DRESSED IN GREEN

Group 1 - Final report
Wageningen University - LAR 36806
Climate responsive planning and design

DRESSED IN GREEN

Colofon

Wageningen, december 2016

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Wageningen University & Research Centre

Period 2, Academic Year 2016/2017
LAR 36806 Climate Responsive Planning and Design
MSc Landscape Architecture and Planning

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1. Introduction

Introduction

The municipality of Arnhem is known to be seriously interested in the exploration of changing the urban fabric to accommodate a better urban climate and basis for the production of renewable energy (Gemeente Arnhem, n.d.). The Spijkerkwartier (figure 1.3) is one of the city's eldest neighbourhood: part of its streets were part of the first city establishments outside of the city walls (van Aken et al., 2016). The Spijkerkwartier is a very vibrant neighbourhood with a young community, made up mostly by students and young adults (van Aken et al., 2016) Although very charming, the neighbourhood is facing some serious issues regarding the urban climate and expected energy transition in the future. Currently the municipality is working together with local stakeholders and participant parties to try and redevelop the Spijkerkwartier in such a way it will be ready for future changes in both climate and energy. Our objective of the course to create an energy neutral neighbourhood, along with creating a more comfortable micro climate.

Expected climate change and current problems

Action needs to be taken in regards to the urban climate: considering the expected climate change, the neighbourhood will need to deal with the corresponding changes. The KNMI estimates four different possible future scenarios. These are presented in figure 1.1. For this design we focus on the Wh scenario, this scenario has the most changes compared with the current climate. Using the Wh scenario means the precipitation will go up with 5.5 percent and the temperature will go up witch 2.3 degrees (Royal Netherlands Meteorological Institute, 2015).

The areas of the Spijkerkwartier that will be most vulnerable in such a climate change, are the areas that are exposed to a relatively high amount of short wave radiation. In the current situation these include areas with a high level of petrification such asparking lots and places with little vegetation or other types of sun blocking elements. Furthermore the increase in precipitation will bring about more problems in regards to rain water disposal, which are already present. Considering most the Spijkerkwartier is paved, this might cause additional problems.

Expected energy consumption and current problems

In addition to the expected climate change, the energy demand is also expected to change in the years to come. Furthermore we are running out of fossil fuels, making it so we have to make the transition towards using renewable energy sources.

Variabele	Indicator	Climate 1981-2010	Scenario changes for the climate around 2050			
			G_L	G_H	W_L	W_H
Global temperature rise:			+1 °C	+1 °C	+2 °C	+2 °C
Change in air circulation pattern:			low value	high value	low value	high value
Sea level at North Sea coast	absolute level	3 cm above NAP	+15 to +30 cm	+15 to +30 cm	+20 to +40 cm	+20 to +40 cm
	rate of change	2.0 mm/yr.	+1 to +5.5 mm/yr.	+1 to +5.5 mm/yr.	+3.5 to +7.5 mm/yr.	+3.5 to +7.5 mm/yr.
Temperature	mean	10.1 °C	+1.0 °C	+1.4 °C	+2.0 °C	+2.3 °C
Precipitation	mean amount	851 mm	+4 %	+2.5 %	+5.5 %	+5 %
Solar radiation	solar radiation	354 kJ/cm²	+0.6 %	+1.6 %	-0.8 %	+1.2 %

Fig. 1.1
KNMI climate scenario's
Source: royal Netherlands Meteorological Institute., 2015
Edited by author

Based on the information of the "Energie in beeld" website we have formulated the expected change in energy and heating demand for 2050. The numbers are presented in figure 1.2.

Regarding the Spijkerkwartier the transition into a new age will probably be more difficult than in other parts of the city of Arnhem considering the Spijkerkwartier is a neighbourhood with a lot of older buildings and a high building density. Older buildings are known to be the least energy efficient (Energie label atlas, 2016), so it will be important to see what can be done to make the energy efficiency of these buildings higher.

PREDICTED ENERGY USE FOR SPIJKERKWARTIER IN 2050

		BUSINESS (kWh per year)	HOUSING (kWh per year)	TOTAL (kWh per year)
2016	ELECTRICITY	9.291.765,00	5.082.860,00	14.374.625,00
	GAS	25.261.357,70	24.686.834,00	49.948.191,70
			TOTAL	64.322.816,70

		BUSINESS (kWh per year)	HOUSING (kWh per year)	TOTAL (kWh per year)
2050	ELECTRICITY	12.663.270,00	3.223.690,00	15.886.960,00
	GAS	24.265.986,30	10.784.151,29	35.050.137,59
			TOTAL	50.937.097,59

Fig. 1.2
Energy use scenario 2050
Based on Energie label atlas, 2016

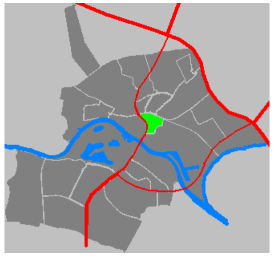

Fig. 1.3
Locatio of the Spijkerkwartier
Source: wikipedia, Arnhem - Spijkerkwartier, 2016

2. Concept

Introduction

To address the problems mentioned in the introduction, in addition to becoming energy neutral, we came up with our concept 'Dressed in Green'. In our concept we interpreter "green" very broad. We will add both vegetation and installations to produce renewable energy (also known as green energy) and improve the urban climate. We will do this to both the buildings and the streetscape.

Concept components

The concept of Dressed in Green exists of three components as depicted in figure 2.1, 2.2, and 2.3. The first element of the concept is the conversion to renewable energy sources by utilizing sun exposure and wind flows in addition to minimizing energy losses. The renewable energy will mainly be generated by PV panels on the roofs and facades of the existing and new buildings. The design will also feature a number of wind turbines to help meet the energy demand.

The second element is the minimization of the urban heat island effect. This will be done by increasing the amount of vegetation on street level and by adding vegetation and PV panels on the facades. By de-paving the parking lots, space will be created to add green on street level. Green will also be added at the facades of several buildings. The cars will no longer be parked in the streets, but in so called Hubs. In these Hubs there is space for parking and community activities.

The creation of space for community activities relates to the third element of our concept:strengthening and redefining the neighbourhood identity. The community Hubs make it possible for citizens to meet and help each other. These Hubs could also contribute to the current trend of the sharing economy, for example by sharing electric cars.

These Hubs will provide spaces where residents can exchange ideas and knowledge, which could also contribute to the transition towards a more sustainable and greener neighbourhood. These three different elements of our concept will dress the Spijkerkwartier in green. Figure 2.4 shows the concept diagram.

1.

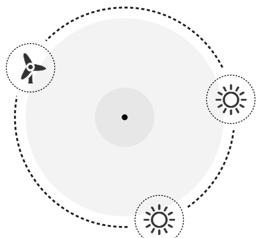

Fig. 2.1
Main princlipe 1 - solar and wind energy

2.

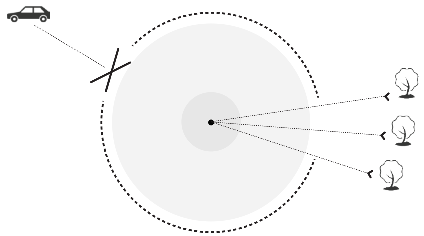

Fig. 2.2
Main princlipe 2 - adding green and banning cars

3.

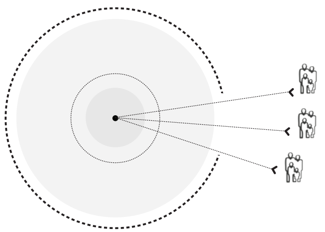

Fig. 2.3
Main princlipe 3 - involving the local community

Fig. 2.4
Concept diagram

3. Streetscape design

Introduction

All of the principles mentioned in the previous chapter resulted in a streetscape masterplan. In response to the goal of increasing the thermal comfort in the streets, we decided to implement urban green into the streetscape of the Spijkerkwartier. Considering the streets of the Spijkerkwartier are relatively narrow, we considered the vertical space to be the most promising. We also focused on the horizontal green in the streets, we will elaborate on that in the next chapter.

