walls are that they are prone to vandalism (e.g. graffity painting), they can create an imprisoned feeling, and they are not famous for their beauty. Both options block the line of sight, but buildings tend to do this to a greater extend, because they are often taller than a noise reducing wall. Since the noise reducing construction it to be built in the South, a tall construction (e.g. building) also create a shaded area to the North. However, the advantage of a noise reducing wall is that it can be made transparent..
Some disadvantages of the noise reducing wall can easily be solved. The use of transparent materials can both reduce the imprisoned feeling and the amount of shade. To make them better looking and reduce the possibility for vandalism they can be coated with vegetation (e.g. grass) (Figure 5.24). It also depends on the creativity of the architect whether the noise reducing wall looks nice or not.

Figure 5.24: *Example for transparent and vegetated noise reducing walls (Eskyiu, 2010)*

5.4.Social interactions

5.4.1.Use of industrial buildings

The buildings of the Wagenwerkplaats were used for the maintenance of the railway materials of the NS (Nederlandse Spoorwegen). The place consists of several buildings, of which the 'ketelhuis', 'smederij' and 'schilderwerkplaats' are the largest. This industrial heritage has an historical and emotional value for the inhabitants of the Soesterkwartier, because most of the inhabitants worked in the Wagenwerkplaats. The reuse of nineteenth-century industrial buildings as historical and cultural monuments is very popular in Europe nowadays. A unique binding agent between old and new is creativity and creation (C-mine, 2010). The goal of the Wagenwerkplaats is social development, creativity and innovation, with a touch of sustainability. This can be done by learning and working (Vries & Kuenen, 2008). Some of the buildings are already in use, such as the architectural company, circusschool and theatre. For the remaining part of the buildings, plans are already in the pipeline. However, not all buildings have a purpose yet.

The Wagenwerkplaats experiences problems with soil contamination. This is due to a long period of industrial work. High amounts of liquid petroleum gas (LPG) and chlorine are present. The site clearance will require a high cost (Amersfoort et. al., 2003). This is important before the area can be built. The large buildings are made of steel, with large windows and a ventilation system (Amersfoort et al., 2003). These stable buildings have a lack of sustainability as the insulation does not reach the standard values. To overcome the problem of using a lot of heat in the winters, the buildings have to be renovated. A search for a compromise exists between maintaining the historical heritage as it looks now and innovation for sustainability.

The Wagenwerkplaats has still buildings that are not in use. We come up with suggestions for a new function. A museum presenting the history of the Wagenwerkplaats is interesting for the inhabitants of the Soesterkwartier, new inhabitants of the Wagenwerkplaats area, but also for people visiting the zoo or city of Amersfoort. Another aspect to attract people from around is the commercial function, like a bar or restaurant. Industrial features, like in the restaurant on the GWL-terrain in Amsterdam, cause a mix between old and new, giving the interior a special identity and supporting creativity (Figure 5.25). The combination of a museum, dining place and 'het Groene Spoor' make the Wagenwerkplaats a touristic attraction.

Some suggestions especially for the inhabitants would consist of a sports centre, with fitness, sauna, hammam, yoga, dancing, etc. and a common room or space for activities with the inhabitants, for the use of rental tools and as a conference room.

Figure 5.25: *Café Restaurant Amsterdam at the GWL-terrain (2010)*

5.4.2. Activities for children from 12+

The Soesterkwartier has already some playgrounds for young children but lacks activities for the youth (12-18 years). Children in their adolescence are uncertain about their personalities. They do not know how to handle their body changes and how to handle conflicts. Sometimes adolescents can be aggressive towards their parents or at school. In this stage of life it is important to build good friendships, and to spend some free time with friends. This helps to build self-confidence, independence and personality. In order to do that, they like to have a place to come together with friends and be active.

This place can include different activities. A skate park is a well known attraction for the youth, because it has both the opportunity to do some sport and to socialize (Figure 5.26 a). Conventionally these types of parks are constructed with a lot of concrete, but there are possibilities to make it sustainable. To cope with the runoff and intense precipitation, the design can include drainage from on-site to off-site where it is drained into small basins. These small basins slow down runoff and promote infiltration into the ground and filter the water through water plants. Solar panels can be incorporated into the design of the skating premises and this solar energy is then used to power the lights in the evening (Luc, 2008). The skate park can be combined with table tennis, a basketball court and wooden benches (Figure 5.26 b). Trees can provide shade to this meeting place, which is important to decrease the heat effect in summers. It is a nice idea to put the location of the spot close to one of the industrial buildings or structures of the Soesterkwartier, to give identity to the meeting place.

