THIS COVER

A CLIMATE PROOF SPIJKERKWARTIER

THESSA BECK
BING DU
BOUWINA MIEDEMA
FELINE VERBRUGGE
RUBEN WEGGEMANS

Interreg North-West Europe
EUROPEAN UNION
Climate Active Neighbourhoods
European Regional Development Fund
WAGENINGEN UR
For quality of life

THESSA BECK
BING DU
BOUWINA MIEDEMA
FELINE VERBRUGGE
RUBEN WEGGEMANS

LAR 36806
CLIMATE RESPONSIVE PLANNING AND DESIGN
DR. DIPL. ING. SANDA LENZHOLZER
DR. ING. SVEN STREMKE
DR. IR. GERT-JAN STEENEVELD

CONTENT

INTRODUCTION

1. AN INEVITABLE TRANSITION

The global society of today is addicted to energy. We simply cannot do without. People demand more and more of it every day, even though the main resources such as fossil fuels and nuclear power are not inexhaustible and moreover unsustainable energy generators (MacKay, 2009). Furthermore, the fossil fuel economy is the cause of multiple environmental and social problems (Droege; 2002, 2006). An excess of greenhouse gas emissions that results from the depletion of fossil fuels is very likely to lead to a changing climate (MacKay, 2009). Hence, we need to make a drastic shift towards a post fossil fuel era, in which renewable, clean and sustainable energy systems have to play a key role (Sijmons et al., 2014; Stremke et al., 2011), in order to provide ourselves with a secure future. The European Union and the G8 have set a goal to reduce greenhouse gas emissions by at least 80% below the levels of 1990 by 2050 (Roadmap 2050, 2011; Sijmons et al., 2014). Important spatial choices and changes will have to be made to achieve this goal and to shape this energy transition (Sijmons et al., 2014; Stremke et al., 2011; Strong, 1992, p. 493). This will be a tough transition that takes a lot from our imagination and flexibility.

2. ARNHEM AS PIONEER CITY

Arnhem has a rich tradition concerning energy generation and usage. It is for example nationally known for its electrically driven public transport and many of its inhabitants work in an energy related sector (Sijmons et al., 2014). Since it is an averagely populated city it is a good representation for a city in the Netherlands as well as for Europe. Therefore Arnhem as a whole could act very well as a pioneer in the energy transition to become the first energy neutral city. The neighbourhood Spijkerkwartier can be the pilot project location within Arnhem to apply the first interventions. It is a characteristic area with many historical and monumental buildings and its inhabitants have very diverse backgrounds. Many of them are enthusiastic and willing to cooperate and participate in new initiatives towards a sustainable future. The latter is a necessity to make a pilot project work. A more elaborate introduction about the neighbourhood will be given in the next chapter.

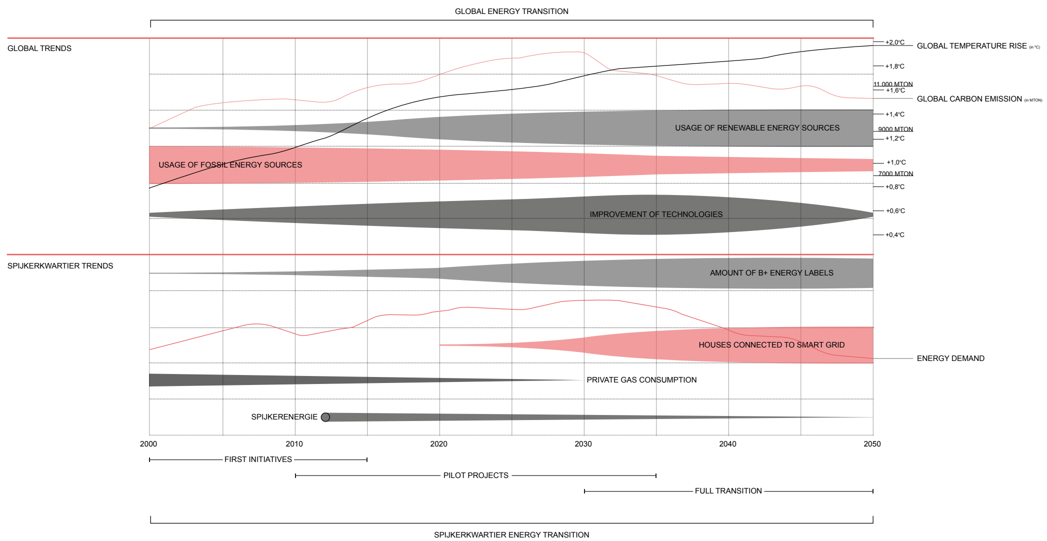


FIGURE 01 // Possible energy transition projected for 2050 (partly based on Sijmons et al., 2014, p. 82-83)

3. ENERGY TRENDS

Globally, several trends related to energy consumption and generation can be expected to occur. Such modelling is difficult and often produces uncertain scenarios for the future. The future energy demand and organisation of energy supply are uncertain as well, yet an indication of a possible future is given in figure 01 (a larger version can be found in Appendix I). It tries to give such indication on both a global and local scale. The model is partly based on Sijmons et al. (2014, p. 82-83), but also uses a personal vision.
The use of renewable energy sources such as solar, wind and biomass will increase and slowly replace fossil energy sources. Next to this, it is key to develop cleaner and more efficient ways to convert fossil fuels. It can be expected that technologies of both renewable and fossil sources will improve, making it possible to use and convert energy more efficiently than nowadays. The total energy demand is stabilising and will be decreasing at some point. A necessary condition to achieve this is to convert all houses to at least energy label B. Gas consumption is projected to decrease to an absolute minimum by 2030, especially since this is one of the aims of the municipality of Arnhem. To

cope with an increasing energy consuming and generating society, smart grids will be developed which can be applied to the Spijkerkwartier. Smart grids adapt the electricity demand and supply by making the system more flexible and circular (Wolters, T., 2011).

4. CLIMATE TRENDS

The IPCC report presented in 2014 indicates that humans have a clear impact on global climate systems. The Earth's atmosphere has been warming during the last three decades and is projected to heat up even more in the coming years (figure ??). Moreover, larger amounts of precipitation are expected in some places, while other places might receive less. Sea levels will continue to rise and greenhouse gas concentrations in the atmosphere will increase (figure ??) (Stocker, 2014).

Based on the IPCC report, KNMI has developed four scenarios (figure 02) specifically applicable for The Netherlands in both 2050 and 2085 (Royal Netherlands Meteorological Institute, 2015). They count with changes in temperature, precipitation and sea level. Each scenario takes into account different amounts of carbon emissions. They differ in how much the Earth will warm up (moderate or warm) and how air flow circulation patterns will change (low or high). The design and calculations that will be presented in this report will be based on these four scenarios.

A changing climate will not only impact natural systems, but society as well. A large percentage of the population lives in cities, and this number will even increase in the future. In cities, long wave radiation is longer retained, more anthropogenic heat is produced and less is evaporated. Therefore, cities tend to warm up more and cool down less easily than rural areas, resulting in urban heat islands (Lenzholzer, 2015). This phenomenon could lead to heat stress, which occurs when extreme heat conditions significantly disturb people's thermoregulation.

5. CONTEXT OF BRIEF

The effects resulting from human activities and an excessive use of fossil fuel energy sources, such as global warming, urban heat islands, urban wind nuisance and deteriorated human thermal comfort can be limited by designing renewable energy interventions and climate responsive cities. The Spijkerkwartier in Arnhem is used as a case study on which energy-conscious design interventions can be implemented on several scales. These interventions must also contribute to a thermally comfortable cityscape.

6. OBJECTIVE

As mentioned before, the goal that was set by the EU is to reduce greenhouse emissions by 80% in 2050. From this starting point the aim is to make the Spijkerkwartier energy neutral by 2050 (Roadmap 2050, 2011) in which exergy is used to its maximum and entropy production diminished to a minimum (Stremke et al., 2011).

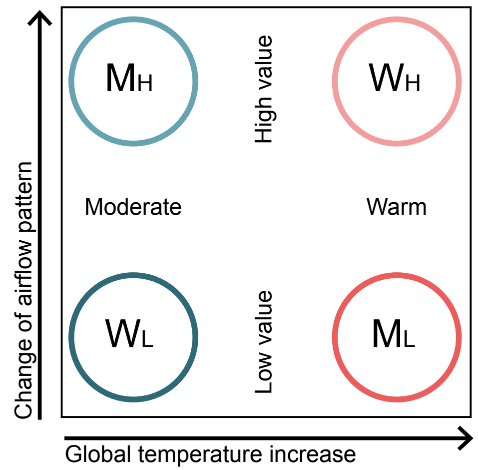


FIGURE 02 // KNMI's climate scenario's (KNMI 2014)

PROJECTAREA

1. LOCATION

The Spijkerkwartier is a neighbourhood located in the city of Arnhem, Gelderland (figures 03 and 04). It is situated next to the city centre, which is located southwest from the neighbourhood (figure 05). The three areas Spoorhoek, Spijkerbuurt and Boulevardkwartier compose the neighbourhood, however, in this project we will solely focus on the Spijkerbuurt and Boulevardkwartier area, which is indicated in figure (??) by the red dotted line.

FIGURE 03, 04 AND 05 // Three maps that show the location of the Spijkerkwartier on three different scales (Bingmaps, 2016)

2. HISTORY

Urban planner and architect Hendrik Jan Heuvelink designed the neighbourhood mid 19th century and construction finished at the end of that century. The name Spijkerkwartier derives from two medieval storages that were located in the area; so called *spijkers*. It was meant as a neighbourhood for wealthy people, which can be seen in the large number of monumental buildings (Keverling Buisman, 2009). However, in the '60's and '70's the area got strongly deteriorated merely because of the high amount of prostitution that started to occur. Much of the public spaces lacked in quality. Fortunately, at the start of this century the area got more popular which led to the renovation of many buildings and the improvement of the public area.

3. CURRENT SITUATION

At this moment, the area we focus on in this project inhabits 5015 people, which means approximately a 12455 people per square kilometre (CBSinuwbuurt, 2015).

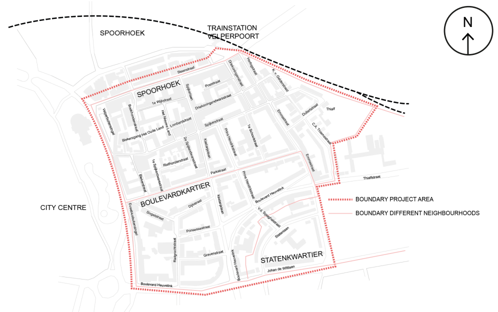


FIGURE 06 // Map that shows the different neighbourhoods and project boundary

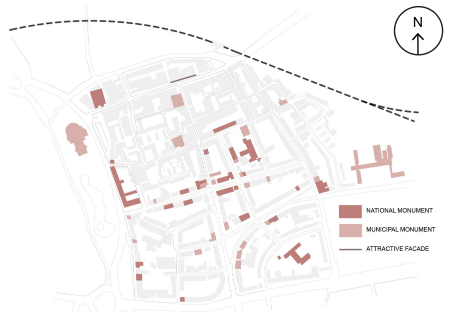


FIGURE 07 // Map that shows the monuments and attractive facades

The neighbourhood is very mixed, its inhabitants have different backgrounds, levels of income and education, and they have different occupations and ages.
The total amount of energy consumption in 2016 can be found in table 01, as well as a prediction for 2050. The amount of households in 2015 is 3375, of which the largest percentage (75%) is composed of single households (CBSinuwbuurt, 2015). The average electricity consumption per household is about 1500 kWh/year, and the average gas consumption per household is 7300 kWh/year (numbers based on table 01).
At last, figure 07 shows the current national monumental buildings, the municipal monumental buildings and attractive facades (WORSpijkerkwartier, 2016).

PREDICTED ENERGY USE FOR SPIJKERKWARTIER IN 2050

		BUSINESS (kWh/year)	HOUSING (kWh/year)	TOTAL (kWh/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/year)	HOUSING (kWh/year)	TOTAL (kWh/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

TABLE 01 // Total amount of energy consumption in 2016 and a prediction for 2050

PROBLEMS

1. PROBLEM ANALYSIS

After analysing the Spijkerkwartier three main problems occur in the neighbourhood. Firstly the heat stress that occurs in some areas on hot summer days. Secondly, flooding can be seen as a problem and as third and last main problem the low energy labels of the buildings is selected. In the next sections these three problems will be analysed more elaborately.