Models and design process

During the process of designing, multiple options were tested, resulting in two models.

The initial model, model A, concentrated on providing both shading and vegetation. Since the Spijkerkwartier is known for its characteristic buildings with many ornamental features, we did not want to erase this part of the neighbourhood identity. Instead of placing the vegetation directly onto the building, we decided on a structure/framework placed away from the building. This framework houses a number of door sized panels: a surface the vegetation can grow on. These panels are placed in such a way they are able to rotate; opening up the wall of panels to allow ventilation. We intended for the structure to be placed every now and then; if buildings would allow for the structure to be placed and if the specific street could benefit from the added shade and vegetation.

The initial model provided a large amount of additional shade to the streetscape, no longer allowing for build or paved surfaces to be heating up. Furthermore the shade provided pedestrians a more comfortable experience of walking down the street on a warm and sunny day: the shade provided by the structure sheltered pedestrians from direct sunlight. However during our interim presentation the initial model faced a lot of resistance. The large amount of shading the first model provided, in addition to the somewhat intruding quality of the structure (because of it being facade and into the street), are what locals and stakeholders experienced to be the most alien about the first model.

Taking into account the feedback on model one, we decided to rearrange the structure: making use of the same tactics as the first model, but eliminating the negative aspects. In the final model (model B, see figure 3.1 and 3.2) we have placed the structure right in front of the building. The door sized panels were kept, only the way they moved was altered: from rotating movement to sliding movement. This allows for people to still be looking out of their windows. In addition to the placement of vegetation onto the door sized panels, we added solar panels into the mix. This way we ensured the production of a larger amount of energy.

Fig. 3.1
Model B - closed

Fig. 3.2
Model B - opened

Streetscape toolbox

The final model, as explained earlier, is made up by a number of different parts. We have designed the structure in such a way it is universal in its application, yet specific enough to be customized to meet the needs and opportunities of each specific location. All of the different elements make up a so called "streetscape toolbox". The toolbox contains: a metal base structure (figure 3.3), door sized panels (figure 3.4), and panel filling (figure 3.6). The position and the filling of panels depends on the orientation of the building and the sun exposure. Two general ways of application, based on the dominant street types in the Spijkerkwartier, have been divined (figure 3.7 & 3.8 on the next page). But of course it is possible to alter the panel filling or their position to fit the preference of the home owner.

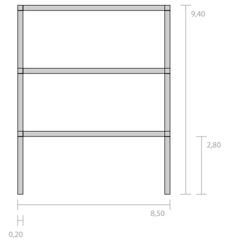

Fig. 3.3
Element I

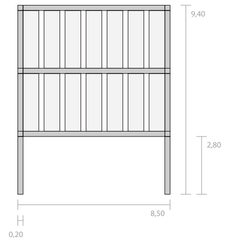

Fig. 3.5
Element I + II

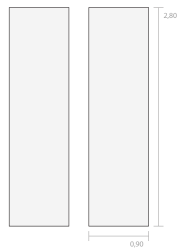

Fig. 3.4
Element II

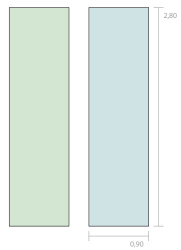

Fig. 3.6
Element III

Design principles

As depicted in figure 3.7 and 3.8, the standard design for East - West oriented streets makes use of the sun exposure by implementing solar panels on the facades facing South. The facades facing North are covered with vegetation. The panels on the facade facing South will be closed during mid-day and opened during the rest of the day. In that way it is possible to exploit the sun exposure to the maximum, in addition to shading the insides of people's homes during the middle of day (typically the time people would be closing their blinds because of the strong and direct sun light and also the time most people are not home but at their job).

As depicted in figure 3.9, the standard design for North - South oriented streets is also based on making use of the sun exposure. In this case placing the panels in a opened position is the best option since it allows for the sun to radiate the solar panels on the Western facade in the morning and the Eastern facade in the evening.

Placement

Figure 3.10 on the next page depicts the locations where we plan on implementing the panel structure. The locations have been chosen on the structure of the buildings: the right window - wall ratio, the absence of ornamental elements prohibiting the placement (e.g. balconies, bay windows), and the amount heat stress currently experienced.

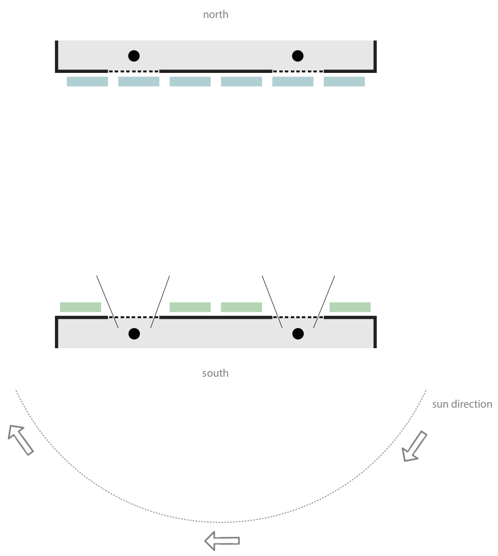

Fig. 3.7
East - West streets, 11:00 - 15:30

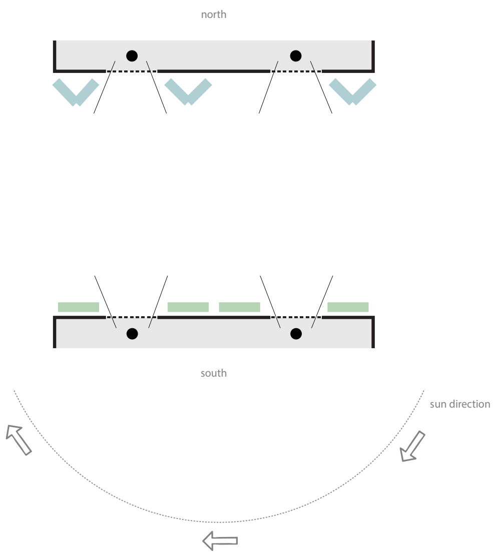

Fig. 3.8
East - West streets, rest of the day

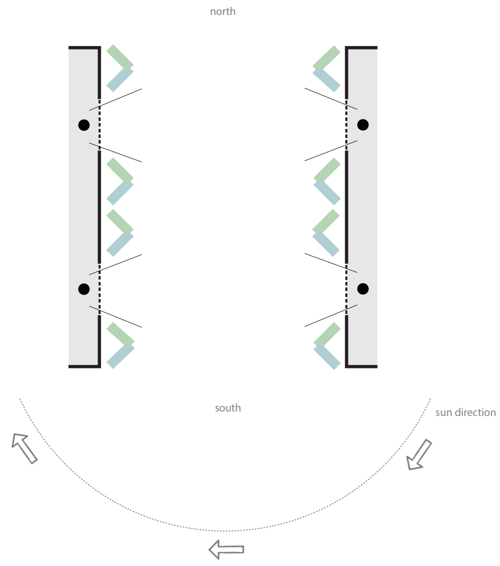

Fig. 3.9
North - South streets, all hours

Energy producing panels

As stated earlier, some of the panels will be filled with solar panels to generate energy. Figure 3.11 depicts the number of panels we plan on filling with solar panels. These locations were determined by the design principles explained earlier. In chapter 5 we will elaborate on the amount of energy produced by these panels.

Food producing panels

Aside from regular vegetation placed in the panels, see figure 3.12, some of the panels will be used for the production of crops. Figure 3.12 illustrates the share of crop filled panels among the larger number of panels. These locations were determined by the presence of a windowless ground floor wall (easy for people to access), or connection to a semi-public space such as the elementary school or near the local shopping street. Additionally they are positioned around the corresponding Hub, as will be explained in the next chapter. The crop filled panels will be part of a community sharing system which we have named "adopt a panel". In this way the crops filled panels will be owned and maintained by locals, being able to renew their ownership of the panel each year.