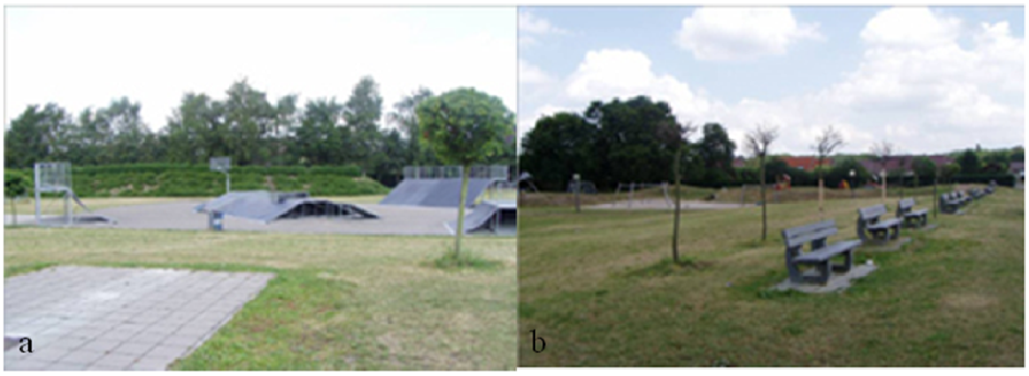

Figure 5.26: *a) Example for a skate park (TC Ham 2010); b) Example for the inclusion of wooden benches (TC Ham 2010)*

5.4.3. Transportation

Car-free neighbourhood

The main aspect of the eco-town in the Soesterkwartier is sustainability. One of the ways to create this is to make a car-free zone which results in a clean, quiet and calm living environment.

When the project team visited the GWL-terrain in Amsterdam, the advantages of having car-free zone became clear immediately. By removing the cars from the living area, a calm and relaxing living atmosphere is created (Carfree UK, 2010). Removing the cars and parking spaces from the neighborhood has several advantages. Firstly, more space is created for living and recreational purposes. Secondly, it removes the noise and pollution problems that cars create. Finally, it is also an environmental friendly statement that makes this neighborhood stand out from other neighborhoods (Carfree UK, 2010). Since the location of the eco-town is next to the train station, public transport is always nearby, so that having a car is not really necessary.

The idea has potential, but real life also needs to be taken into account. People are used to the advantages of cars and the freedom that they provide. It would be a utopia to completely remove them from the neighborhood. For this the project team can refer back to the excursion in Amsterdam. For the 591 apartments there, 135 parking places were constructed at the edges of the eco-town. An assumption is made that a car per inhabitant ratio of 1 per 4.3 was adequate (Carfree UK, 2010). Since Amsterdam has one of the most extensive public transport systems in the Netherlands this is a reasonable understanding. In reality however, it turned out that there was too little parking space, as a waiting list of seven years existed for getting a parking space. Therefore, a smaller ratio would be recommended for the development of the Soesterkwartier.

To overcome some drawbacks of having a car-free environment, there should be alternatives present for inhabitants to travel or transport things. Since the area will be closed for cars, bike racks should be plentiful around the eco-town. Also carts or trays should be available when heavy / large objects have to be moved from the parking lot to the apartments. Another option could be to include freight bicycles (Figure 5.27) so that inhabitants can easily transport large objects.

Figure 5.27: *Old fashioned freight bicycle (Wikipedia, 2010)*

Parking

Another point of attention is the accessibility of parking spaces for inhabitants. They should be within walking distance in order to make this not a big drawback of the eco-town. It could be an interesting option therefore to put the cars underground, for instance by constructing a parking garage underneath the eco village. In this way the cars are removed from the living area but are still within the neighbourhood. A drawback for this would be the costs and technical difficulties. Also, this low-lying infrastructure could be more affected for high groundwater levels. An option to address the costs is the possibility to merge it with the existing P & R (Park & Ride) of Amersfoort central station. In this way the parking garage can earn itself back. Parking spaces for inhabitants can also be created at the existing P & R, but then the living area could become too remote from the cars.

Car-sharing

A design idea that reduces the amount of parking spaces needed and consequently reduces the amount of cars in the area is car-sharing. As the project team noticed in Amsterdam, this concept seems to work well. The main advantage is that inhabitants can make use of a car and remain flexible, but do not need to possess one. This saves space, both in terms of parking and of living area in the neighborhood. Moreover, this car-sharing contributes to the green image of the eco-town. If it works well, it can even act as a stimulation to sell your car. To make it an interesting alternative, car-sharing should be promoted by giving these cars priority in parking for instance.

To make sure that car sharing works in the Soesterkwartier, several issues have to be addressed. For instance, several cars need to be present to make sure that there are enough cars to meet the demand. Moreover, users should be able to make or adjust reservations easily, for instance via internet or by their mobile phone. A limit might be necessary to prevent overuse (i.e. holiday). Finally, the prices have to be in line with the market; if it is too expensive nobody will use it. To get an idea of the prices, Amsterdam is used as an example: The fixed costs were 25 euro subscription per month. For the variable costs an inhabitant pays 2.75 euro per hour and an additional 12 cents per kilometer (Diks Autodate, 2010). An interesting option for the future could be the inclusion of electric vehicles like the Mitsubishi I-MIEV (Figure 5.28). A final remark is that there should be a company who is willing to provide these services to the inhabitants of the eco-town.