2. URBAN MICROCLIMATE

Figure 08 depicts the areas that are most likely to suffer from heat stress during heat waves in summer. The locations are based on a shadow analysis, and these are the locations that will have no shade at all during summer. The north-western part of the neighbourhood has only few full grown trees and is therefore the warmest area. Especially the Steenstraat – the main shopping street of the neighbourhood – copes with a lot of shortwave radiation on street level due to the little amount of trees. Residents that live on the first and second floor of the houses have problems with sleeping during tropical nights. A couple of courtyards in this part of the neighbourhood will have heat problems in summer as well, especially since these areas are fully paved and have no or only few trees. Since climate change will lead to more heat waves and thus tropical nights, these problem areas have much potential to tackle by using clever design solutions to prevent heat stress.

3. FLOODING

If flooding in combination with Spijkerkwartier is searched for in Google, many pictures and videos appear that clearly indicate a major problem in the area. During peak hours of precipitation, the sewage system in especially the north-eastern area (figure 09) cannot cope with the high amount of water, causing substantial floods in the streets. Currently the sewage system is under reconstruction, but it can be questioned whether it is enough.

4. ENERGY LABELS

As a last a big problem that needs to be handled in order to become energy neutral by 2050 is the current quality of insulation of most of the buildings. Since most of the buildings in the neighbourhood were built before 1900's they have very low energy labels, about E on an average (figure10). To achieve the set goal it is a necessity to think of a way that not only generates energy, but also saves as much as possible despite the current construction of the buildings. In figure 11 the difference between energy label E and B is shown regarding the amount of energy that is necessary.

5. POTENTIAL

Although the latter mentioned problems seem to be difficult to tackle altogether, it will still be the main aim for this design project. In the next chapter the principles that are used for the design will be presented as well as our interventions that could potentially solve the problems in the neighbourhood. Not only will the design be based on the problems in the area, it will also use them as potentials from which interesting interventions can be created.

FIGURE 08 // The areas where heat stress problems can occur

FIGURE 09 // Map that shows the areas with a flooding problem, the lower areas and the topography

FIGURE 10 // The energy labels of the houses in the Spijkerkwartier (energielabelatlas.nl)

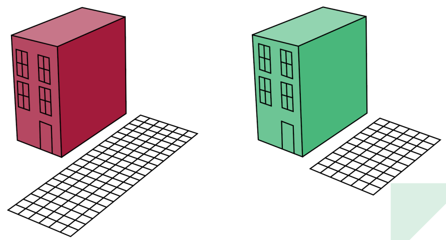
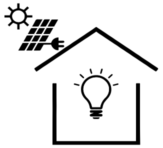


FIGURE 11 // Difference between amount of solar panels necessary for energy label E or B

CONCEPT

1. PRINCIPLES

As start of our design we defined five principles our design needs to comply to. These are part of the assignment but also important aspects to address referring to both the problems and strengths of Spijkerkwartier.

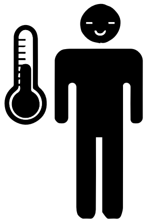


Energy generation

The design needs to focus on generating energy with the use of solar panels for the neighborhood and being self-sufficient as much as possible.

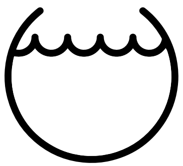
Energy saving

The design needs to help save energy for heating and cooling in houses. The design needs to save energy on top of the amount energy that is saved by insulating the houses.



Thermal comfort

The design needs to provide thermal comfort during the year and especially in summer. In summer the design needs to decrease the heat stress of people during extreme hot days (>30°C).



Water storage

The design needs to be able to store water during peak rainfalls to prevent major floodings in the neighborhood.

Preserve spatial quality

The design needs to preserve the spatial quality of the neighborhood. Especially focusing on preserving the facades of monuments and beautiful buildings.

With these principles in mind we designed three interventions and within those interventions extra principles were created. These will be explained in the next section.

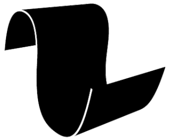
2. INTERVENTIONS

The design is based on three interventions: the courtyard cover, street cover and a bioswale network in the streets and courtyards. The street cover is used as an introduction for the design and functions as a landmark when entering the Spijkerkwartier. The courtyard covers provide different services to the residents and can be seen as the heart of our design. The bioswales are used as a connecting structure between the courtyard interventions and the street cover.

Courtyard cover

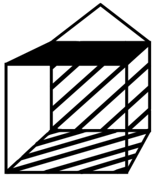
Energy generation is done by placing solar panels on the roof surfaces and if possible facades of the cover. Solar panels and solar boilers will be implemented on all possible roofs in the neighbourhood.
Energy saving is done by adding an extra layer to the building using the courtyard cover as an extra insulation for the house.
Thermal comfort is reached for summer and winter. In summer this intervention can be used to cool down the surrounding area and within the courtyard cover.
Water storage is done on the ground level of the courtyards by providing space for a bioswale. It is also possible to harvest rainwater from the roofs in barrels or underground storages.
Preserve spatial quality is done by focusing on the backyards of the houses so the (monumental) facades in the streets are preserved.

The design of the courtyard cover has also specific principles focusing on the design of the intervention.



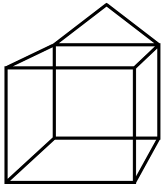
Flexibility

The courtyard cover needs to be flexible to comply with the desires of the residents and the thermal comfort. In summer the cover needs the possibility to be open and in winter it needs to be closed.



Shaded in summer

The courtyard cover needs to be shaded in summer to decrease the amount of sunlight that can heat up the surface and therefore decreasing the heat stress.



Sunlight in winter

The courtyard cover needs to let sunshine in when it is winter so the buildings will have enough daylight.

The use of greenhouses to insulate houses and increase the amount of space that can be used the whole year is done for example in EVA-Lanxmeer in the Netherlands. Here a wooden structure is used in combination with glass and solar panels on the roof (Bewonersvereniging EVA-Lanxmeer, 2016). Covering the public space is something that is not done yet but an example could be Lumen building at the Wageningen University or an elderly home with in the middle a courtyard completely covered. The Serreburgh in Spijkenisse is an example of such an elderly home. The cover helps with insulating the house, less maintenance on the outside building materials (less weather influence on the quality), space for community gardens and social gathering (Kin, 2011).

Street cover

Energy generation is done by the use of solar panels on the roof and facade of the street cover. The roof of the cover is tilted to create a better efficiency of electricity generation than flat lying solar panels.
Thermal comfort is reached by covering the part of the street that has the most sunshine through the summer and therefore the surface will heat up less and decrease the heat stress.
Preserve spatial quality is done by placing the covers on the parts of the streets without monuments or aesthetically nice buildings.

Bioswales in streets and courtyards

Thermal comfort is reached by using green in the street that will evaporate and therefore cool down the air temperature.
Water storage is done by creating space where water can be stored and slowly infiltrate in the ground.
Preserve spatial quality is done by doing the intervention horizontal on ground level and therefore not intervening with the facades of beautiful and/or monumental buildings. It also provides the street with a greener and aesthetically nice look.

For the streetscape itself and extra principle is made that provide unused space that can be used for the street cover and bioswales. This principle is based on the future scenario that people will share cars and use self-driving cars that can pick-up people at home and are parked on central locations within the neighborhood. Therefore less cars are needed what results in decreasing the need for space for cars within streets.

More space for pedestrians and cyclists

The streets need to give space to pedestrians and cyclists instead of cars to increase a liveable and nice streetscape. Diminishing the amount of cars in the street also gives space for the interventions of the street cover and bioswale.

DESIGN

COURTYARD COVERING

In the courtyards the intervention is composed from an extension of the houses into the courtyards with the use of a greenhouse structure; the courtyard cover. This extension will help to improve the insulation of the house and it creates a space for people to sit outside in winter comfortably.

Figure 12 shows the different layers of the courtyard cover. As mentioned before the intervention can be compared with a greenhouse. The construction consists of glass with solar panels on top to generate solar energy. The courtyard uses a combination of open and closed areas. This will create different spaces for people that can have different functions. The ground floor of the courtyard cover can be used for urban farming or as an extension of the house. In the open space there can be a bioswale on the surface to store water during rainfalls and there can be grass for people to play or to sit in the sun in the open air. Underneath the courtyard cover a heat and cold storage will be placed to regulate the temperature within the intervention. In summer the heat will be stored underground and used in winter to heat up the air within the courtyard cover and this will also happen the other way around for cooling. Within the courtyard cover the temperature will be at the maximum of twenty-eight degrees in summer and in winter twelve degrees (Van Beek et al., 2009).

The courtyard cover is possible to be applied on all courtyards that are shown in figure 13. Each courtyard has its own characteristics (heights of buildings and ground), type of use and different groups of residents. Therefore, the design of each courtyard will be specific for that location. To show how it could differ and look like three courtyard types (figures 14a, b and c) are chosen and further designed.

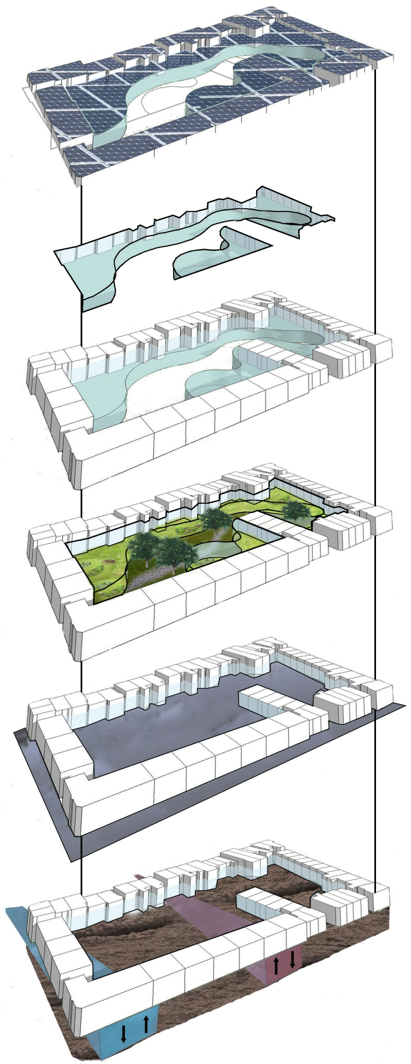


FIGURE 12 // Functionality layers of the courtyard cover intervention

FIGURE 13 // The courtyards in Spijkerkwartier and the selected ones (from left to right: public-open, private-closed, public-closed)

1. PUBLIC-OPEN

This courtyard (figure 14a) is a square with both front and backdoors and has a school located next to it. At this moment it is totally paved, with some trees and a small strip of grass next to the buildings. Through our design intervention we want to unpave parts of this space and turn it into a green area. It is public and open, because it is possible to enter the courtyard from all directions and a street is going through it. The applied intervention covers parts of the street where hot spots are located.

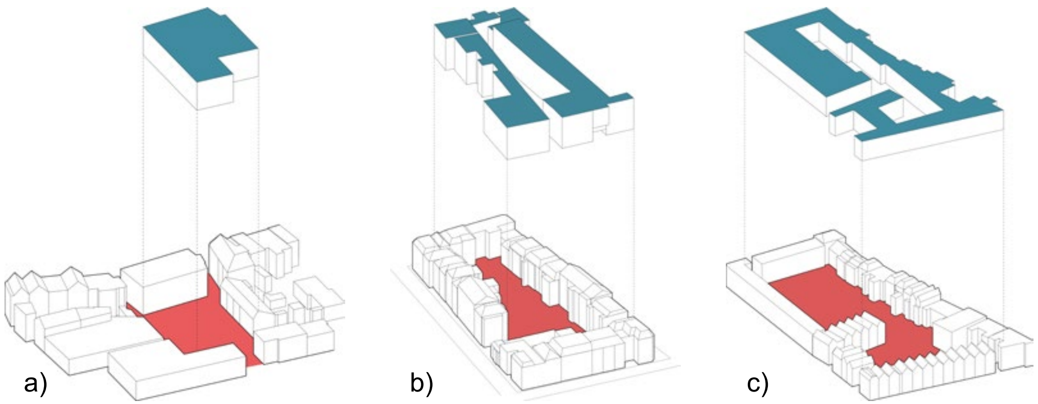


FIGURE 14 // Courtyards with their covers, from left to right: public-open (a), private-closed (b) and public-closed (c)

Figure 15 shows the design of this courtyard and that the cover goes around the trees. The section (figure 16) shows that next to the buildings the area can be used for urban farming and near the school a playground can be created. Covering the playground gives the school the opportunity to use it through the year in all weather circumstances (rain, snow, storms, hot days).