Fig. 3.10
Placement of streetscape structure

PET (ºC)	Thermal perception	Grade of physiological stress
	Very cold	Extreme cold stress
4		
	Cold	Strong cold stress
8		
	Cool	Moderate cold stress
13		
	Slightly cool	Slight cold stress
18		
	Comfortable	No thermal stress
23		
	Slightly warm	Slight heat stress
29		
	Warm	Moderate heat stress
35		
	Hot	Strong heat stress
41		
	Very hot	Extreme heat stress

Fig. 3.14
PET in relation to thermal perception and grade of physiological stress
Source: Steeneveld, 2016

Fig. 3.11
Placement of solar panel filling

Fig. 3.12
Placement of regular vegetation filling

Fig. 3.13
Placement of crops filling

PET calculations

The materials used on the streetscape design have several characteristics related to urban climate and thermal comfort as both the vegetation and the solar panels help battle heat stress. With the PET, Physiologically Equivalent Temperature, the effects of radiation, wind, humidity and air temperature are taken into account in one number for fair comparison of different outdoor situations (Steeneveld, 2016). The PET gives a more accurate impression of the experienced thermal perception and experienced physiological stress compared to a number in degrees Celsius of only the air temperature. In figure 3.14 (previous page) the degree of PET in relation to thermal perception and grade of physiological stress is shown.

Some aspects of our design interventions have the ability to decrease the PET. According to literature, vegetation, solar panels and solar boilers are able to decrease the air temperature (Alexandri & Jones, 2008; Masson et al, 2014). In terms of vegetation, a decrease in air temperature is effected by the amount and geometry of the vegetation itself. When both walls and roofs are covered with vegetation a temperature decrease of maximum 8,4 degrees is possible. The more narrow a street canyon is, the bigger the effect of green roofs and green walls have on air temperature decrease.

Two locations in our study area are chosen as example situations how the PET could be decreased with some of our design interventions. Our design interventions of placing solar panels and green panels on suitable facades have different design principles dependent on the street orientation, as explained earlier. For the calculation we chose a representative street for each of the design principles. Steenstraat is an example of an East-West orientation, Drieharingenstraat is an example of an North-South orientation. Important to note: the amount of green panels, solar panels on facades differs between the two streets, based on the amount of suitable wall/building space. Also the amount of solar panels, solar boilers and green on the rooftops differs between the two streets.

The Steenstraat with its design interventions could decrease the air temperature with 2.65 degrees during day (2.78 during night) and the Driekoningenstraat could decrease the air temperature with 3.63 degrees during day (3.8 during night). Why the Driekoningenstraat with design intervention is able the decrease the air temperature more could be explained because of the higher amount of solar panels on the rooftops with green roofs and the situation of a more narrow street. The full overview of the different manipulations we have used for the calculation is presented in Appendix A.

The sky view images, input for Rayman, are shown in figure 3.15 - 3.21. A full overview of the data input for the Rayman calculations in presented in Appendix A.

Calculations are made for 2 PM and 11 PM. The outcomes of the PET calculation are presented in the figures below. For both streets the thermal perception is changed from hot to warm with our design interventions during day. Also the grade of heat stress is changed from strong heat stress to moderate heat stress with our design interventions for both streets. The sky view factor is lower for the Driekoningenstraat than for the Steenstraat, so more sky is visible in the Steenstraat. For both streets the sky view factor decreases very slightly with our design interventions, so less sky is visible with our design interventions

		Day	Day - with Design interventions	Night	Night - with Design interventions
Steenstraat	**Air temperature**	33.3 °C	30.65 °C	20.3 °C	17.52 °C
	PET	35.9 °C	32.2 °C	17.1 °C	14.0 °C
	Thermal perception	hot	warm	slightly cool	slightly cool
	Heat stress	Strong heat stress	moderate heat stress	slight cold stress	slight cold stress
	Sky view factor	0.394	0.392	0.394	0.390

Fig. 3.15
Influence of Design interventions on air temperature and PET during Day and Night for Driekoningenstraat
Source: KNMI, 2016; Rayman, 2016

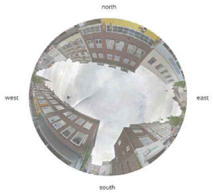

Fig. 3.16
Sky view image Steenstraat
Before

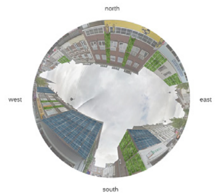

Fig. 3.17
Sky view image Steenstraat
Day

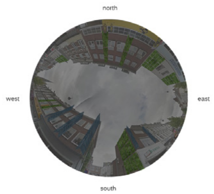

Fig. 3.18
Sky view image Steenstraat
Night

		Day	Day - with Design interventions	Night	Night - with Design interventions
Driekoningenstraat	**Air temperature**	33.3 °C	29.67 °C	20.3 °C	16.5 °C
	PET	36.6 °C	31.0 °C	17.2 °C	13.1 °C
	Thermal perception	hot	warm	slightly cool	slightly cool
	Heat stress	Strong heat stress	moderate heat stress	slight cold stress	slight cold stress
	Sky view factor	0.248	0.246	0.248	0.246

Fig. 3.18
Influence of Design interventions on air temperature and PET during Day and Night for Driekoningenstraat
Source: KNMI, 2016; Rayman, 2016

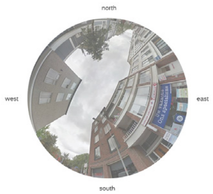

Fig. 3.19
Sky view image Driekonin-genstraat
Before

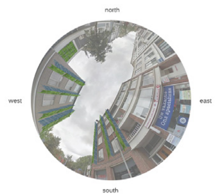

Fig. 3.20
Sky view image Driekonin-genstraat
Day

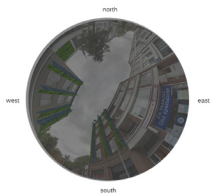

Fig. 3.21
Sky view image Driekonin-genstraat
Night

Design impressions

The streetscape design, as described before, can be seen in its application in figures 3.22 and 3.23. The chosen location is the Steenstraat, near the cross road with the Tuinstraat.

Phasing

Considering the streetscape design is part of larger number of design interventions (e.g. the Hubs), the phasing has been combined to give information about the phasing of the project in its enterity. The phasing will be explained in the next chapter.

Fig. 3.22
Impression Steenstraat
13:30 h

Fig. 3.23
Impression Steenstraat
16:30 h

4. Hub design

Introduction

The Spijkerkwartier has a relatively high building density, however there are still open spaces in the neighbourhood, most of them are used as parking space. These paved areas don't have many trees on this moment and therefore have a lack of shadow. Because these surfaces are paved they also contribute to the flood problem in the neighbourhood. Considering space in the Spijkerkwartier is limited, our goal is to use the available space very efficient. We want to do this by creating multiple Hubs: a landmark with different functions, the most predominant one being parking to provide us with more usable space in the streetscape. A landmark according Kevin Lynch, (1960) is a reference point to observers; a simple physical element which may vary widely in scale. A landmark creates spatial predominance through contrast with surrounding elements. This makes them unique or memorable in the urban context. Our Hubs have to become landmarks, therefore we made some decisions in the design process of our Hubs. These will be elaborated on further in this chapter. The Hubs as landmarks will provide a new layer to the identity of the Spijkerkwartier. The Hubs will become part of the skyline of Arnhem (title page). Additionally they profile the Spijkerkwartier as an energy neutral and climate adaptive neighbourhood.

Location selection

We based the location for the Hubs on the two following requirements: currently unbuilt spaces and spaces large enough to fit the intended building and accompanying functions. We also took into account the distribution of the locations on a neighbourhood scale: making sure they would not all be in one corner, considering that would be very inefficient when the Hubs will be used for parking. The distance between the hub and the house of the resident has a maximum distance of 200 meter as the crow flies, see figure 4.1. As stated previously the parking in the Hubs makes it possible to remove parking from the streets. Eventually we came up with four Hubs, each with a different theme. This will be explained later in this chapter.