Figure 5.28: *Electric car sharing in Tokyo, Japan (JFS, 2008)*

6. Recommendations

This chapter contains several recommendations to that make sure that the eco-town is prepared for future climate change effects. Moreover these recommendations will make sure that the eco-town is sustainable and becomes an integrated neighbourhood in Amersfoort. In selecting the design options the following criteria are taken into account:

Expected climate effects
Studies show that increasing temperatures will change the precipitation pattern. All the scenarios generally show a trend with wetter winters, and most of the scenarios drier summers. The intensity of rainfall is expected to increase in both summer and winter. This aggravates the problems related to excess surface runoff and a high groundwater level. Consequently, the recommended design options have to withstand or reduce these effects.

Sustainability
Sustainability is a concept that aims to meet the human needs but at the same time preserve the environment and its resources in order to meet the needs of future generations. This requires the reconciliation of environmental, social, and economic demands, the so called "three pillars" of sustainability. The recommended design options have to fulfill these criteria in order to assure the durability of the new eco-town.

User friendliness
The recommended options for the eco-town should be convenient for anybody. Options which require additional effort from the inhabitants are not considered user-friendly and therefore not taken into account.

Social aspects
The new eco-town should not be considered as a separate neighbourhood but integrated in the existing Soesterkwartier. With the recommended design options the social interaction between the current and new inhabitants should be promoted in order to create a lively community.

Costs
The cost aspect has to be taken into account while recommending design options. The options need to be economically feasible.

This has resulted in four different categories of recommendations (Table 5.1). First recommendations for the expected climate change effects are given. They are followed by recommendations for the sustainability, ecological and green feeling. The recommendations are finalized by recommendations for the social and neighbourhood aspects. An overview is given in the table below.

Table 6.1: *Overview of the recommendations within four different categories.*

1. Climate effects	1.1 Vegetated roofs
	1.2 Retention basin
	1.3 Permeable roads
2. Sustainability	2.1 Composting
	2.2 Toilet flushing
	2.3 Water and energy saving
	2.4 Intelligent architecture
	2.5 Thermal storage
	2.6 Solar Power
3. 'Green' feeling	3.1 Green belt
	3.2 Community gardens
	3.3 Wall plants (creepers)
	3.4 Noise barrier
4. Social interaction	4.1 Wagenwerkplaats hotspot
	4.2 Activities children 12+
	4.3 Car sharing

6.1 Climate effects

6.1.1 Vegetated roofs

It is estimated that the Soesterkwartier will experience more intense precipitation in the future which will increase the surface runoff. In order to adapt to these changes, the inclusion of vegetated roofs are recommended. Vegetated roofs allow the precipitation to infiltrate and by doing so reduce the formation of run-off. Both the intensive and extensive type extend the lifetime of the waterproof roof material by 30-40 years. The extensive type has advantage over the intensive type because it is less heavy, a lot easier to maintain, and contains drought resistant plants such as sedum and succulents. These plants are able to tolerate the typical roof top conditions (temperature extremes and drought). Therefore it is recommended to include the extensive type of vegetated roofs.

6.1.2 Retention basin

A retention basin is an interesting solution to face high groundwater levels and expected higher amounts of runoff. The basin itself has multiple functions. First, it lowers the groundwater level so that fewer problems with high groundwater levels occur. Secondly, it will act as a reservoir or buffer for extreme precipitation events. The vegetation in the basin provides an attractive natural environment that will stimulate recreation. Moreover, vegetation will also filter some of the pollutants from the water. The basin combined with the green areas can enhance the aesthetic beauty of the new Soesterkwartier neighbourhood. A possible problem when including a basin is stagnant water, resulting in water quality issues or mosquitos. This problem can be solved by exploring the possibilities of connecting urban creeks (city drainage for runoff) to the basin which in turn can be connected to the River Eem. The main advantage here is that water does not stagnate and keeps flowing. These urban creeks can also attain a more natural look by planting plants and shrubs. From the climate research it is expected that the most scenarios will result in higher groundwater levels and increased runoff in the Soesterkwartier. The runoff will flow from the South side of the Soesterkwartier, so it is suggested to construct the basins in the South end of the eco-town.

6.1.3 Permeable roads

It is recommended to make use of as much permeable road material as possible to prevent large amounts of runoff and to make sure that precipitation can infiltrate quickly. Permeable road services are recommended for both roads and parking spaces. Smaller roads for bikes and pedestrians in the town can be constructed with even more sustainable materials like sandstone or shell surfaces. These surfaces improve the infiltration and cooling effect in summer, but need more maintenance than ordinary roads. Wood chippings can be used for smaller paths between the gardens and in between the different cultivated places.

6.2. Sustainability

6.2.1 Composting

Bio-degradable waste constitutes for a big percentage of the total municipal waste. Since the eco-town has a green image, it has to be made sure that this problem is addressed. Waste management can be made much more sustainable for instance if biodegradable waste is segregated at the source. The separated biodegradable waste can then be composted and used for fertilization in the gardens of the eco-town. This design option also reduces the volume of waste going to the landfills. Drum composting is a good solution for use in a high density neighborhood like the Soesterkwartier because problems regarding the smell, pests (flies and rats) and vandalism can be solved with the closed system.