2. PRIVATE-CLOSED

This courtyard (figure 14b) consists private gardens of the houses surrounding it and it can be entered by two small entrances on the west side. The design of the cover of this courtyard depends on the residents and their wishes. In this design half of a garden is covered to also provide space for people to sit in a non-covered garden (figure 17). The residents themselves can arrange what will happen in the covered and uncovered space, for example urban farming (figure 18).

3. PUBLIC-CLOSED

This courtyard (figure 14c) is enclosed by buildings and is composed of a garden that is open to everybody. The design of this courtyard depends on the best location for generating solar energy and decreasing the heat stress. Therefore, the width of the cover can adapted to the shadow patterns (figure 19). Within the cover urban farming can take

FIGURE 15 // View of the design of the public-open courtyard, from left to right: base map (a), walls (b) and complete intervention (c)

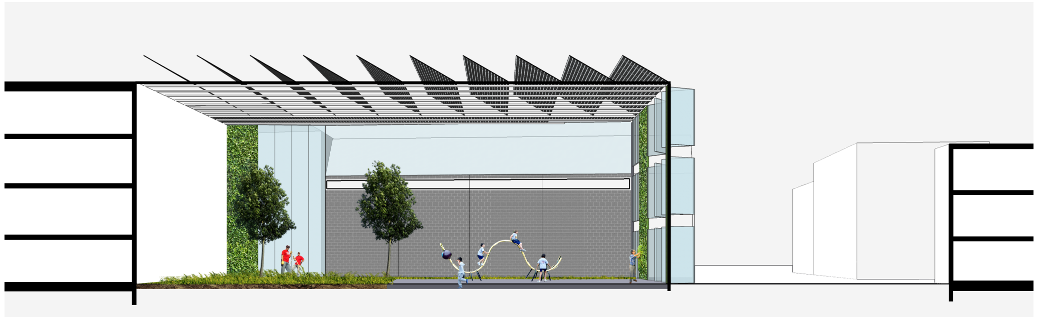


FIGURE 16 // Section of the public-open courtyard

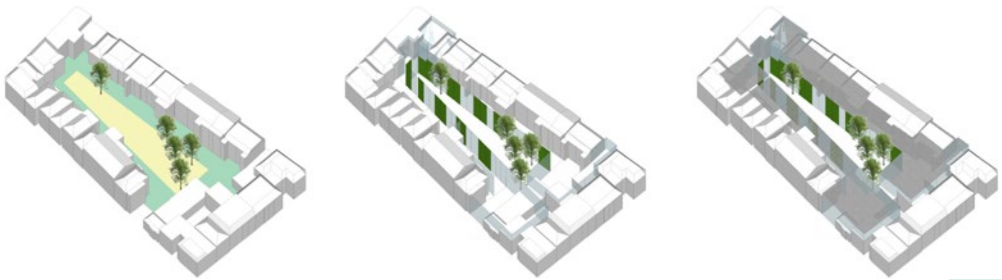


FIGURE 17 // View of the design of the private-closed courtyard, from left to right: base map (a), walls (b) and complete intervention (c)

FIGURE 18 // Section of the private-closed courtyard

FIGURE 19 // View of the design of the public-closed courtyard, from left to right: base map (a), walls (b) and complete intervention (c)

FIGURE 20 // Section of the public-closed courtyard

place, in the unclosed area water can be stored in bioswales and open green spaces can be used for relaxation or sports (figure 20).

4. CONSTRUCTION AND MATERIALS

The construction of the courtyards is made of a non-flexible skeleton with movable panels with semi-transparent solar panels (figure 21). The skeleton is based on a greenhouse, because this construction is easy to apply and therefore, it could save money and time to build it. The movable panels on the roof can be opened and tilted to have the optimal tilt for solar energy generation and to let warm air escape. The movable panels on the facades can be opened to enhance a natural air circulation or when the residents have the desire to open them.

The non-flexible skeleton is composed of a wooden structure where climber plants can grow on (figure 23b). These climber plants provide cooling in summer by evapotranspiration and shading. The panels within the glass structure have semi-transparent solar panels on it (figure 23a). These semi-transparent solar panels can be placed in different configurations on the panels to give room for creativity of artists or residents. The panels are placed differently depending on the direction towards the sun (figure 22).
In summer blinds can be used to shade the covered courtyard in order to decrease heat stress in this area (figure 23c).
Figure 24 and 25 show how the courtyard cover can look like from the building towards the courtyard and from the open area in the couryards towards the cover.

STREETSCAPE

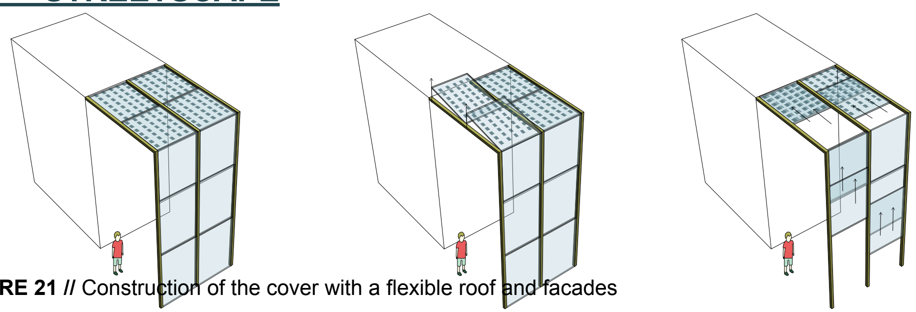


FIGURE 21 // Construction of the cover with a flexible roof and facades

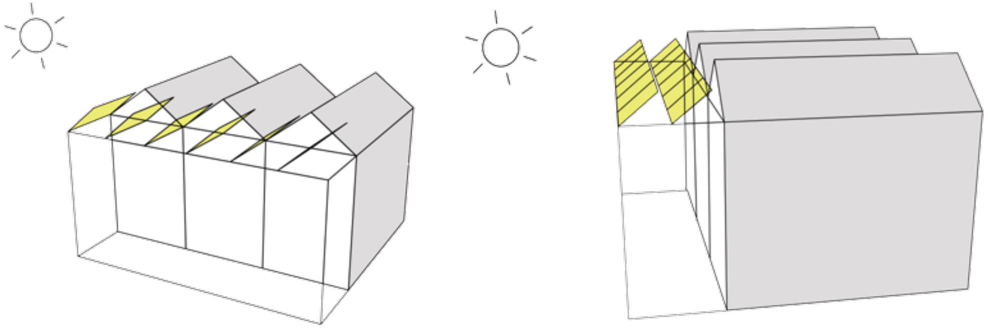


FIGURE 22 // The solar panels on the roof always face the sun

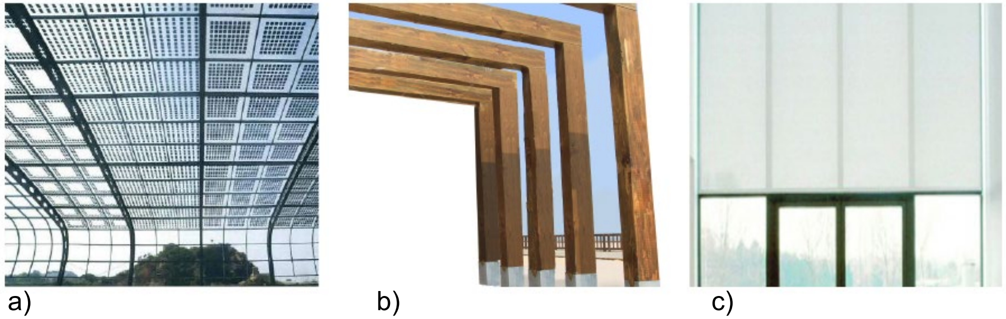


FIGURE 23 // Materials of the construction, from left to right: semi-transparent solar panels (a), wooden skeleton (b), blinds (c)

FIGURE 24 // The courtyard cover from the open area within the courtyard

FIGURE 25 // The courtyard cover from the inside of the building towards the backyard

In the streetscape two different interventions can be found: the street cover and the bioswale. Both these interventions will be explained in the coming sections.

1. STREET COVER

The street cover is another version of the courtyard covering adapted to be implemented in a streetscape. The chosen location for this intervention is the Steenstraat especially because this street suffers most from heat stress and we expect that the street cover can diminish that effect. Since the Steenstraat is the entrance of the neighbourhood, with the shopping street, church and the bus and train station next to it, the intervention could function as an eye-catcher as well. Moreover, the Steenstraat is seen as one of the wider streets, which makes it easier to apply the intervention combined with other functions in the street. A photograph of how the Streenstraat looks at this moment can be seen in figure 28. The schematic outcome of the Steenstraat is shown in figure 26 in top view and in a birds eye in figure 27.

The street cover has a similar construction as the courtyard cover (figure 29). The difference is that the roof is somewhat tilted to increase the efficiency of the solar energy generation. The panels can be even tilted up further depending on the time of the year. The roof panels are filled with fully-transparent photovoltaic files to let through as much light as possible.
On the vertical panels that are located every 3 metres between the beams, semi-transparent solar will be placed. They start at 3 metres above the surface to prevent damaging to the solar panels to happen. On the back of these panels temporary art can be exhibited created by for example students from Artez or other artists based in Arnhem or Spijkerkwartier. In winter these art panels can be removed in order to have sunlight under the street covering.
Along the beams and underneath the solar panels on top, vegetation will be planted. Possible species are *Wisteria sinensis*, *Parthenocissus quinquefolia* and maybe even *Bougainvillea spp.* or *Vitis vinifera* (grapes). These vegetation types will provide shade and have a cooling effect in summer, but will lose their leaves in winter so they won't block any direct sunlight.

FIGURE 26 // Schematic outcome of the Steenstraat in top view

FIGURE 27 // Schematic birds eye of the Steenstraat with its different functions: the cover, bioswale and human activities

FIGURE 28 // Current view on the Steenstraat

FIGURE 29 // Proposed view on the Steenstraat

FIGURE 30 // Current view on the Kastanjelaan

FIGURE 31 // Proposed view on the Kastanjelaan

2. BIOSWALE

The bioswale is used to store water especially during and after a peak rainfall. In figure 32 a structure for the bioswale network is shown. The main flooded areas, lower areas within courtyards and smaller streets are areas that are allocated for this intervention. The smaller streets act as connections for all bioswales to create more surface to store and infiltrate rainwater.

Within the streets the locations of the parking spaces can be used for this intervention. In the trends for mobility in the future people will use less cars and with central parking at certain locations within the neighbourhood it is possible to decrease the amount of parking in the streets. More information about this future scenario is explained in the next chapter mobility.
The bioswales can look differently in each street because this depends on the amount of space in the streets and what people prefer.

In figure 33 different types of bioswales are shown. Figure 33a and 33b are bioswale types that are small and therefore also suitable for small streets. Figure 33c and 33d are larger and therefore take too much space within small streets.
An example of a bioswale in the streetscape a visualisation of the Kastanjelaan (figure 31) is made, with a photograph of how it is at this moment (figure 30). Here two bioswales of the types ecological (instead of parking lots) and semi-urban (near the houses at the right) are show.