Design process

Initially we designed the Hubs using a split level floorplan with three rows of parking on the same floor. This way the building height stayed relatively low. However this low height resulted in a large floorplan: the garage taking up almost all of the available space, completely overwriting the current streetscape. Additionally the low height prohibited us from utilizing the roof for the production of wind energy, which was also one of our aims.

Fig. 4.1
Location of Hubs

In order to make a true landmark, we decided the building needed to be high: a building visible from other parts of the city to really make the Spijkerkwartier recognizable within the urban fabric. We changed the design of the Hub to a higher building with a smaller floor plan (two rows of cars). The cars will we be moved from floor to floor by using an elevator system.

To make the roof efficient for solar and wind energy we tried different shapes. The solar panels need to be faced south to maximize its efficiency, while the wind turbine needs a certain height (two times the height of the surrounding buildings).

Hubs toolbox

To address the different problems the neighbourhood is facing, we included different functions in the Hubs. All of the Hubs contain vegetation and solar panels on the vertical outside space (making use of the streetscape design explained in the previous chapter). On the inside the Hubs will consist of parking, community space, and water retention. The roof of the Hubs will be used for the production of energy by use of both solar and wind energy. In the next chapter we will elaborate on the amount of generated energy for the Hubs.

Considering all of the functions listed above, the former parking spaces will be transformed into green energy producing hubs with room for community activities. Figures 4.2 to 4.4 illustrate the way all of these functions will be housed in the Hubs. The ground- and top floor will contain the community functions. The middle part of the Hub will be used for parking. The floors beneath the surface of the ground floor will be used for rainwater storage.

The Hubs have been designed in such a way their composition of different functions can be altered to fit both the location and the inevitable future changes (e.g. car demand). Floors can easily be transformed to accommodate another function.

The ground floor has a height of 4.5 meter, this is a comfortable height for indoor public functions like playgrounds and markets. The parking stories will have a height of three meters, because this is more economical for car parking as well as for potential future functions.

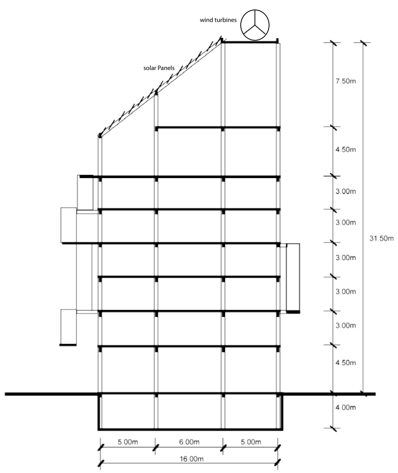

Fig. 4.2
Hub toolbox measurements

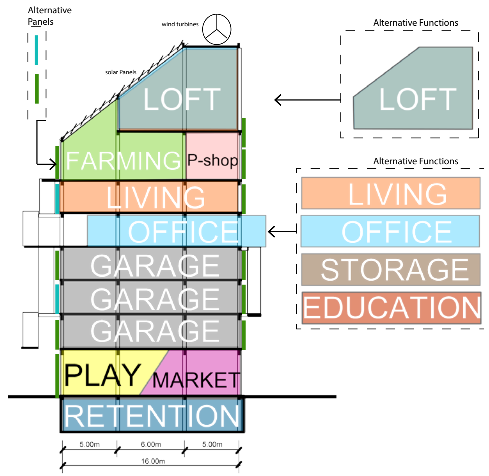

Fig. 4.3
Configuration one

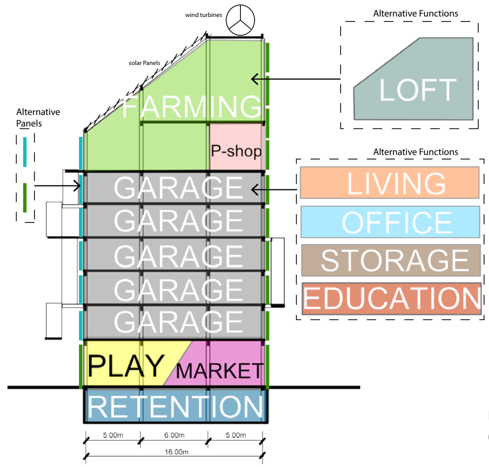

Fig. 4.4
Configuration two

Parking

In the current situation the amount of passenger cars in the Spijkerkwartier is 1430 (Statline CBS, 2016). Taking into account a decrease in car ownership of 20% in 2050 in addition to the transition to electric cars (Nijland et al, 2012), the amount of passenger cars in 2050 will be 1144. Currently the spijkerkwartier contains 1187 public parking spots, see figure 4.5. The total amount of parking spaces realized in the Hubs will be 930. In this way 930 public parking spots in the streets could be removed and 257 public parking spots remain (e.g. the parking lot in front of the Albert Heijn grocery store, since we consider this to be required) of which 214 are needed in 2050. Based on the prediction that 10% of population will take part in car-sharing in 2050 (CPB & PBL, 2015), each parking garage in our Design will have 10% of parking spots reserved for electric sharing cars for residents.

The current Dutch government projected to have 1 million electric cars in the Netherlands in 2025. To achieve the ambition of the European Commission to reduce CO2-emissions in the transport sector with 60% in 2050 relative to 1990 all passenger cars need to be electric in 2050 (Nijland et al., 2012). The decrease in car ownership for 2050 is estimated between 10-20%, because of the fact that the higher the purchase price of electric cars in the future, the higher the decrease in car ownership in the future. It is expected that other modes of transport will increase for daily movements, such as public transport (increase of 10%) and cycling (increase of 5%) and walking. Making more use of planes and trains for long distances instead of using the car is also predicted. The amount of times using a car is expected to decrease, but the amount of km of one ride will increase (Nijland et al., 2012). The idea of not owning a car, but making use of a car-sharing system reacts to this prediction.

Electric cars need charging poles. By providing 930 charging poles for every electric car in our new Hubs, which have an energy battery and are the centres of the solar energy system (this will we explained further on), there is no need to put a large amount of charging poles in the streets.

Solar energy

The roofs of the different Hubs and the facades which are facing South, East and West will contain solar panels. The East and West facade will have a toothed system, so they are more efficient(figure 4.13 on the next page). The nexter chapter will elaborate on the amount of energy that can be generateed on the Hubs.

Water retention

Water from the streets and roofs will be collected in a separate sewage system (figure 4.6), this water could be stored in an underground water storage. The height of the underground water retention basin is based on the maximum rain water data from KNMI. If we want to store water during a heavy rainfall, the height of the retention base has to be 2,8 meters. We only calculated the height of the water retention for the garden hub. The water in the retention base could be used to spray the paved streets during a heat wave, in addition to watering the plants in the panels during dry periods.

Fig. 4.5
Current parking

Energy storage

The amount of solar energy which is generated on the roofs and facades of the houses and commercial buildings is larger than han the residential and commercial energy usu at that time. Additionally the peak in the production of solar energy is not on the same moment as the peak of the most energy use. Therefore we have to store this energy.The ideal location for energy storage is a public or semi-public area in the Spijkerkwartier, therefore we think that the Hubs are a good location to install these energy storing systems (figure 4.7). The capacity of these energy storage systems will be discussed in the next chapter.

Fig. 4.6
Water network

Fig. 4.7
Energy network

Wind

Building the Hub will influence the wind fluxes: the height of the buildings results in new/altered wind flows. To transform these wind flows into energy, we will put wind turbines on the roof. The shape of the roof is designed in such a way it will strengthen the wind fluxes, that way we are able to optimize the amount of generated energy (figure 4.12). The corresponding energy calculations are presented in the next chapter.

Because the facades of the building are not smooth (the plants and the toothed system of solar panels and green panels at the east and the west side of the building), it will help decrease the downwash effect. Important to note is pedestrian path on the outside of some of the Hubs: this construction will also protect people from the downwash of the wind, because it increases the roughness of the building. The new wind flows are shown in figures 4.8 to 4.12.