6.2.2 Toilet flushing

The reuse of rainwater – harvested from the rooftops – is a sustainable way to reduce the use of potable water. In the developed countries 25% of the potable water is flushed down the toilets, so it is a subject worth focusing on. Two toilet systems are available that reuse rain water.

The first toilet system uses rainwater for flushing. In this system rainwater is collected into storage tanks on the top floor or basement and is then stored for use. This is a simple solution but faces several drawbacks. Some drawbacks of the collected rainwater are that it is prone to decay of dissolved pollutants which can result in emission of unpleasant smell. It can also be infested with bacteria and algae in extreme cases. The storage of the collected rain water is also a problem as it has to be stored at a higher place to make it sustainable by using less energy to pump back the water to the toilets.

Grey water is another option for water recycling. Waste water (grey water) from the kitchen and bath can be collected and treated to be reused in the toilets for flushing, before it enters the municipal sewerage system. This can be achieved by having a small treatment plant in the basement for individual houses. For the apartment blocks a common treatment plant will be more feasible. Drawbacks of these systems are that they are more expensive and technical. As a result, it is difficult to make a clear decision. More research is required to make a clear decision.

6.2.3 Water and energy saving measurements

Some measures that reduce or limit the resource use of the eco-town are recommended. For instance, installing water and energy meters that show the energy and water consumption are an attractive option. Normally they are already included in housing, but are mostly hidden away. It would be interesting to make them more present. The main purpose of these measures is to create awareness by the inhabitants, which eventually results in less resource use. Several measurements exist, such as a water meter in the shower which shows the amount of water that has been consumed. The same can be said for the inclusion of a visible power meter in the living room for instance. Additional to these systems, there are several solutions which use fewer resources than conventional designs. Examples are water saving showerheads and toilets with two flushing system to economize the use of water. An interesting development is the inclusion of motion or heat detecting sensors which switch the light on or off automatically. Installing such systems does not force changes on the users but it will stimulate them to do so and make sure that the resource use of the eco-town will be lower than in comparable neighbourhoods.

6.2.4 Intelligent architecture

Intelligent architecture refers to options that make a building more sustainable and less energy consuming. The focus is on the use of natural lighting and heating, and on the insulation. Big windows facing the South take advantage of the solar energy so that less energy is required for heating. During the summer a retractable awning can prevent sunlight from entering the room to prevent that the room from becomes uncomfortably hot. The window and doors placed in opposite sides facilitates the draft to pass through easily cooling the room. Recommended as well is to make use of natural insulation materials such as wool, cellulose or cork and to make use of double glazing with an anti-reflectivity coating. Recycled materials are proposed for the window-frames as they are more efficient than aluminum frames.

6.2.5 Thermal storage (KWO / WKO)

Energy saving can be also achieved by taking advantage of the temperate difference of the air and subsoil. The soil heat exchanger is a system which utilizes these temperature differences, by passing the coolant deep in the earth and using it for cooling the houses during summer and warming the houses in winter. The advantage of using this closed system compared to an open groundwater based system is that it is less invasive and does not interfere with the aquifers. It would be most efficient to include this KWO / WKO in larger buildings, as they have a larger surface and can thereby provide more room for the coolant containers. This increases their size and as a result their capacity. Also the transportation-lines will be shorter which results in a higher efficiency.

6.2.6 Solar energy

Solar collectors (i.e. solar boilers) collect sunlight to heat up tap water which results in energy savings. A drawback is that this tap water also needs to be pumped up, which requires electrical energy which lowers the efficiency. Solar collectors are not recommended for the eco-town because they take up a lot of space on the roof of buildings. Photovoltaic panels (PV-panels) on the other hand, use sunlight to generate electricity which reduces the use of conventional electricity sources. A disadvantage is that the amount of electricity generated is variable due to differences in solar intensity (e.g. due to the time of year and cloud cover). But in general it is good method to lower the resource use. It is therefore recommended to place PV-panels on the roofs of large buildings such as schools, apartment buildings or even on the Wagenwerkplaats. Of course, it is then recommended to move the solar panels out of sight in order not to affect the historical image of the Wagenwerkplaats. A final application for solar energy is to use smaller PV-cells for street lighting.

6.3. 'Green' feeling

6.3.1 Green belt

Vegetated areas are an essential part of sustainable urban planning as they provide services for both social and environmental aspects. For the new eco-town the idea is to shape the area like a belt to connect the station with the leisure area in the west. The vegetation in the green space promotes a micro-climate regulation, filter the air, and improve air quality. And this advantage is pronounced when coniferous and deciduous trees are inter-planted. Additionally, it increases biodiversity of the neighborhood since the canopy of the plant hosts birds and other animals. Moreover it plays a role in the reduction of runoff, erosion, and CO_2 sequestration. Besides these environmental merits, it promotes social interaction between the new and current inhabitants. Picnic spots, pavilions, barbecue facilities, and benches at several spots in the area are some of the examples applicable to increase social interaction. The interaction can be enhanced if the belt is located at the northern part of the Wagenwerkplaats. However to address the hydrological aspect, it would be best to place the green belt in the southern part.