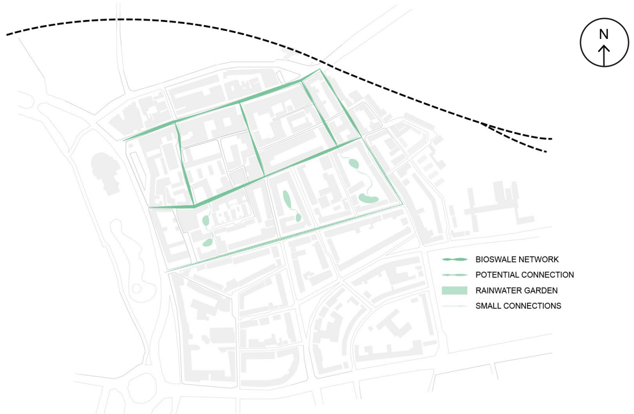


FIGURE 32 // The bioswale network proposed for the Spijkerkwartier

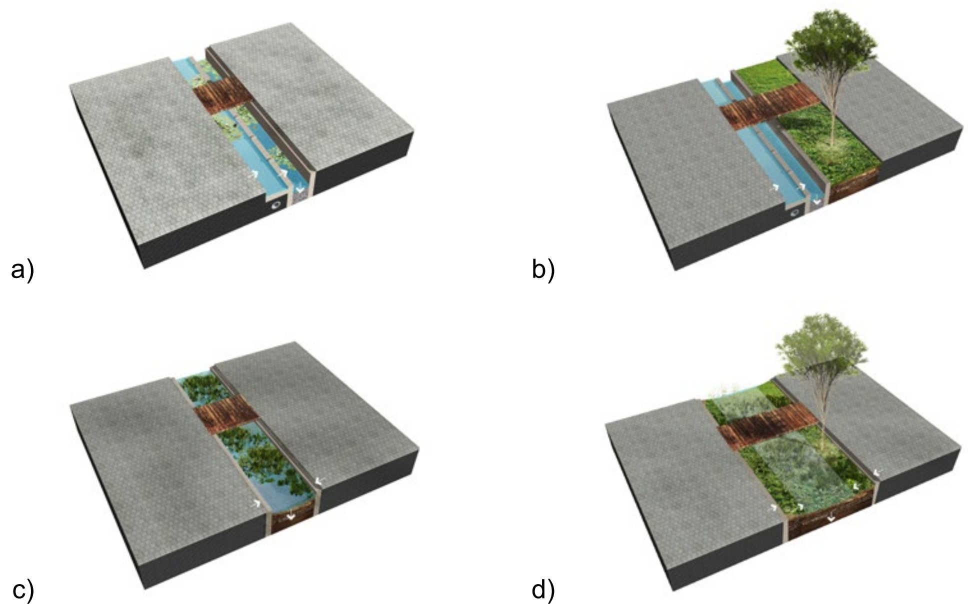


FIGURE 33 // Different types of bioswales: type urban (a), type semi-urban (b), type eco-urban (c), type ecological (d)

MOBILITY

In this section we looked at mobility trends analyzed by different authorities (Arnhem.notudoc.nl, 2016; Geo1.arnhem.nl, 2016; Pickup et al., 2015). A large mobility transition scheme can be found in Appendix II.

In our vision, two characteristics, electric cars (e-cars) and car sharing, will shape the future of the mobility in Spijkerkwartier in order to address these focal points. Our idea is to implement principles such as comfort (self-driving cars that pick you up at your house), central parking, implement e-cars and share cars in our new mobility plan.

1. E-CARS

E-cars have many advantages, especially for urban areas like Spijkerkwartier (Holland et al., 2015; Holms et al., 2010). First of all, they do not pollute, thus reduce CO2 emissions, and therefore, the air quality improves significantly, which has valuable health benefits (Kimnet.nl, 2016). Another benefit is the reduction of noises, which improves the living quality significantly.
We live in a time where private ownership world is still the norm(Kimnet.nl, 2016), but preferences of the young generation are changing towards public transport, cycling and car sharing (Raivereniging.nl, 2016).

The amount of purchased e-cars is rapidly increasing and is promoted by the Dutch government. The Dutch government is supporting the purchase of e-cars with tax incentives and has set a target of 1 Mio. Electric vehicles in 2025 (NU, 2016). The government is even planning to ban the purchase of petrol and diesel cars from 2025 (Nos.nl, 2016). Furthermore, through the increase of purchased e-cars, a more dense loading infrastructure and longer lasting batteries, will enhance purchases of those (Nykvist, & Nilsson, 2015).

2. CAR SHARING

The second feature is car-sharing. There are many forms of car sharing, which allow a more efficient use of cars (Kimnet.nl, 2016). Especially, a decrease in need for parking space is promising for Spijkerkwartier, because these areas can be used in another way, e.g. for bioswales and other vegetation that will provide a better living environment.

3. PARKING

Another new feature are self-driving cars, which are likely to become more popular in the next years (mijnspijkerkwartier.nl, 2016; Tesla.com, 2016). With that technology it is not necessary to park your car in front of your house, as the car is self-driving and could park somewhere else, e.g. in a central placed parking hub. In figure 35 an example of such parking lot is shown. Due to the fact we want an efficient hub with a smaller footprint, a multi layered hub is necessary which provides more space for greenery around the neighbourhood. The parking structures need to be designed as flexible structures that can transitions as parking needs can de- or incline in the future (Macht, 2016). The facades should be green in order to tackle the UHI and the roof should be filled with PV solar panels. Research has shown that people want to walk up to 120 meters for parking (Smith & Butcher, 2008). By making a map (figure 34), using a radius of 60 meter to be on the safe side, it shows we can cover whole Spijkerkwartier with these nine hubs on mostly current parking places which are mostly paved.

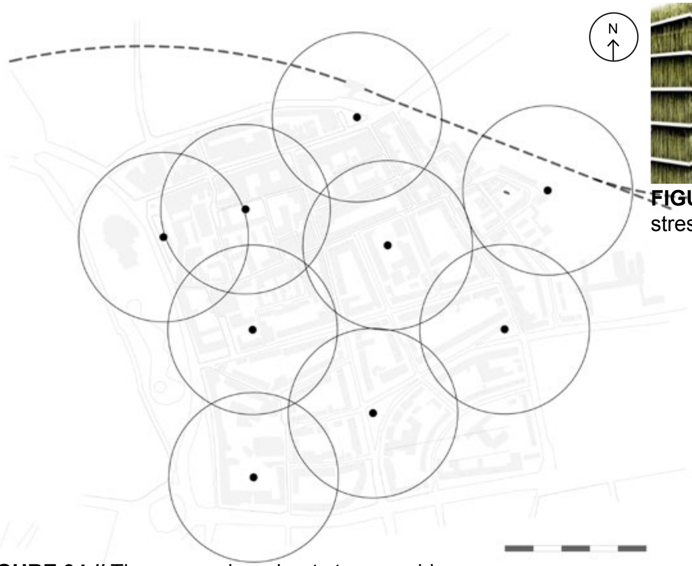


FIGURE 34 // The areas where heat stress problems can occur

FIGURE 35 // The areas where heat stress problems can occur

CONCLUSION

1. ENERGY GENERATION

With this energy calculations we want to quantify the amount of energy we can produce with our interventions to investigate if Spijkerkwartier can be energy neutral. The whole calculation can be found in Appendix III. We first calculate the total consumption in the district and then total energy production per intervention.
Table 02 shows us the final numbers we are using for our energy demand (more information in Appendix III).

INTERVENTIONS

Renewable electricity generation using solar photovoltaic technologies plays an important role in our efforts of energy neutrality, because photovoltaic and solar thermal energy are proven to have the highest potential for urban integration. Wind energy provides minor potential in an urban fabric due to the small wind speeds and biomass production covers too much space, so we solely focused on solar energy (Eicker, 2012).
In order to be self-sufficient we have to be rigorous, so every space on top of the houses that is suitable for solar, PV and thermal, panels should be used.
Assuming the 2050 energy figures, we can state that only 18,8% of the energy demand can be covered by using the current solar technology on all current available roof surfaces in Spijkerkwartier.
Our main intervention is the courtyard covering, which would provide more than enough solar energy to be self-sufficient on a yearly basis. Nevertheless, solar panels are 25% less effective during wintertime so the dwellings still need access to electricity either from the net or from storages. Our second largest energy providing intervention are the parking lots, which can also provide a substantial amount of electricity. Our final intervention is the roof covering at Steenstraat. In terms of power production it has not a great impact, but can have an impact on the great amount of people passing by. It can convince people to switch to solar power by making them more aware of the energy production (renewableenergyworld.com, 2016). The total amount can be found in table ??. With our interventions we can cover 36,7% of the total energy demand in 2050.

PREDICTED ENERGY USE FOR SPIJKERKWARTIER IN 2050

		BUSINESS (kWh/year)	HOUSING (kWh/year)	TOTAL (kWh/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/year)	HOUSING (kWh/year)	TOTAL (kWh/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

TABLE 02 // Total amount of energy consumption in 2016 and a prediction for 2050

THERMAL SOLAR PANELS ON EXISTING ROOFS	2.880.000
PV SOLAR PANELS ON EXISTING ROOFS	6.700.000
COURTYARD PV SOLAR PANELS	6.790.000
PARKING LOT PV SOLAR PANELS	2.200.000
STEENSTRAAT PV SOLAR PANELS	100.900
TOTAL PRODUCTION	**18.670.900 kWh/year**

TABLE 03 // Total amount of energy generation by our interventions, see Appendix III for the calculations

2. HEAT STRESS REDUCTION

In this section we analyse the heat stress reduction potential of our design. We did this for the street facade in Steenstraat and the courtyard covers and will be explained in the next sections.

STREET FACADE IN STEENSTRAAT

Steenstraat is exposed particularly to heat stress, because there are a few trees and the street has a low height/width ratio. Therefore, the sun can heat up the building environment and long wave radiation is trapped in the night.We chose two different interventions to reduce the heat stress: a partial street covering and more avenue trees. For this purpose, we divided Steenstraat into three areas. In the blue areas we implement a partial street covering (area 1 and 3). In the red area (area 2), we plant more trees to preserve the historical facades (figure 36).

To quantify the urban heat stress in Spijkerkwartier the mean radiant temperature was calculated with the software "Rayman". Thereby, the Physiologically Equivalent Temperature (PET) was calculated which helps to express the thermal comfort. We chose an exemplary summer day with a temperature of 30 degrees, a relative humidity (RH) of 40%, wind speed of 2m/s and a 2/8 cloud cover at 15:00. The input values (RH, wind speed, cloud cover) are the averaged values of the days with more than 30 degrees at day between 2011-2016 at the KNMI station Deelen (to the north of Arnhem). The same input data is used to calculate the PET in a night (24:00) with a temperature of 20 degrees. The wind is reduced about 40% after the use of the wind adjustment factor (WAF) calculation (Molenaar et al., 2016).

The design includes several interventions which can cool down the air temperature in the street canyon. In area 1 the following interventions reduces the air temperature about approximately 2.5K at daytime and 2K at nighttime:

- the bioswale contributes to the cooling effect with approximately 1.7K during daytime and 1.1K during nighttime (Hyunjung et al., 2016)
- the increase in pavement reflectivity and improved permeability of the pavement reduces the temperature around 0.6K (Santamouris, 2013; Pomerantz et al., 2016)

FIGURE 36 // Schematic outcome of the Steenstraat in top view

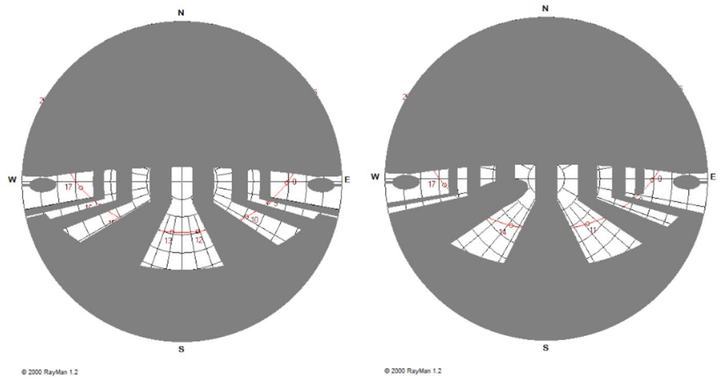


FIGURE 37 // Sky view factor Steenstraat, left: between two panels, right: underneath a panel

- solar panels contributes to the reduction with approximately 0.2K at day and 0.3K at night (Masson et al., 2014).

Furthermore, the change in sky view factor (between 0.13 and 0.15) was included in the calculation (figure 37).