Fig. 4.8
Wind flows after
Normal wind direction

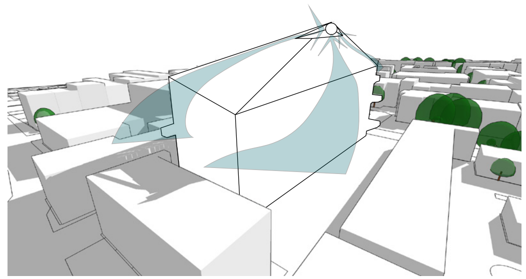

Fig. 4.12
Wind flows towards turbine perspective

Fig. 4.10
Wind flows perspective
Normal wind direction

Fig. 4.9
Wind flows after
Summer wind direction

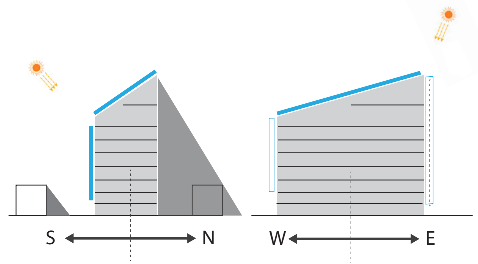

Fig. 4.13
Solar panels on the Hubs

Fig. 4.11
Wind flows perspective
Summer wind direction

Horizontal green

As stated earlier we take out most of the current parking in the streets. This former parking space will be de-paved, plus vegetation will be added (figure 4.1). One of the advantages is that depaving the street and adding green will influence the PET (Lenzholzer, 2013). The second advantage is that by depaving parts of the street the permeability increases. This could reduce the water nuisance which the Spijkerkwartier is facing. A third positive point is that green has more esthetic value than parked cars.

Hub typologies

We have assigned each Hub a different theme. The themes are strongly based on the different community functions which are added inside of the Hubs. The themes of the different Hubs are as follows: water Hub, garden Hub, social Hub and sport Hub. Each of the themes have been applied to the place we think would suit the specific theme the best. See figure 4.1 on page 13.

Water Hub

The water Hub contains the following functions: water retention, energy storage, parking, energy production, and a water themed community space. Water that flows from the streets and roofs will be collected and will be guided towards the cellar of the waterhub, see figure 4.6 on page 15. In this Hub the water will be cleaned by helophyte filters. The cleaned water is also used in the swimming pool, located on the ground floor (figure 4.18 on the next page).

Garden Hub

The garden Hub contains all the functions mentioned in the description of the waterhub, except the water themed community space will be changed into a garden themed community space (figure 4.15). The garden Hub will be the heart of the adopt a panel community system mentioned in the previous chapter. This hub is a plant nursery located where plants for the panels and gardens of citizens grow. When the plants on the panels die or the citizens wants different plants they could get them at the garden Hub. They could switch their own panel with one of the panels on the outside of the garage (figure 4.19 on the next page). The water retention basin, again located in the basement of the building, will collect water from the roofs and streets. This water could be used to water the plants in the Hub in periods of drought.

Social Hub

Just like the garden Hub, the social hub contains all the functions mentioned in the description of the waterhub, except the community space is designed to be a space for social interaction. The building will include a rooftopbar (see figure 4.16 on the next page), a restaurant, and apartments. The rooftop bar will offer visitors a beautiful view of the city. The residents from the neighbourhood could come here together to meet each other and to organise different community activities like a repair café. In the restaurant they will serve food which is produced on the panels of the garden Hub.

Sport Hub

This Hub will contain all previously mentioned functions, the community space will be based on sporting and playing. This hub has the largest surface and therefore we chose this hub to be the sport hub. Here is room for indoor soccer, hockey and basketball.

Fig. 4.14
New horizontal green

Also are there different playground equipment's installed. Children could play here in a nice and comfortable environment. See figure 4.17 on the next page

Three of the four hubs mentioned above (sport, garden, and water Hub) have a special feature for people to enjoy: a pedestrian path along the outside of the building. It will be possible for visitors to walk up to the community spaces on the highest floors of the buildings along the outside of the building; offering pedestrians in interesting 360 view of the surroundings as they walk up. This path is depcited is figure 4.19 on the next page.

The exterior of the Hub is depicted in figure 4.20 on the next page.

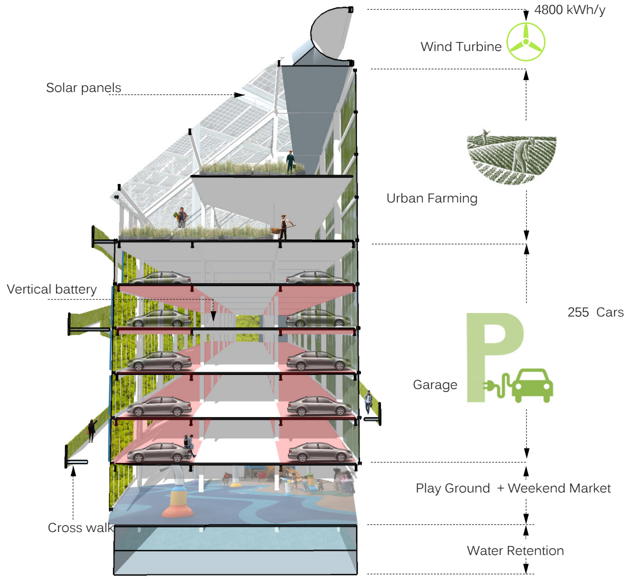

Fig. 4.15
section garden Hub

Fig. 4.16
Impression social Hub rooftopbar

Fig. 4.17
Impression sport Hub gym

Fig. 4.18
Impression water Hub swimming pool

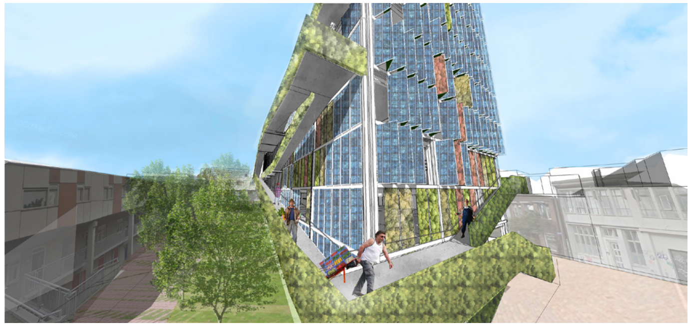

Fig. 4.19
Impression garden Hub exterior & pedestrian path

Fig. 4.20
Impression garden Hub exterior streetlevel

Phasing

In figure 4.20 we propose a phasing to implement our plan. The Spijkerkwartier has already a workgroup called SpijkerEnergie that tries to produce more sustainable energy in the Spijkerkwartier. They could help to encourage people to install PV panels and solar boilers on their roofs. They already have a large network in the neighbourhood, they could use this network to make more residents of the neighbourhood enthusiastic for PV panels and Solar boilers. With pilots for both the facades and the hubs we try to make the community enthusiastic for further development. The neighbourhood could also work as a showcase for a neighbourhood which tries to become energy neutral and which adapts to climate change. The results of these pilots will be evaluated, so these results could be used in developing the neighbourhood. The function and the themes of the hubs could change in time if it is necessary.

The lifespan of the solar panels is approximately 25 years (Milieucentraal, n.d.) after that time they could be replaced by new more effective solar panels. The energy production of the neighbourhood will then enhance further, when this happens also new batteries have to be installed.

According to Lenzholzer, (2013) are the creation of green facades and green parking garages no regret solution. The same counts for intensive and irrigated green roofs and de-paving surface (Lenzholzer, 2013)

Fig. 4.20
Phasing diagram

5. Energy calculations

Introduction

As stated in chapter one, the current energy use will continue to grow in the years to come. Additionally the transition into renewable energy sources demanded us to think of new ways to generate the amount of necessary energy. For our design we have chosen to utilize the sun exposure in addition to exploiting the existing wind flows by enhancing their energy productive power. This decision was backed up by the fact solar and wind energy are proven to be among the most efficient renewable energy sources (Stremke, 2015), in addition to them being suitable for the location.