6.3.2 Community gardens

It is recommended to have a place where the inhabitants can come together to increase the social interaction and at the same time maintain a part of the local environment. Community shared gardens are places where the inhabitants can grow vegetables and ornamental plants. It offers two types of advantages: social and environmental. A community shared garden is therefore recommended for the new eco-town in Amersfoort. Because the inhabitants will come from different parts of the neighbourhood it provides the opportunity to get to know each other. At the same time a community garden helps to create a sustainably minded society. In the other way, having a garden helps to have the concern of the society for the ever-changing environment. It also takes part in encouraging composting, runoff reduction, maintaining microclimate, to make use of collected rain water. Management costs like monitoring, maintenance, designing layout, and contamination need to be considered when deciding to have garden.

6.3.3 Wall plants (creepers)

Wall plants are a simple and cheap solution that gives the neighbourhood a 'green' image. A green wall is either free-standing or part of a building that is partially or completely covered with vegetation. Moreover, it functions as an extra insulating layer which reduces noise and keeps temperature more stable. It also provides nesting places for attractive birds. Other benefits of wall plants are blending in an unsightly wall, providing an idyllic character and air purification. Moreover it filters the sunlight which has a cooling effect on hot concrete buildings. Prunning fast-growing plant is necessary in order to keep it away from house parts (window frames, roof eaves, siding, etc.). So maintenance has to be kept in mind when deciding to have creepers in the eco-town.

6.3.4 Noise barrier

The train station directly to the South of the Soesterkwartier is a large source of noise. The old noise wall between the Soesterkwartier and the houses at the Soesterweg was destroyed in 2007. It may therefore be a required to construct a new noise reducing wall between the eco-town and the railway station. It is recommended to construct a noise reducing wall with a mixed design of transparent material and vegetation cover. A large row of buildings – intended to reduce the noise – would take up a lot of space and greatly reduces the creativity of the design of the eco-town. A partially transparent wall is recommended, because it reduces both the imprisoned feeling and the amount of shade caused by the wall. It is advised to construct a noise reducing wall that is at least taller than the height of the railway cables. Moreover, it is recommended to cover the non-transparent parts with vegetation. Vegetation on the noise barrier prevents vandalism (e.g. graffiti) and adds to the 'green feeling' of the neighbourhood.

7. Conclusion

The secondary information obtained from the literature study and analysis for the proposed eco-town show a change in precipitation pattern due to climate change. An increase surface runoff and higher groundwater level is expected in the future. Based on these deductions, a recommendation for developing a sustainable eco-town was made. These recommendations are based on five criteria including: 1. Expected climate effects, 2. Sustainability, 3. User friendliness, 4. Social aspects and 5. Costs.

Four categories of recommendations are given. Climate is the first category and recommendations such as vegetated roofs, retention basin, and permeable roads to address the issues of increased runoff in the future were made. Sustainability recommendations include the drum composting, reuse of grey water and rainwater for toilet flushing, permeable roads, intelligent architecture, water and energy saving and thermal storage (KWO). Recommendation for enhancing the 'green feeling' in an urban setting, include green areas, community gardens, creepers and noise barriers. For social interaction community gardens, green parks, car sharing, appraisals of Wagenwerkplaats to a trendy hangout place are some of the recommendations for making the proposed eco-town a hotspot for sustainable living.