During daytime our design is lowering the PET up to 5.5K (figure 38), during night time up to 2.9K (figure 39).
In area 2, we want to preserve the facades, so we chose to plant trees instead of implementing a partial street cover. Following interventions reduces the air temperature around 3.3K at day and 2.8K at night :

- the trees have a cooling effect up to 1.6K at day and 0.5K at night (Hyunjung et al., 2016).
- the bioswale contributes to the cooling effect with approximately 1.7K during daytime and 1.1K during nighttime (after Hyunjung et al., 2016)
- the increase in pavement reflectivity and improved permeability of the pavement reduces the temperature around 0.6K (after Santamouris, 2013; Pomerantz et al., 2016)

In figures 40 and 41, we can see that the avenue trees can reduce the PET up to 4.4K at day and up to 2.3K at night.

COURTYARD COVER

In the following, we analyse the thermal comfort in the outside part of the courtyards, of which the results can be seen in figures 42 and 43. The improvement in thermal comfort is due to the increased fraction of vegetation, the implementation of advanced pavements and improvement on shading.
The public courtyard offers a larger heat stress reduction potential, because the shape of the cover can be adjusted according to the incoming solar radiation. Furthermore, formerly paved surface, e.g. parking lots can be transformed into green spaces and high-albedo pavements can be changed into low-albedo pavements.

With these measures the design can already reduce the air temperature around 1.3K at day and 1.4K at night (the effect of the solar panels included).

In the public-closed and private-closed courtyards there is already a lot of vegetation, so there is no need to add more. Only the solar panels on the courtyard cover (only 0.2K reduction during day and 0.3K at night) and the change in sky view factor are decreasing the PET about approximately 0.4K at day and 0.2K at night.

In table 04 all interventions and its effect on PET are shown. Our design can significantly reduce the PET between 0.4-5.5 degrees during daytime and 0.2-2.9 degrees during night time. Therefore the heat stress will also decrease significantly. This is important as temperatures are increasing in the future and hot days are going the be more frequent (KNMI, 2014).

	DAY			NIGHT		
	T	MRT	PET	T	MRT	PET
STEENSTRAAT (COVERING)	2.5	7.9	5.5	2.0	1.0	2.9
STEENSTRAAT (AVENUE TREES)	3.3	3.9	4.4	2.8	0.8	2.3
CLOSED COURTYARDS	0.2	0.7	0.4	0.3	-0.1	0.2
OPEN COURTYARD (PUBLIC)	2.5	2.9	3.3	2.0	0.8	1.6

TABLE 04 // Summary of the changes in air temperature, in mean radiant temperature and in PET (all in degrees Celsius)

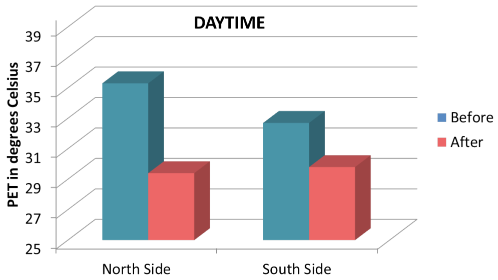


FIGURE 38 // Changes PET before and after intervention, daytime under trees

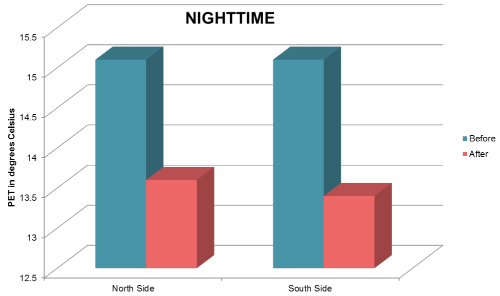


FIGURE 39 // Changes PET before and after intervention, nighttime under trees

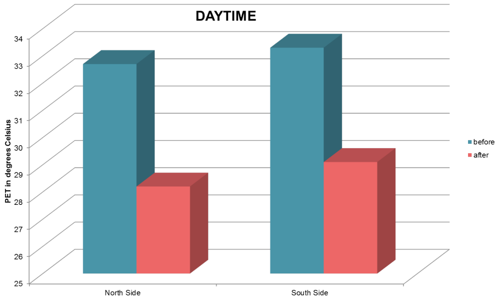


FIGURE 40 // Changes PET before and after intervention, daytime under covering

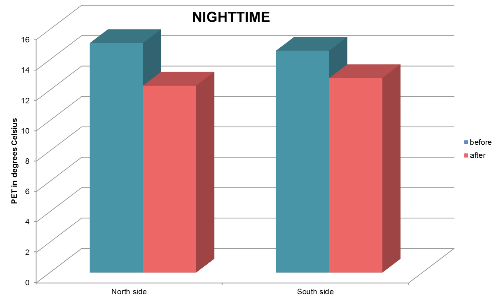


FIGURE 41 // Changes PET before and after intervention, nighttime under covering

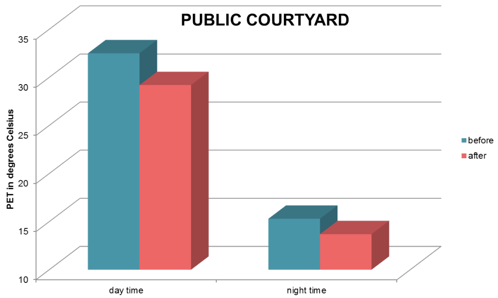


FIGURE 42 // Changes PET before and after intervention, public courtyard

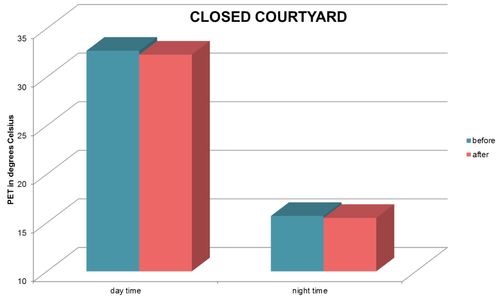


FIGURE 43 // Changes PET before and after intervention, closed courtyard

3. MATRIX FOR EACH INTERVENTION

COURTYARD COVER

The courtyard intervention can generate enough energy to make the whole courtyard self-sufficient in energy. It also provides an extra layer of insulation for the buildings and this will help to save energy. The thermal comfort this intervention provides will differ. It can be less than one degrees when it is opened, but when the system is closed it will stay around twenty-eight degrees and can therefore provide a significant difference with the outside temperature.

The materials of the intervention can be sustainable, but it is depending on how it is manufactured and the locations where it is from. There will be regular maintenance on the intervention itself, because the glass needs to be cleaned to have enough sunlight entering the courtyard. On the other side, the outside wall of the buildings where the intervention is located needs less maintenance, because the weather has less effect on them.

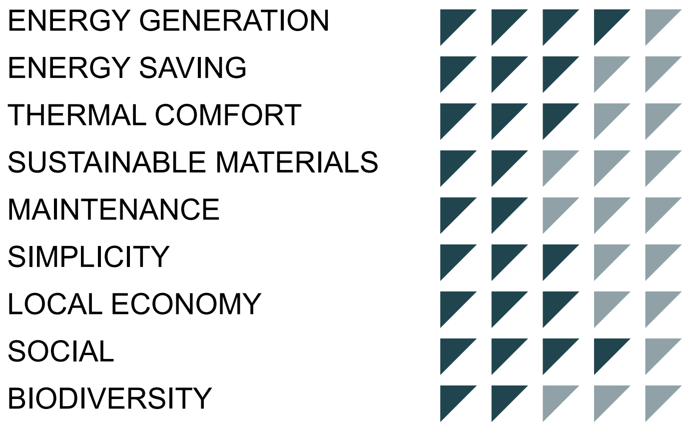


FIGURE 44 // Matrix for the courtyard cover intervention

The construction of the cover is simple, because it is the same as from a greenhouse. The techniques around the cover (solar panels, flexible roof and walls and a heat-cold storage) are more complex.
The space underneath the covers can be used for urban farming and the climber plants can also provide food. This will foster the local economy. It also provides space for people to meet and work together and therefore has quite an effect on the social welfare. It will have less effect on the biodiversity in the neighborhood, because this depends on what kind of vegetation will be placed in the different courtyards and the courtyards cannot be easily entered by species.

In total the courtyard generates enough energy to be self-sufficient, it helps to save energy and has extra benefits for the social welfare and local economy.

STEENSTRAAT COVER

The street facade will not generate enough energy to make the neighborhood self-sufficient and it also has less effect on saving energy. Mainly because the construction will be open.
The thermal comfort underneath the facade will increase, because it provides shade and cooling by the climber plants.
The materials of the intervention can be sustainable, but this is depending on how it is manufactured and the locations where it is from. There will be regular maintenance on the intervention itself, because the glass needs to be cleaned to have enough sunlight entering the courtyard. Also the climber plants on the construction need to be maintained regularly. The outside wall of the buildings where the intervention is located needs less maintenance, because the weather has less effect on them.
The construction is the same as that of a greenhouse and therefore easily to construct, but the flexible walls and roof are more complex. Therefore the simplicity of the construction is average.
The climber plants can give fruit and the walls can create work for local artists. This will somewhat foster the local economy.
The social welfare is increasing a little, because people can have influence on the the type of art within the structure and picking fruits. The green on the facades are only around the construction and will increase the biodiversity within the Steenstraat, but it is not enough to increase it significantly.

In total the street facade do not completely comply with all the principles but it will create an entrance for the neighborhood and the courtyard covers.

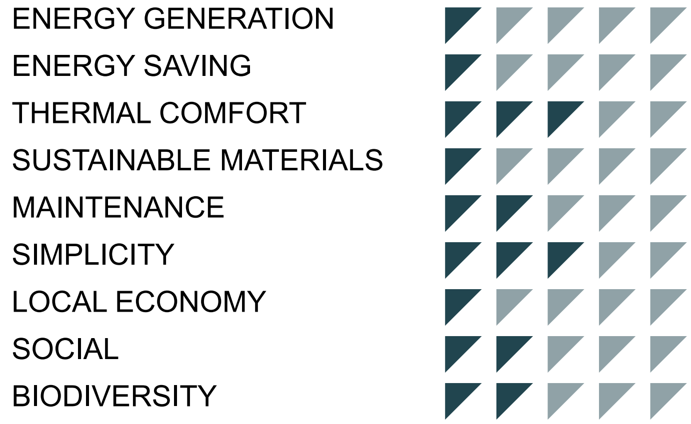


FIGURE 45 // Matrix for the Steenstraat cover intervention

BIOSWALE

The bioswale will not generate energy. It can provide material for generating energy from biomass, but this is neglectable. The bioswale is located on the ground floor and therefore it has no effect on insulating and saving energy for the buildings. It does have an effect on the thermal comfort by cooling the air by evapotranspiration.
The materials are sustainable when the ecological type is implemented. It depends on the materials that will be used with the urban types if these types are also sustainable.
The vegetation within the bioswales need to be maintained, especially during summer.
The construction of the bioswale differ from the type, but they are all simple to create.
The bioswale will not foster the local economy, but it has an effect on the social welfare.
It creates a greener environment and this increases the health of the inhabitants.

The bioswale will increases the biodiversity in the whole neighborhood, because different types of vegetation are located in this intervention and it is connected through the whole neighborhood.

In total the bioswale has no influence on energy generation of saving, but it contains of sustainable materials, increases the biodiversity and increases the social welfare of the inhabitants.

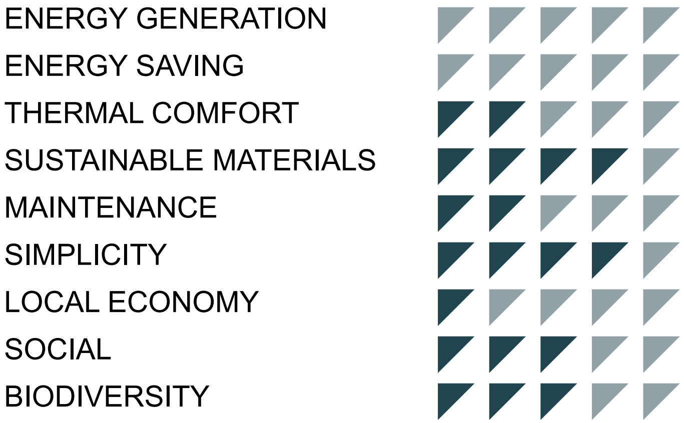


FIGURE 45 // Matrix for the bioswale intervention

DISCUSSION

Climate change adaption and mitigation has received a lot of attention in the last decades. In this studio we were focusing on how to reduce negative impacts of climate change and use the potential of natural energy sources. Furthermore, our design is addressing negative urban climate impacts. One major difficulty hereby remains the climate variability and the underlying high uncertainties. Working with scenarios always bears high uncertainties. The PET calculations in Rayman are only conducted for single points and extrapolation always bears many risks.