Solar energy is our main type of natural energy source. As explained before, both the streetscape design and the Hubs will contain solar driven, energy producing elements. But we have also chosen to add additional solar panels to all the existing roof space in order to try meet the required energy need. Simply said, the total amount of sun driven energy producers will be contributed throughout the neighbourhood in both horizontal and vertical fashion. Between the borders of the Spijkerkwartier we used the roofs for the placement of horizontal solar panels. For the placement of vertical solar panels we have extended the border slightly to incorporate both sides of the bordering streets. Wind energy is our secondary natural energy source. As explained before this energy producing element is used in the Hubs.

To provide a clear and detailed overview of the calculations we have made, we will first present the energy demand. Thereafter we will present the two sustainable energy sources separately. At the end of this chapter we will combine the results to show the total amount of generated energy.

Energy demand

The total energy use for the Spijkerkwartier is divided into both the use of electricity and natural gas. Based on the IEA-scenario of limiting global warming with two degrees (Warringa & Rooijers, 2015) we can state the following for the Spijkerkwartier:

- Electricity use is expected to slightly increase from the current 14,4 million kWh per year (Energie in Beeld, 2016) to almost 15,9 million kWh per year in 2050.

- Natural gas use is expected to decrease with around a third of the current amount in 2016: from approximately 4,8 million m^3 (Energie in Beeld, 2016) to 3,4 million m^3 in 2050.

Solar energy

One average solar panel, sized 2,5 m2, produces 225 kWh per year (Milieu Centraal, 2016C). Based on the size of this average solar panel a sloped roof needs about 1,6 m2 per solar panel. In contrary, a flat roof needs 4 m2 per solar panel because of the extra structure needed for its construction plus taking into account the shade provided by neighbouring solar panels. On average 2,5 m2 roof is needed per solar panel (Milieu Centraal, 2016A).

As stated earlier, we have chosen to add solar panels to all the existing roof space in order to try meet the required energy need. The total amount of available roof space in the Spijkerkwartier adds up to about 92.527,50 m2. This results in the following energy generation potential:

(92.527,50 m2 / 2,50 m2) × 225 kWh/Y = 8.327.475 kWh per year

In addition to placing solar panels on the existing roof space, we have also placed solar panels in the streetscape of the Spijkerkwartier. The total amount of square meters of solar panels on the streetscape structures measures up to 2.905 m2 on the double sided panels (East - West streets) and 1.700 m2 on the one sides panels (North - South streets).

This results in the two following energy generation potentials:

(2.905 m2 / 2,50 m2) × 225 kWh/Y = 261.450 kWh per year

(1.700 m2 / 2,50 m2) × 225 kWh/Y = 153.000 kWh per year

In sum the total amount of generated energy on the streetscape structure is about 414.450 kWh per year.

The solar panels placed on the Hubs are the third and final components to the generation of solar energy. The total amount of roof space on the new buildings measures up to 7.450 m2. Additionally the amount of wall space suitable for the placement of solar panels measures up to 640 m2. This results in the two following energy generation potentials:

(7.450 m2 / 2,50 m2) × 225 kWh/Y = 670.500 kWh per year

(640 m2 / 2,50 m2) × 225 kWh/Y = 57.600 kWh per year

In sum the total amount of generated energy on the Hubs is about 728.100 kWh per year.

By adding up all separate energy potentials for solar energy, the total potential solar energy can be estimated. The total amount of potential solar energy generation in this design is 9.470.025 kWh per year. The complete overview of all the calculations presented above can be found in Appendix B.

Wind energy

In the design of the Hubs we made use of smart interventions to guide the wind towards the turbines on the highest point of the building. As explained in the previous chapter, the roof of each Hub is shaped in such a way it is guiding and increasing the wind (speed). On the each of the highest point we have placed a wind turbine, type Vetar 15. This type of wind turbine produces around

23958 kWh per year with an average wind velocity of 5,76 m/s. Rotor of 2,5 m and turbine diameter of 3,62 m (Poduhvat, 2016). The total amount of Hubs measures 5, this results in the following energy generation potential:

23958 kWh/Y x 5 = 119.790 kWh per year

This number also indicates the total amount of potential wind energy generation in this design, as these five large turbines are the only turbines that were included. The complete overview of the calculation presented above can be found in Appendix B.

Solar boilers

In order to deal with the current and future demand of natural gas we have implemented solar boilers into the design. These solar boilers will help to replace the natural gas as an energy source for heating. It could be the case that natural gas is not used anymore in the Netherlands in 2050, and that the use of natural gas is transformed to renewable sources instead and only electricity is used and generated. In this case the devices natural gas are used for, are then translated into kWh, but because in the current situation m^3 is still common and our quickly introducible design intervention of solar boilers use m^3, the translation from m^3 to kWh is not made in the calculations.

On average one solar collector for one solar boiler needs about 3,5 m2 (Milieu Centraal, 2016B). Based on the Zonatlas website we concluded 917 roofs of total amount of existing roofs of the Spijkerkwartier are suitable for solar collectors (Zonatlas, 2016A). One solar boiler is known to produce up to 200 m3 per year if it contains a storage tank of 150 liters (Milieu Centraal, 2016B). Based on the information above, we can calculate the amount of heating potential for the 917 existing roofs:

200 m3/Y x 917 = 183400 m3 per year

In addition to the placement of solar boilers on the existing roofs, we have also places solar boilers on the Hubs. The amount of heating potential for the Hubs is as follows:

200 m3/Y x 4 = 800 m3 per year

In sum the total amount of generated heating energy is about 184.200 m3 per year. The complete overview of the calculation presented above can be found in Appendix C.

Total energy generation

When all of the numbers stated earlier are added up, the total energy potential for the design is calculated. In this case adding up the energy potential for both solar and wind energy results in the following:

728.100 kWh/Y + 119.790 kWh/Y = 9.589.815 kWh per year

Comparing this number to the number for energy demand in 2050, which is 15,9 million kWh per year, it is clear the total amount of energy produced by our design makes only a dent in the total amount of expected energy consumption (see figure 5.1). Since after the implementation of both the solar panels and the wind turbines we will be able to generate 60,4 percent of the local energy demand. Figure 5.2 depicts the renewable energy sources and their percentage of energy potential in regards to the local energy demand in 2050. Considering our design is unable to meet the demand, additional energy generation will be needed in order to make the Spijkerkwartier self-sufficient and energy neutral.

Comparing the total amount of generated heating energy by the solar boilers with heating demand in 2050, which is 3,4 million m^3 per year, indicates the design will not be able to meet the heating demand (see figure 5.3). As depicted in figure 5.4, after the implementation of the solar boilers we will be able to cover 5,4 percent of the local heating demand.

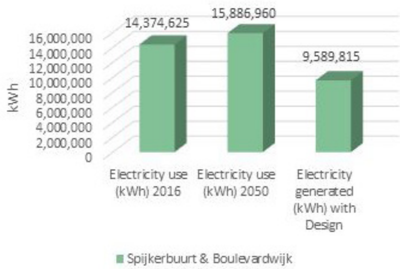

Fig. 5.1
Electricity use 2016, 2050, and our design

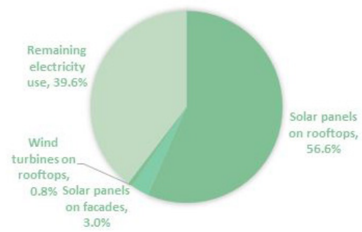

Fig. 5.2
Percentage of electricity production

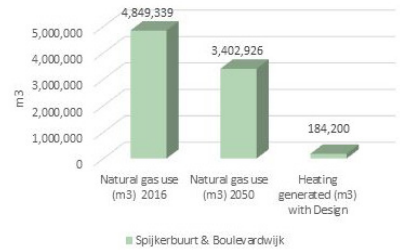

Fig. 5.3
Natural gas use 2016, 2050, and our design

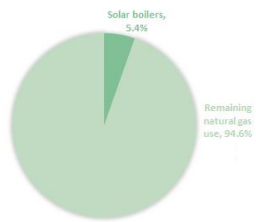

Fig. 5.4
Percentage of heating production

Energy storage

Although the total energy demand for the Spijkerkwartier was not met with our design interventions, there will be a need for energy storage. Considering most of our generated energy is generated by use of solar panels it is important to take into account the energy production flows during each month as energy production during summer will be higher than energy production during winter, see figure 5.5. June is one of the most productive months in harvesting solar energy, because 13% of the yearly energy production produced is produced in June (Milieucentraal and Sidera, n.d.).