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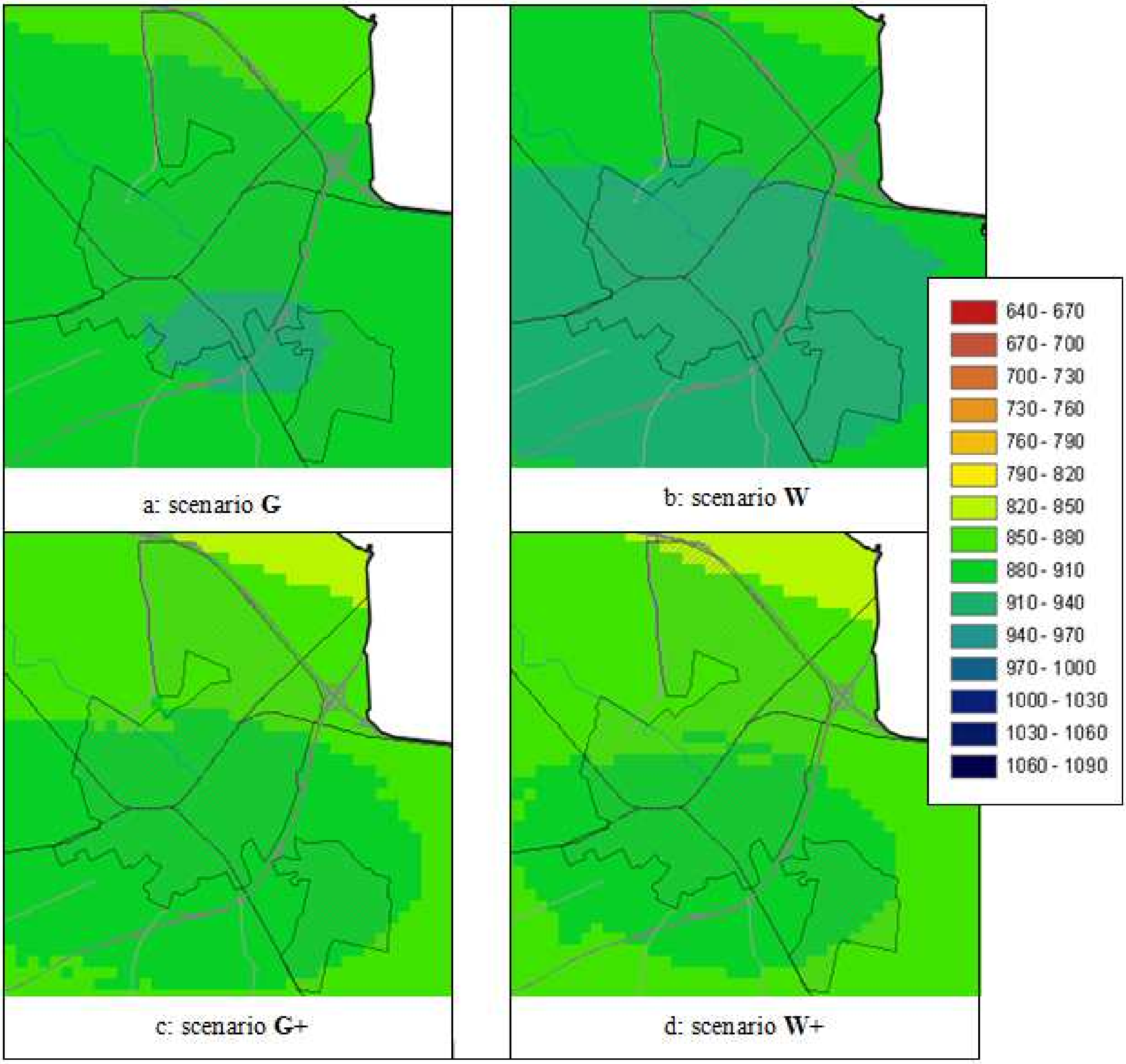
ANNEX

Annex I a

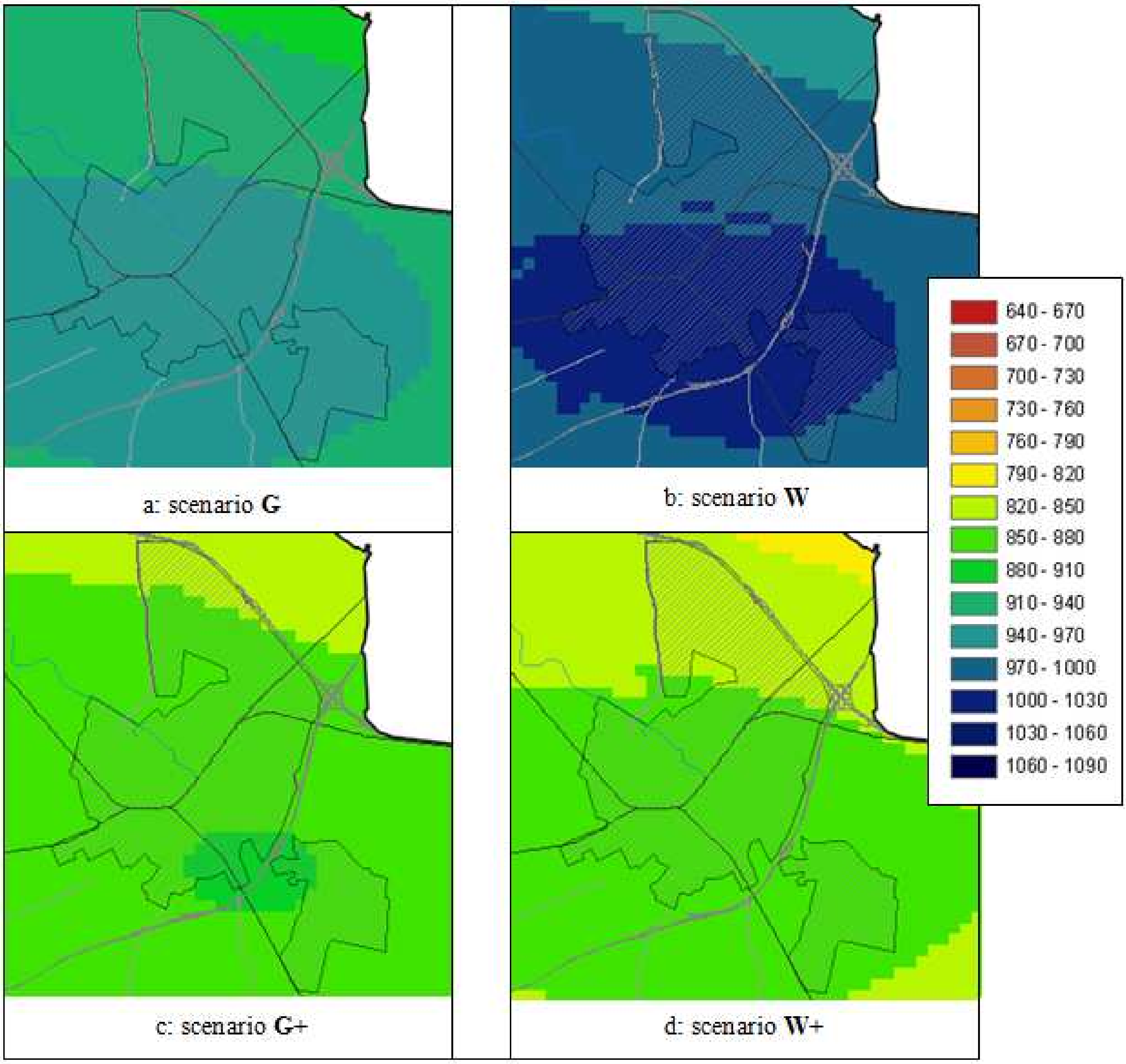
MEAN ANNUAL PRECIPITATION CHANGE BY 2020