After identifying heat stress as one of the most serious problems, we did a major investigation on possibilities for urban heat island reduction. Nevertheless, we have to mention that some of our interventions are trade-offs, e.g. open space is often perceived to be pleasant and also helps to improve the feeling of safety, but also suffers most under heat stress.

Furthermore, we want to make clear that all our calculations are based on assumptions, so they are rather approximations. We only took existing technologies into account, but we are sure that there will be new, more efficient technologies in the future.

A big challenge remains the energy generation in winter, because our calculations are only valid for the average annual energy generation. Especially in winter, solar energy alone is not sufficient and other technologies have to be implemented. Moreover, energy storage possibilities, like hot and cold storages or the use of e-cars as large batteries have to be explored further.

As planners and designers we know about the challenges of implementing projects. Many projects require not only the approval of the inhabitants, but also active participation. Such projects, e.g. the arts project related to our street covering in Steenstraat, can be chances and challenges at the same time. A neighbourhood such as Spijkerkwartier is highly complex, that is why many interventions have to be tailor-made.

A major task for the future is the reduction of the energy demand of the business sector, which has the highest share of the energy consumption. Our interventions were not able to cover such a high-energy demand. Furthermore, the increase in use of e-cars also requires larger energy generation.

For future projects, followings aspects should be taken into account: the air quality in Spijkerkwartier and the possibilities of generating energy to enhance the use of e-cars.

RECOMMENDATIONS

In this chapter recommendations will be given for each inhabitant of the Spijkerkwartier, the Spijkerkwartier as a whole and the city of Arnhem. This will improve the transition of the Spijkerkwartier towards a neighbourhood that is mitigating and adapting to climate change, as well as enhancing the use of renewable energy sources. In figure 46 the approach to implement this project is shown and the recommendations are based on this.

The recommendations for the individual residents of Spijkerkwartier are mainly focusing on one household. The recommendations are:

INSULATE YOUR HOUSE

With insulation you decrease the amount of energy you need to cool and heat the building. This will save you money and the amount of energy you need to generate to be self-sufficient for energy.

SOLAR PANELS ON ROOF

With solar panels on the roof there is the possibility to generate your own energy and therefore you need less electricity from the net. This decreases the demand for electricity of the net and the need for fossil fuels to generate this electricity.

USE OF SHARING AND/OR E-CARS

It is possible to take the bicycle or public transport when you need to be in Arnhem or close surroundings. There is the possibility to share cars with people from the neighborhood to use the car efficiently. The cars themselves need to change into e-cars to decrease the need for fossil fuels.

The recommendations for individual residents can be scaled up for the whole Spijkerkwartier with the proposed design. Important is to start with pilot projects to test and adjust the interventions and gain support of the whole neighborhood.
The recommendations for the three interventions for Spijkerkwartier are:

PILOT BIOSWALE NETWORK

In figure 46 it is shown that starting to create the bioswale network can be done as soon as possible. Start with a pilot project in one street that support the intervention and test it and use it to gain support from the other residents in Spijkerkwartier. In the end it is possible to have the whole bioswale network in the coming years.

IMPLEMENT STREET COVER IN STEENSTRAAT

Figure 46 shows that this intervention will take a few years before it will be build. It is necessary to first gain support by the municipality of Arnhem, the local companies and residents of the Steenstraat. This can be done by involving them in a further design of this intervention and showing the possibilities for them to use the intervention as a way to promote their companies, work or their street/neighborhood. It can act as a landmark for Spijkerkwartier.

PILOT COURTYARD COVER

It can be seen in figure 46 that starting the creation of the courtyard cover cannot be done as soon as possible. First there needs to be a courtyard allocated for the intervention. This can be done by finding people who support the intervention and/or people who wants to have a special courtyard, like the ecological garden or water garden. The pilot for this intervention can be promoted as an energy garden and can be further designed together with the residents of the allocated courtyard. After the pilot study adjustments can be made in the design and will be further expand to other courtyards in the neighborhood.

INTEGRATION OF COMPANIES

A company uses more energy than one household and therefore it is important to also look at the integration of companies within the interventions. Energy generated by solar panels on the interventions and houses can be partly used by companies to decrease their demand of energy from the net. For some companies heat can be used for the heat and cold storage of the courtyard cover, heating up the courtyard cover and/or households in winter.

The recommendations for the municipality of Arnhem are supporting the interventions for Spijkerkwartier. They are:

TURN OVER TO SHARING CARS, USE OF ELECTRIC CARS, CAR-HUBS AND A SELF-DRIVING CAR SYSTEM

Arnhem can support and facilitate the transition towards e-cars, sharing and a self driving car system with parking on central locations in Arnhem. Spijkerkwartier can be the neighborhood to test this pilot project and Arnhem can promote and provide the structure for this project. In the end whole Arnhem can have this system and be the first city that changed all the streets mainly for people instead of cars.

ENERGY NETWORK

Arnhem can give support, for example in the form of subsidies, for insulating the buildings in Spijkerkwartier and changing old heaters in buildings to modern and less energy demanding heaters. This will decrease the energy demand and therefore better energy labels for the neighborhood.

BIOSWALE NETWORK EXPANSION

Arnhem need to expand the bioswale network in Spijkerkwartier over the whole municipality. This will help to minimize flooding during and after peak rain falls in Spijkerkwartier and in the rest of Arnhem. In the near future the intensity of rainfall will increase and with more locations through the city that can store and infiltrate water the pressure on Spijkerkwartier will not increase. Therefore, the bioswale interventions in Spijkerkwartier will reduce the effect of floodings.
The recommendation for Alliander is supporting the energy system behind the proposed design:

DIFFERENT ELECTRICITY SYSTEM OF ENERGY GENERATION AND STORAGE

Alliander can create and maintain the energy system of the solar panels on the roofs and interventions and the storage (and extraction of) of electricity in the batteries of the (self-driving) e-cars. They can provide a system that is flexible to the needs of the users and deliverers.

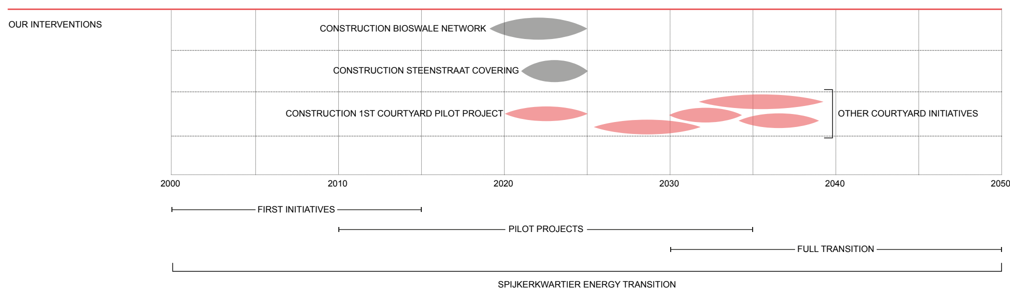


FIGURE 46 // Recommendations for the future Spijkerkwartier

REFERENCES

Arnhem.notudoc.nl. (2016). Agenda voor de Politieke Maandag van 28 februari 2011. [online] Available at: http://arnhem.notudoc.nl/cgi-bin/agenda.cgi/action=punt/id=54449 [Accessed 22 Dec. 2016].

Beek, van de A. & Haar, ter H. (2009) Bouwen met groen en glas. Innovaties uit de glastuinbouw voor wonen en werken. 1st ed. Boxtel: Æneas, p. 1361

Bewonersvereniging EVA-Lanxmeer (2016) Kaswoningen [Online]. http://www.eva-lanxmeer.nl/over/nu/woningbouwprojecten/kaswoningen [Accessed 22nd of December 2016]

Bingmaps (2016). [online] https://www.bing.com/maps/ [Accessed 22nd of December 2016].

BV, I. (2016). hellingshoek zonnepanelen. [online] Dezonnepaneelexpert.nl. Available at: http://www.dezonnepaneelexpert.nl/informatie-zonnecel-informatie-zonnepaneel-informatie-zonne/hellingshoek-zonnepanelen/ [Accessed 22 Dec. 2016].

CBSinuwbuurt (2015). Aantal inwoners – buurten [Online]. http://www.cbsinuwbuurt.nl/#buurten2015_aantal_inwoners. [Accessed 22nd of December 2016].

de Groot, J. (2016). UW OPBRENGSTSCAN ZONNEPANELEN. 1st ed. [ebook] ede: zonnepanelen.net. Available at: https://www.zonnepanelen.net/wp-content/uploads/2013/12/VOORBEELD_OPBRENGST_SCAN.pdf [Accessed 22 Dec. 2016].

Derek Mitchell, S. (2016). Sunpower SPR-305-WHT-U (305W) Solar Panel. [online] Solardesigntool.com. Available at: http://www.solardesigntool.com/components/module-panel-solar/Sunpower/514/SPR-305-WHT-U/specification-data-sheet.html [Accessed 22 Dec. 2016].

Devabhaktuni, V., Alam, M., Depuru, S. S. S. R., Green, R. C., Nims, D., & Near, C. (2013). Solar energy: Trends and enabling technologies. Renewable and Sustainable Energy Reviews, 19, 555-564.

Droege, P. (2002). ‘’Renewable energy and the city: urban life in an age of fossil fuel depletion and climate change’’ Bulletin of Science, Technology and Society 22, 87-99.

Droege, P. (2006). The Renewable City, A Comprehensive Guide to an Urban Revolution, Great Britain: Wiley-Academy.

Ecology Action Centre (2009). Energy Issues Committee [Online]. https://ecologyaction.ca/electricity-and-greenhouse-gas-emissions-tracking. [Accessed 21st of December 2016].

Eicker, U. (2012, May). Renewable Energy Sources Within Urban Areas–Results From European Case Studies. In Chicago Winter Conference.

Energieconsultant.nl. (2016). Omrekening van m3 (n) naar kWh - Onafhankelijk Energieadvies - De Energieconsultant. [online] Available at: http://www.energieconsultant.nl/energiemarkt/energie-berekeningen-uit-de-praktijk/omrekening-van-m3-n-naar-kwh/ [Accessed 22 Dec. 2016].

Geo1.arnhem.nl. (2016). geo1.arnhem.nl - /ruimtelijkeplannen/plannen/NL.IMRO.0202.STV794-/NL.IMRO.0202.STV794-0201/. [online] Available at: http://geo1.arnhem.nl/ruimtelijkeplannen/plannen/NL.IMRO.0202.STV794-/NL.IMRO.0202.STV794-0201/ [Accessed 22 Dec. 2016].

Harms, L. W. J. (2011). Blik op de personenmobiliteit. Kennisinstituut voor Mobiliteitsbeleid.

Holland, S. P., Mansur, E. T., Muller, N. Z., & Yates, A. J. (2015). Environmental benefits from driving electric vehicles? (No. w21291). National Bureau of Economic Research.

Holms, A., & Argueta, R. (2010). A Technical Research Report: The Electric Vehicle.

Hyunjung Lee, Helmut Mayer, Liang Chen, Contribution of trees and grasslands to the mitigation of human heat stress in a residential district of Freiburg, Southwest Germany, Landscape and Urban Planning, Volume 148, April 2016, Pages 37-50, ISSN 0169-2046, http://dx.doi.org/10.1016/j.landurbplan.2015.12.004.

Keverling Buisman, F. (2009). Arnhem van 1700 tot 1900. Utrecht, The Netherlands, Matrijs.

Kimnet.nl. (2016). Mijn auto, jouw auto, onze auto. [online] Available at: https://www.kimnet.nl/actueel/nieuws/2015/12/8/mijn-auto-jouw-auto-onze-auto [Accessed 22 Dec. 2016].