Figure 5.6 shows the energy production and usage at a day in June. There is more energy produced than used around noon. Because of this surplus we have to store this energy so it could be released on a moment when we need more energy than we produce. As shown in the figure we have to store at least 1200 kWh. This is the cumulative amount of energy which is not used. If we divide this surplus over the four hubs than each hub has to store 300 kWh. Storing this amount of energy is already possible in a large scale battery (Electric Car Parts Company, n.d.).

If the efficiency of PV panels increases the capacity of the batteries has also to become higher. In the period when there is no hub and no batteries are installed is it possible to release the excessive energy to the current electricity network. In this figure we did not taken into account the energy that the wind turbines generates. Wind energy depends less on time than solar energy and in our plan it only generates 0,8% of the total amount of energy which will be produced.

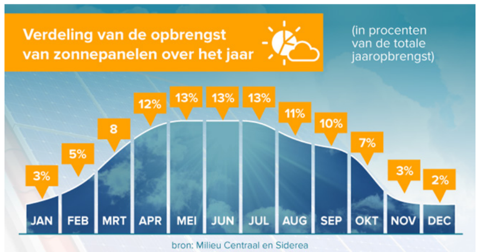

Fig. 5.5
Energy poduction during the year
Milieu centrale and Sidera

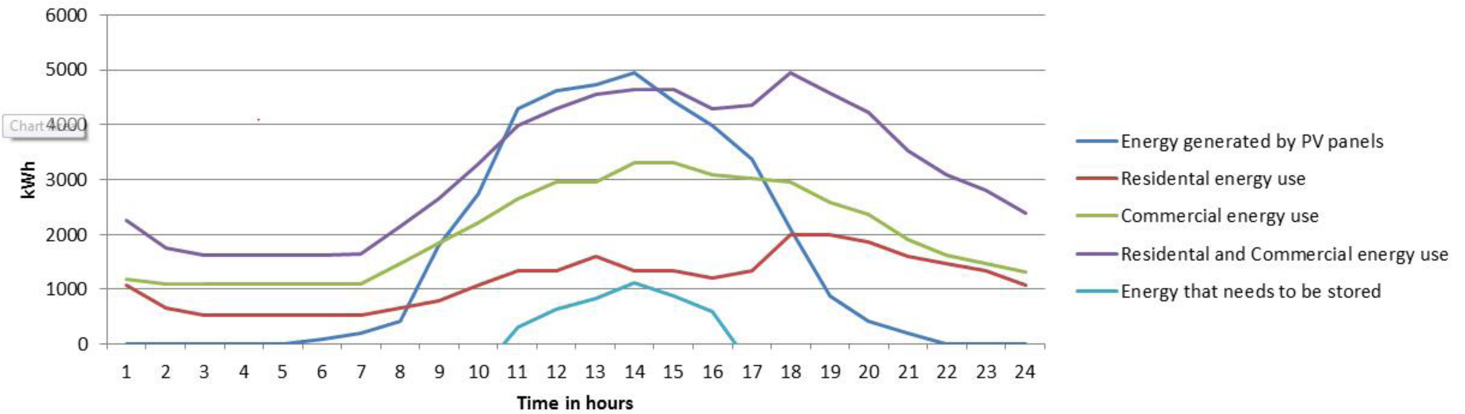

Fig. 5.6
Energy use and production in the Spijkerkwartier on a day in June.
Adjusted by author based on (Energie in beeld, 2016) (Lawrence Berkeley National Laboratory, 2005) (EVnetNL, 2013)

6. Conclusion & discussion

Introduction

Based on the information presented earlier we have formulated both a conclusion and reflection. These will be presented in this chapter.

Conclusion

Our goal was to become an energy neutral neighbourhood. Unfortunately, this goal is not reached, however a large amount of the current electricity use namely 60,4% could be generated with our design interventions in this neighbourhood. This is mainly achieved by installing PV-panels on the roofs and on the facades. The natural gas usage will decrease with 1/3 in the future, however we only produce 5,4% of the needed amount for heating with solar boilers. With our design it is not possible to make the neighbourhood climate neutral yet, based on the current energy use and the used energy use predictions for the future.

By creating the Hubs, parking spots will be able to be removed from the streetscape and vegetation could be added instead. This de-paving and adding vegetation at the streetscape could decrease the PET in the street and would reduce heat stress. Adding PV-panels and panels with green the suitable facades of the current buildings and new hubs will also decrease the PET on the street. During day time at a heat wave the PET of the Steenstraat will drop with 3,4 degree and the PET of the Driekoningenstraat with 5,6 degree with our design interventions. The lowering of the PET on a hot day will decrease the Urban Heat Island effect.

Next to the (indirect) cooling aspect of the hubs, the idea is also that hubs function as in a social aspect as a landmark and that the hubs could provide different facilities for the residents. The Garden Hub also provides plants for the different panels and The PV-panels and green panels on the facades could upgrade the visual appearance of the street by covering for example graffiti. Some of the placed PV-panels and green panels on the facades could also provide shade. Apart from the heat stress green is also able reduce psychological stress and increase biodiversity.

In energy aspect the hubs are garages and charging locations for the electric (sharing) cars and provide a place where the energy, when it is not used, could be stored.

These proposed interventions could make the neighbourhood more resistant against the Urban Heat Island effect and it also contributes towards the shift of a sustainable future in an energy aspect, a social aspect and an environmental aspect. With the different elements on the facades, roofs and in the streetscape, we propose to dress the neighbourhood in green.

Discussion

In what way design interventions could decrease the PET is based on literature. This report did not succeed to find suitable literature to show how all design interventions could decrease the PET. The de-paving of a certain amount of parking spots and adding green, the four new hubs and the wind turbines are for this reason not taken into account in our PET calculations. Another discussion point is that for only two locations the PET is measured with Rayman. The PET could have been measured for more locations, this because not every street is the same which influences the sky view factor and not every intervention is implemented everywhere. Because of limitation in time and resources we only calculated the PET for the Steenstraat (East- West oriented) which is one of the most important streets of the neighbourhood and the Driekoningenstraat (North-South oriented). Because our interventions differ for East-West and North-South interventions these two streets where chosen. The PET calculations are based on two time selections (2 PM and 11 PM) on the same date of a heatwave in the past in Arnhem. If other time selections of the day where taken into account, it would have been visible how the PET would have changed during the day. If another date was chosen, also other inputs of air temperature, wind speed, relative humidity and cloud cover would have appeared, put into Rayman and other PET outcomes would have appeared. PET calculations of a mild day or a cold day are not taken into account in this report, because heat stress would not appear. For this report the focus was how our design could decrease heat stress, which is attempted to show in the PET-calculation in this report.

The predicted energy use for 2050 is based on the IEA-scenario of limiting global warming with two degrees of Warringa & Rooijers (2015) and on the numbers of the energy use of Spijkerbuurt and Boulevardwijk in 2016 of Energie in Beeld (2016). If the predicted energy use of 2050 was based on other future scenarios, other target numbers for 2050 would have appeared. In case of other target numbers the possibility exist that our design interventions could have reached these other targets. The predicted energy our design would be able to generate is based on the best information which was available to find in this time period. The generalizations which are made in the calculations are attempted to be made clear as possible.

From the four hubs we only detailed one hub, namely the Garden hub. The other three hubs will be built in the same structure, but because of a different locations the dimensions of the three other hubs will differ. Except of the theme of the community space contains each hub the same elements.