(edited from Klimaateffectatlas, 2010)

Annex I b

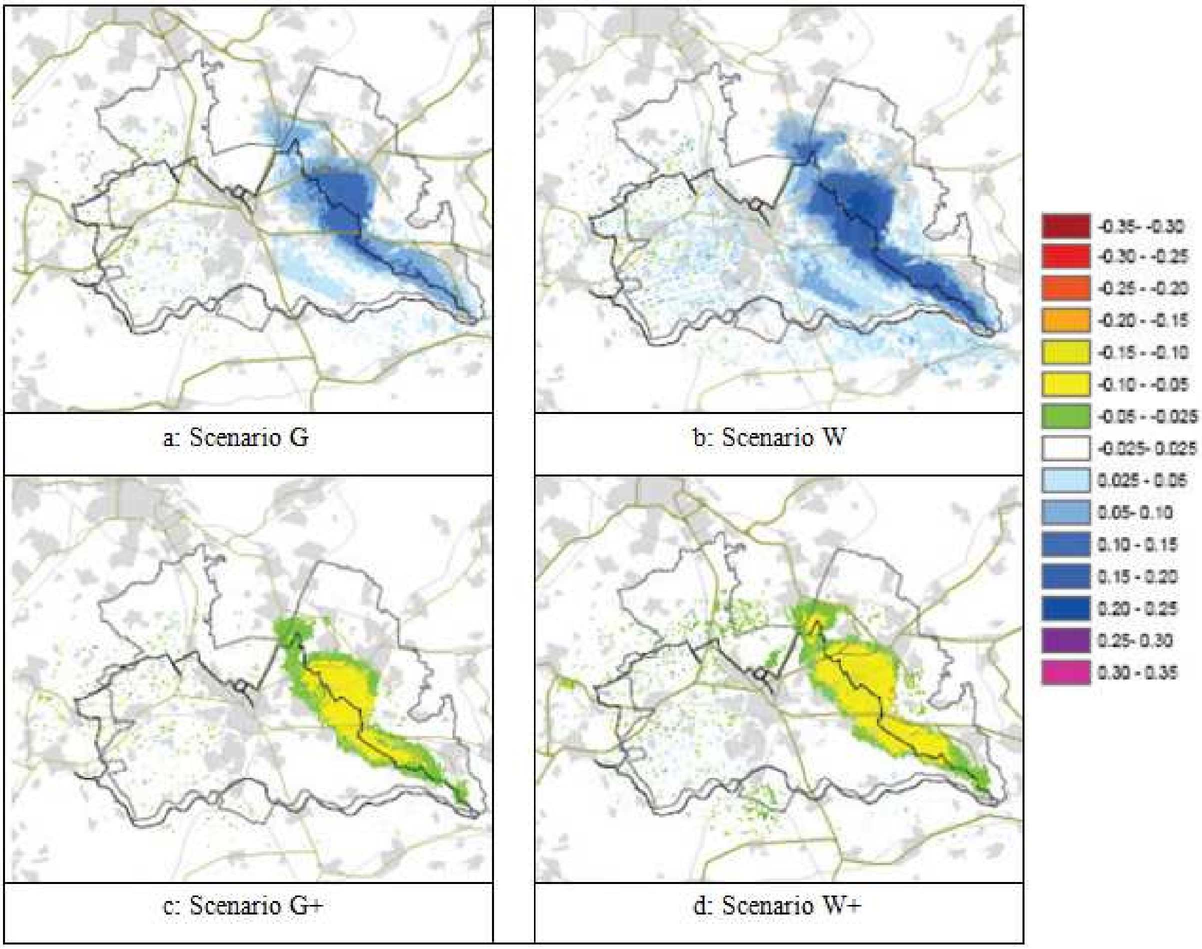
MEAN ANNUAL PRECIPITATION CHANGE BY 2100