Kin, S., Quanjel, E., Harsta, A., Wolters, L., Haar, ter H. (2011) Renoveren met groen en glas. Brochure woonwijken als bron van vitaliteit en energie

KNMI (2014): KNMI’14: Climate Change scenarios for the 21st Century – A Netherlands perspective by Bart van den Hurk, Peter Siegmund, Albert Klein Tank (Eds), Jisk Attema, Alexander Bakker, Jules Beersma, Janette Bessembinder, Reinout Boers, Theo Brandsma, Henk van den Brink, Sybren Drijfhout, Henk Eskes, Rein Haarsma, Wilco Hazeleger, Rudmer Jilderda, Caroline Katsman, Geert Lenderink, Jessica Loriaux, Erik van Meijgaard, Twan van Noije, Geert Jan van Oldenborgh, Frank Selten, Pier Siebesma, Andreas Sterl, Hylke de Vries, Michiel van Weele, Renske de Winter and Gerd Jan van Zadelhoff. Scientific Report WR2014-01, KNMI, De Bilt, The Netherlands. www.climatescenarios.nl

Kruydenberg, M. (2008). De toekomst van parkeren. 1st ed. Den Haag: P1.

Lenzholzer, S. (2015). Weather in the city: how design shapes the urban climate. Rotterdam, The Netherlands: nai010 publishers.

M. Santamouris, Using cool pavements as a mitigation strategy to fight urban heat island—A review of the actual developments, Renewable and Sustainable Energy Reviews, Volume 26, October 2013, Pages 224-240, ISSN 1364-0321, http://dx.doi.org/10.1016/j.rser.2013.05.047.

Macht, W. (2016). Flexible Parking Structures as Civic Catalysts - Urban Land Magazine. [online] Urban Land Magazine. Available at: http://urbanland.uli.org/infrastructure-transit/flexible-parking-structures-civic-catalysts/ [Accessed 22 Dec. 2016].

MacKay, D. J. C. (2009). Sustainable energy--without the hot air. Cambridge, England: UIT.

Masson Valéry, Bonhomme Marion, Salagnac Jean-Luc, Briottet Xavier, Lemonsu Aude (2014), Solar panels reduce both global warming and urban heat island. Frontiers in Environmental Science, Volume 2, DOI=10.3389/fenvs.2014.00014

Masson, V., Bonhomme, M., Salagnac, J. L., Briottet, X., & Lemonsu, A. (2014). Solar panels reduce both global warming and urban heat island. Frontiers in Environmental Science, 2, 14.

mijnspijkerkwartier.nl. (2016). Feestelijke opening zonne energie dak de Lommerd. [online] Available at: https://www.mijnspijkerkwartier.nl/groep/spijkerenergie/bericht/feestelijke-opening-zonne-energie-dak-de-lommerd [Accessed 22 Dec. 2016].

mijnspijkerkwartier.nl. (2016). mijnspijkerkwartier.nl. [online] Available at: https://www.mijnspijkerkwartier.nl/buurtverbetering/id=112 [Accessed 22 Dec. 2016].

Molenaar, R. E., Heusinkveld, B. G. and Steeneveld, G. J. (2016), Projection of rural and urban human thermal comfort in The Netherlands for 2050. Int. J. Climatol., 36: 1708–1723. doi:10.1002/joc.4453

Momo (2009). Autodelen factsheets

Nijland, H., Meerkerk, J. van & A. Hoen (2015). Effecten van autodelen op mobiliteit en CO2-uitstoot. Den Haag:

Nos.nl. (2016). Tweede Kamer: vanaf 2025 alleen nog duurzame auto's. [online] Available at: http://nos.nl/artikel/2095952-tweede-kamer-vanaf-2025-alleen-nog-duurzame-auto-s.html [Accessed 22 Dec. 2016].

NU. (2016). 'Miljoen elektrische auto's in 2020'. [online] Available at: http://www.nu.nl/auto/1941207/miljoen-elektrische-autos-in-2020.html [Accessed 22 Dec. 2016].

Nykvist, B., & Nilsson, M. (2015). Rapidly falling costs of battery packs for electric vehicles. Nature Climate Change, 5(4), 329-332.

PICKUP, L with BIOSCA, O, FRANCKX, L, KONINGS, H, MAYERES, I, PLAUT, P, SHACH- PINSLY, D, UNAL, B, VAN DIST, S and M, VAN HULSEL (2015). MIND-SETS: A new vision on European mobility. Deliverable 2.1A of the MIND-SETS project. European Commission Directorate General for Research, Covent Garden, Brussels.

Pidwirny, M. (2006). Earth-Sun Relationships and Insolation. Fundamentals of Physical Geography, 2nd Edition [online]. http://www.physicalgeography.net/fundamentals/6i.html. [Accessed 21st of December 2016].

Pinterest (2016) Explore Building Wur, Lumen Building, and more! https://www.pinterest.com/pin/502503270895095629/ [Accessed 22nd of December 2016]

Pomerantz, M., Pon, B., Akbari, H., & Chang, S. C. (2000). The effects of pavements' temperatures on air temperatures in large cities.

Raivereniging.nl. (2016). Trends in Mobiliteit in 2030 | RAI Vereniging. [online] Available at: https://www.raivereniging.nl/artikel/trends-in-mobiliteit-in-2030.html [Accessed 22 Dec. 2016].

renewableenergyworld.com. (2016). What's the most effective way to convince people to switch to solar power. [online] Available at: http://www.renewableenergyworld.com/topics/m/video/53489573/what-s-the-most-effective-way-to-convince-people-to-switch-to-solar-power.htm [Accessed 22 Dec. 2016].

Roadmap 2050, (2011). Power Perspectives 2030, On the road to a decarbonized power sector, European Climate Foundation (ECF).

Royal Netherlands Meteorological Institute (2015). KNMI ’14 Climate scenarios for the Netherlands.

Sijmons, D., Hugtenburg, J., Hoorn, A. van, & Feddes, F. (2014). Landscape and energy: designing transition. Rotterdam: Nai010 Publishers.

Slideshare.net. (2016). Booosting Building Integrated PV JW Tolkamp, Scheuten, 1 april 2010. [online] Available at: http://www.slideshare.net/booosting/booosting-building-integrated-pv-jw-tolkamp-scheuten-1-april-2010 [Accessed 22 Dec. 2016].

Smith, M. and Butcher, T. (2008). How Far Should Parkers Have to Walk?. 1st ed. National Parking Association.

spijkerkwartier.net (2016). 1st ed. [ebook] Arnhem: spijkerkwartier.net. Available at: http://www.spijkerkwartier.net/actueel/ParkerenWaarJeWezenMoet.pdf [Accessed 22 Dec. 2016].

Stocker, T. (2014). Climate change 2013: the physical science basis: Working Group I contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom: Cambridge University Press.

Stremke, S., Dobbelsteen van den, A., Koh, J. (2011). Exergy landscapes: exploration of second-law thinking towards sustainable landscape design. Int.J. Exergy 8-2.

Strong, M.F. (1992). ‘Energy, environment and development’, Energy Policy, Vol. 20, pp.490–494.

Teh, C. (2012). Electricity demand and supply in Peninsular Malaysia: Energy efficiency, renewable energy, or nuclear? [online]. http://www.christopherteh.com/blog/2012/10/electricity-msia-04/. [Accessed 22nd of December 2016].

Tesla.com. (2016). All Tesla Cars Being Produced Now Have Full Self-Driving Hardware. [online] Available at: https://www.tesla.com/blog/all-tesla-cars-being-produced-now-have-full-self-driving-hardware [Accessed 22 Dec. 2016].

TNS NIPO (2014). Monitor Autodelen 2014. Autodelen: wordt de markt volwassen? Amsterdam: TNS NIPO.

van Hout, R., BV, G. N., Tamminga, G., & Bie,(2014) J. Mobiliteit als service: onze visie op de mobiliteit in de komende 40 jaar.

Woonnet Rijmond (2016) Eikenlaand 45-G Spijkenisse [Online]. https://www.woonnetrijnmond.nl/detail/spijkenisse/groenewoud/eikenlaan-45g/100008195 [Accessed 22nd of December 2016]

WORSpijkerkwartier (2016). Visiedocument openbare ruimte, Spijkerbuurt & Boulevardkwartier. Werkgroep Openbare Ruimte Spijkerkwartier.

Zonatlas.nl. (2016). GA NAAR DE ZONATLAS | Zonatlas Arnhem. [online] Available at: http://www.zonatlas.nl/arnhem/ontdek-de-zonatlas/ [Accessed 22 Dec. 2016].

Zonnepanelen-weetjes.nl. (2016). Het rendement van een zonneboiler. [online] Available at: http://www.zonnepanelen-weetjes.nl/zonneboiler/rendement-zonneboiler/ [Accessed 22 Dec. 2016].