We did not succeed in creating the neighbourhood with our design energy neutral. One of the reason is that not all facades where feasible for installing PV panels, because the presence of balconies and ornaments on the facades. Also some of the buildings are monuments and have therefore building restrictions. The second reason is that there are only windmills on the hubs and not on the existing buildings, this is because windmills on the existing buildings are not very efficient, because these windmills do not catch enough wind to be effective. The third reason is that the scope of our project is 2050, however we took the efficiency of the PV panels of today. We could assume that the technique of PV panels will increase and that the PV panels will be more efficient in the future. The fourth reason is that in our design interventions not all alternative sources of renewable energy are taken into account. Interventions which would be suitable on a larger scale such as cold and heat storage are not taken into account because of the smaller scale of the Spijkerkwartier. It is also possible to connect the neighbourhood on the heat network of Arnhem instead of the current gas network. The energy could also be generated on a sustainable way outside the neighbourhood like at a windmill park at sea.

In our report it is not shown how our design interventions could be a share in decreasing energy use. Green roofs and green walls could for example work as a form of insulation and lead to a reduction, but accurate numbers to show this effect were unfortunately not found. It was assumed this effect and other energy reduction measures were taken into account in the IEA-scenario for the predicted energy use in 2050.

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Appendix A

Intervention	**Max reduction in air temperature (in degrees)**	**Streenstraat**	**Driekoningenstraat**	**Explanation**
Facades and roofs fully with green have more effect the more narrow the street	-8.4	-	-0.5	Driekoningenstraat is a more narrow street
green panels fully on both facades	-2.1	-1.5	-1.0	14 strokes of green panels for the Steenstraat 9 strokes of green panels for the Driekoningenstraat
green roof both sides	-1.8	-0.9	-1.8	North side roofs of Steenstraat are not taken into account for green roofs, because these houses are outside the border of Spijkerbuurt.
solar boiler + solar panels on rooftop	-0.2	-0.1	-0.2	North side roofs of Steenstraat are not taken into account for solar panels and solar boilers, because these houses are outside the border of Spijkerbuurt.
solar panels fully on both facades	-0.2	-0.15	-0.13	10 strokes of solar panels for the Steenstraat 7 strokes of solar panels for the Driekoningenstraat
Total reduction during Day		**- 2.65**	**- 3.63**	
Solar boiler + solar panels on rooftop at night (extra)	-0.1	-0.05	-0.1	North side roofs of Steenstraat are not taken into account for solar panels and solar boilers, because these houses are outside the border of Spijkerbuurt.
solar panels fully on both facades at night (extra)	-0.1	-0.08	-0.07	10 strokes of solar panels for the Steenstraat 7 strokes of solar panels for the Driekoningenstraat
Total reduction at Night		**- 2.78**	**- 3.8**	

Table 1
Reduction in air temperature by interventions
Sources: Alexandri & Jones, 2008; Masson et al., 2014

	Day	**Night**
Date	22-07-2013	22-07-2013
Time	02.00 PM	11.00 PM
Place	Arnhem	Arnhem
Geogr. longitude	5°55	5°55
Geogr. latitude	51°59	51°59
Air temperature	33.3 degrees	20.3 degrees
Relative humidity	32%	79%
Wind speed	3.0 m/s	1.0 m/s
Cloud cover	5 octans	6 octans

Table 2
Example Day & Night of Heatwave in Arnhem, used for Rayman
Source: KNMI, 2016

- Alexandri and Jones (2008, p. 478) measured that green walls can on average decrease 1.7 to 2,1 degrees during daytime and for green walls and green roofs together an average decrease between 3.0 and 3.8 degrees during daytime are measured for colder climates such as in London, Moscow and Montreal. It is assumed that the situation in Arnhem in the Netherlands can be compared to these colder climates and that approximately the same average numbers can be used.

- In terms of solar panels and solar boilers, approximately the same average numbers of Masson et al. (2014) are applied. Masson et al. (2014) measured that when using 1/30 of a roof for a solar thermal panel for a solar boilers and the rest for solar panels, the air temperature during the day decreases with 0,2 degrees and the air temperature during the night decreases with 0,3 degrees.
Based on above mentioned literature these average numbers are translated into an maximal decrease in air temperature per intervention: see table 1.

- Based on data from the KNMI, the air temperature, wind speed, humidity and cloud cover is found for 2 PM and 11 PM.

- To calculate the sky view factor of the two streets with design interventions are added to the Streetview Stereographic images and later put into Rayman. With a SVF of 1 the sky is completely visible.

See table 2.

Appendix B

Intervention	*Amount of m2*	*Amount of solar panels & turbines*	*Potential kWh electricity generated per year*	*Calculations*	*Sources*
solar panels on current rooftops	92.527,5 m2	37011	**8.327.475 kWh**	95737 m2 - 3209,5 m2 = 92527,5 m2 92527,5 m2 : 2,5 m2 = 37011 panels 225 kWh x 37011 = 8.327.475 kWh	• suitable rooftops for solar panels (Zonatlas, 2016A) • measure tool for m2 suitable rooftops for solar panels (Edugis, 2016) • a sloped roof needs 1,6m2 per solar panel, but a flat roof needs 4m2 per solar panel, because of the extra structure which is needed and the shade of the other panels. On average 2,5m2 roof is needed per solar panel (Milieu Centraal, 2016A). • one average solar panel produces 225 kWh per year (Milieu Centraal, 2016C).
two sided movable solar panels on facades	2.905 m2	1162	**261.450 kWh**	0,9 m x 2,8 m = 2,5 m2 2905 m2 : 2,5 m2 = 1162 panels 225 kWh x 1162 = 261.450 kWh	
one sided solar panels on facades	1.700 m2	680	**153.000 kWh**	0,9 m x 2,8 m = 2,5 m2 1700 m2 : 2,5 m2 = 680 panels 225 kWh x 680 = 153.000 kWh	
solar panels on rooftops new buildings + 1 current parking building	7.450 m2	2980	**670.500 kWh**	5850 m2 new multifunctional buildings + 1600 m2 current parking building = 7450 m2 7450 m2 : 2,5 m2 = 2980 panels 225 kWh x 2980 = 670.500 kWh	
Solar panels on facades new buildings	640 m2	256	**57.600 kWh**	640 m2 : 2,5 m2 = 256 225 kWh x 256 = 57.600 kWh	
Wind turbines on new buildings	30 m2	5	**119.790 kWh**	Rotor of 2,5 m 5 x 6 m2 = 30 m2 23958 kWh x 5 = 119.790 kWh	• wind turbine type Vetar 15 produces around 23958 kWh per year with an average wind velocity of 5,76 m/s. Rotor of 2,5 m and turbine diameter of 3,62 m (Poduhvat, 2016).
Total	105.252,5 m2	42.089 solar panels & 5 turbines	**9.589.815 kWh**		

Table 1
Potential electricity generated for Spijkerbuurt & Boulevardwijk

Appendix C

Intervention	*Amount of m2*	*Amount of boilers*	*Potential m3 heating generated per year*	*Calculations*	*Sources*
solar boilers on rooftops	3209,5 m2	917	**183.400 m3**	3,5 m2 x 917 = 3209,5 m2 200 m3 x 917 = 183400 m3	• 3,5 m2 needed for one solar collector for one solar boiler (Milieu Centraal, 2016B) • 917 suitable rooftops for solar boilers (Zonatlas, 2016A) • measure tool for m2 suitable rooftops for solar collectors of solar boilers (Edugis, 2016) • 200 m3 heating produced per year with one solar boiler with a storage tank of 150 litres (Milieu Centraal, 2016B)
solar boilers on new multifunctional buildings	14 m2	4	**800 m3**	3,5 m2 x 4 = 14 m2 200 m3 x 4 = 800 m3	
Total	*3223,5 m2*	*921*	***184.200 m3***		

Table 1
Potential heating generated for Spijkerbuurt & Boulevardwijk