(edited from Klimaateffectatlas, 2010)

Annex II a

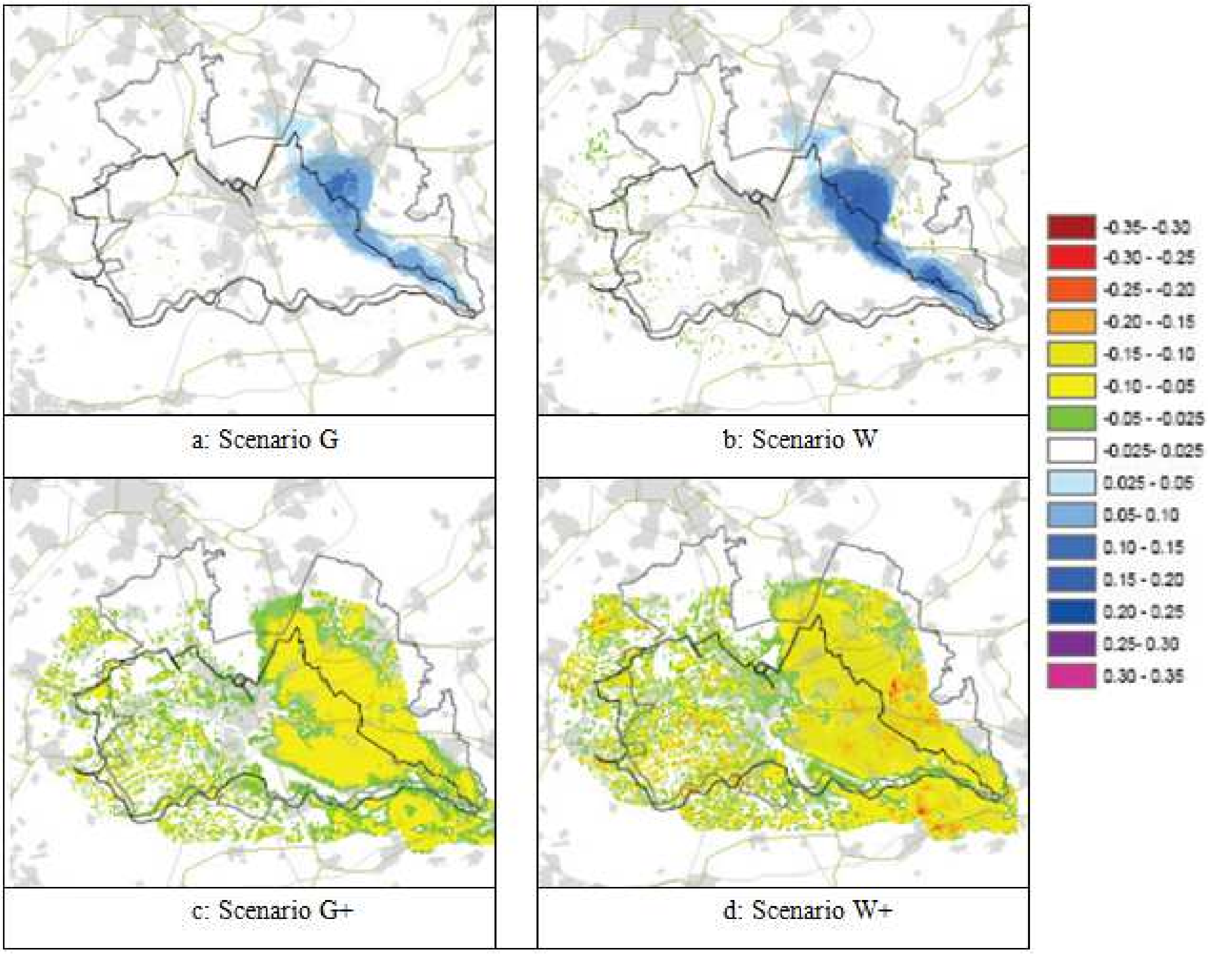
GHG



Values are in meters. In the Soesterkwartier the GHG is expected to increase by 5 – 10 cm in the G and W scenarios, and decrease by 2,5 – 5 cm in the G+ and W+ scenarios. (edited from Bakel et al., 2008)

Annex II b

GLG



Values are in meters. In the Soesterkwartier the GLG is expected to decrease by 5 – 10 cm in the G and W scenarios and decrease by 2,5 – 5 cm in the G+ and W+ scenarios. (edited from Bakel et al., 2008)