APPENDIX I

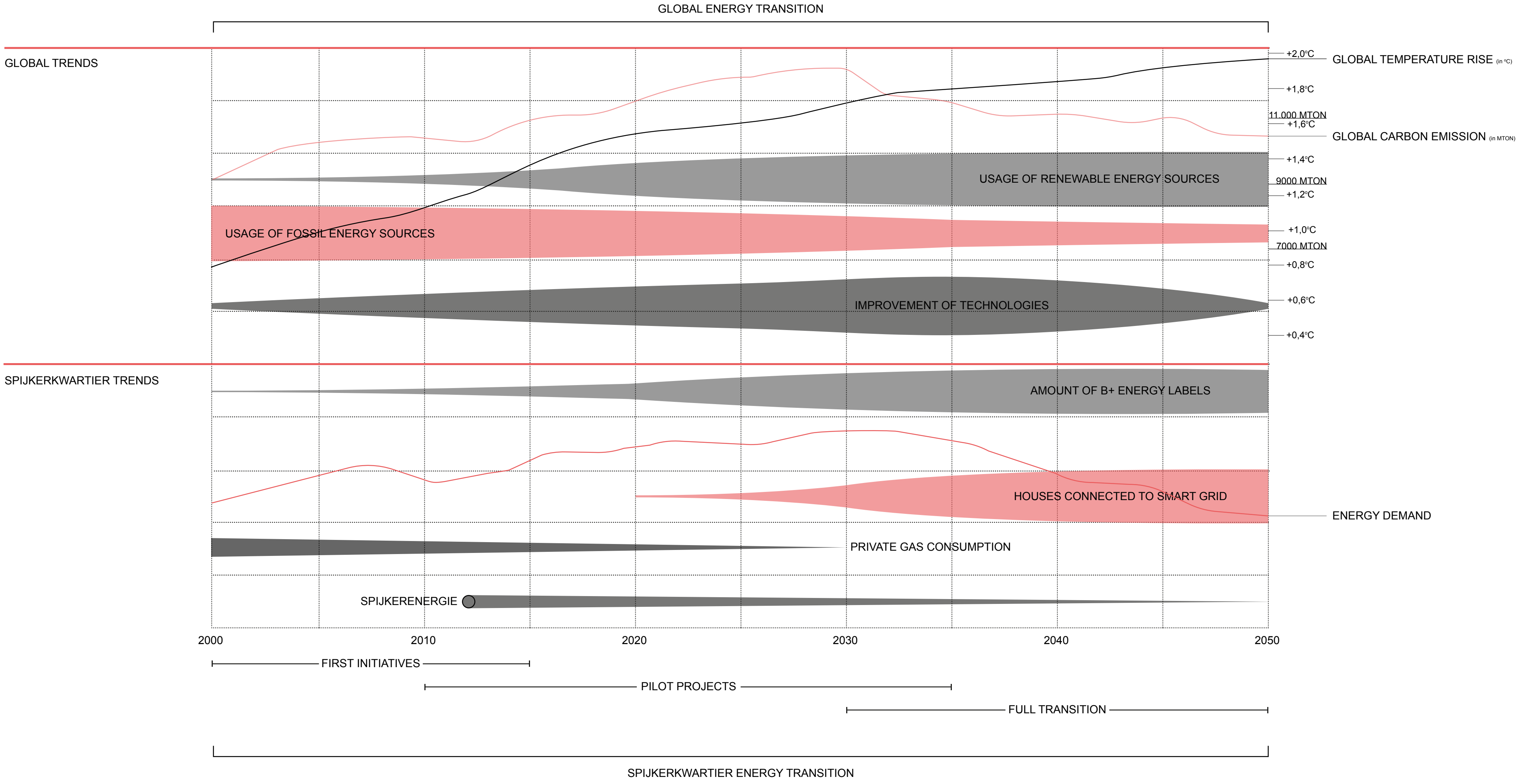


FIGURE 47 // Future trends, globally and in Spijkerkwartier

APPENDIX II

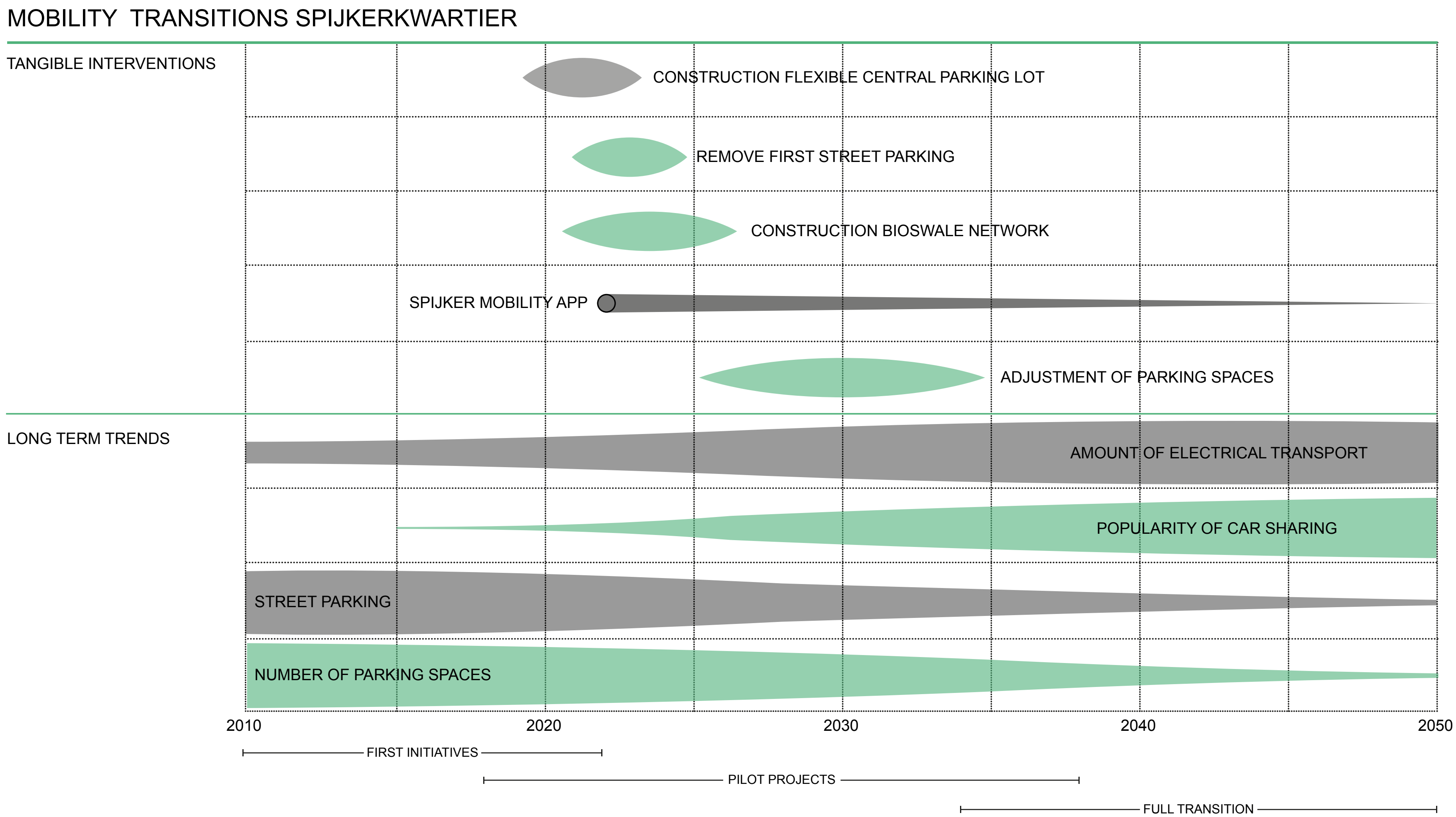


FIGURE 48 // Mobility transitions for Spijkerkwartier

APPENDIX III

1. ENERGY DEMAND IN THE FUTURE

First, we need a calculation of the total demand for energy nowadays and a prediction for the future energy demand. The results show a strong to very strong reduction in the total Dutch primary energy demand. The calculation is based on the IEA ETP 2-degrees scenario. If we look at the primary consumption for low temperature heat, the heat that is used for households and building by burning gas, we see a decline from 790 PJ in 2012 to 530 PJ in 2050 (Warringa, G.E.A. en Rooijers, F.J. 2015). Meaning that by 2050, primary energy demand for low temperature heat has decreased by 33%.This is caused by the fact we use better insulation in the future. In order for Spijkerkwartier to become climate neutral, especially the building rehabilitation needs to be addressed as the average energy label of the houses is an E/D (Warringa, G.E.A. en Rooijers, F.J. 2015). With some simple intervention this could easily be B. Also note that this is primary energy, the fraction of the end use will be smaller, but is hard to predict. That is why we used this number to be on the safe side. Gas m3 is converted into kWh so we can replace it by electricity, think for example of electric heaters instead of natural gas boilers (Energieconsultant.nl, 2016). Electricity use for the neighbourhood will most likely stay the same, the small difference is caused by the shift in energy resources. The total demand is shown in the table below.

PREDICTED ENERGY USE FOR SPIJKERKWARTIER IN 2050

		BUSINESS (kWh/year)	HOUSING (kWh/year)	TOTAL (kWh/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/year)	HOUSING (kWh/year)	TOTAL (kWh/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

TABLE 05 // Total amount of energy consumption in 2016 and a prediction for 2050

2. EXISTING ENERGY PRODUCTION POTENTIAL

In order to calculate the total amount of roof surface in Spijkerkwartier we utilized a tool called Zonatlas (Zonatlas.nl, 2016). This tool shows how much solar photovoltaic potential exists for residential rooftops in the town of Arnhem. Almost every house in Spijkerkwartier is suitable for solar energy and the tool also shows where to place the solar panels. By using AutoCAD we estimated the total amount of roof surface available in Spijkerkwartier by using it as our base map in Photoshop. In Photoshop we can count the amount of pixels which shows the solar radiation and make a square out of the total amount of counted pixels. By measuring the square with our scale bar we can calculate the total surface. This method is quite fast however, this method is not very precise so we estimated a total of ±46900 m2 of available roof surface for solar energy production to be on the safe side.

Now we have to total available space we can use them for solar energy. As we have to consider both thermal and PV solar panels, how much space do they need. As thermal solar panels are more efficient we give them priority. Only 1 m2 of thermal panel per capita is needed (Masson et al., 2014).

A vacuum tube solar collector of 2.5 m2 has a yield of 5.1 GJ per year, which is about 145 m3 or 1400 kWh of natural gas per year (Zonnepanelen-weetjes.nl, 2016).

As Spijkerkwartier has 5149 we make an Hypotheses on the available space for solar panels given by the following calculation:

5149 inhabitants x 1 m2 per capita needed= 5149 m2 thermal solar panels
5149 m2x 1400kWh / 2,5 m2 ≈ 2.880.000 kWh/year saved for heating
46900 m2-5149 m2= 41751 m2 available for PV panels

The capacity of solar panels is expressed in Watt-peak (Wp), regardless of the type of the panels. The energy yield is often read as kilowatt hours (kWh) per year. However, the ratio kWh / kWp is not the same for all modules. The conversion factor from kWp into kWh in Arnhem is 0,86 (de Groot, 2016).

We chose the PV module with one of the best kWp/m2 today; SUNPOWER POWERGUARD® 553 SUNPOWER 305W Panels (Mitchell, 2016). Those panels have 187.0 Wp/m2. This gives us the following estimated production if every suitable house in Spijkerkwartier places solar panels on their roofs.

187 x 0,86= 161 kWh/m2
41751 x 161 ≈ 6.700.000 kWh/year
(6.700.000 + 2.880.000) / 50.937.097,59 x 100% = 18.8%

3. INTERVENTION ENERGY PRODUCTION POTENTIAL

Courtyard

Our vision is to make as many houses in Spijkerkwartier energy neutral. We want to do this by showing the importance of saving by insulation en production by solar energy. For instance the roof of the community center de Lommerd is already equipped with solar panels: 126 panels of 270Wp which deliver approximately 31000kWh annually. The annual consumption of the center is about 30000kWh per year (mijnspijkerkwartier.nl, 2016). By showing it is also possible in their own home we hope the idea will be more tangible. This calculation helps to quantify the magnitude of possible solar photovoltaic (PV) potential in Spijkerkwartier.

For this calculation we used the courtyard Spijkerstraat and Parkstraat shown in figure 49.

FIGURE 49 // Existing solar potential in the public-closed courtyard

This picture also shows us the amount of roof surface we can use for solar panels, we used the same method as before by using Photoshop. Which is roughly 1292 m2. This courtyard consists out of 83 dwellings when we look at the energielabelatlas.nl . Spijkerkwartier has an average of 2,14 residents per house. 83 x2,14≈ 355 residents in this area.

Thermal solar panel use is 355 x 1 m2 ≈ 355 m2
355 m2 x 1400kWh / 2,5 m2 ≈ 198.800kWh/year
1292 m2 - 355 m2 = 937m2 left for PV panels
937x 161 ≈ 150.900 kWh/year total possible current production

The total energy demand in the future for housing in Spijkerkwartier is 14007841,29 kWh. We use this number as our target number. Spijkerkwartier has 2403 houses, our courtyard has 83. Thus we need 14007841,29 kWh / 2403 x 35 = 483.833 kWh in this courtyard.

483.833-150.900-198.800= 134.133 kWh is still needed in order to be self-sufficient.

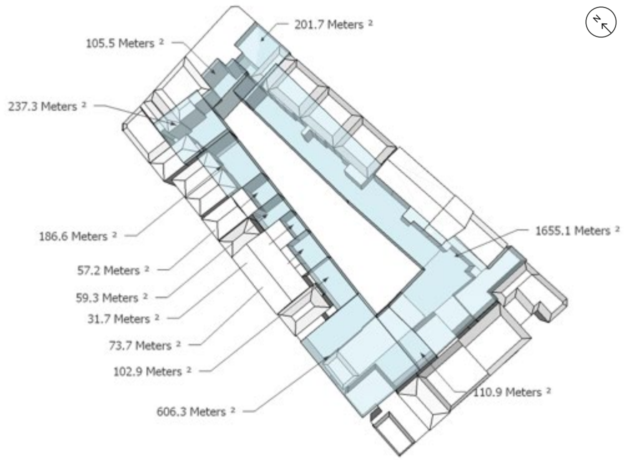


FIGURE 50 // Courtyard covering total surface

Our courtyard has 3428,2 m2 of free space on which we can place PV panels. These panels are however semi-transparent panels, which means they let through 40 to 75% of the light (Slideshare.net, 2016). This makes an average of 42,5 % covered by solar panels. Therefore our courtyard can produce:

3428,2m2 x 0,425 x 161 kWh/m2 = 234.575kWh/year

So this courtyard overproduces 234.575- 134.133= 100.442 kWh /year which can be used for commercial use.
If we make a rough calculation we can extrapolate this production towards to whole neighbourhood.

234.575kWh/year of total courtyard production per 83 dwellings means 234.575/83 x 2403 = 6.790.000 kWh/year produced by the courtyards in total.

Parking lots

Our second large intervention are the parking lots. A Dutch pre-war quarter has parking norm of 0,7 (Kruydenberg, 2008). Spijkerkwartier has an average of 0,4 car per household, so this should be sufficient including the extra of 0,3 cars per household in case of visitors (Kruydenberg, 2008). 0,7 x 3610 households in Spijkerkwartier means 2527 parkings spots should be available. Ontwerp-structuurvisie Arnhem 2020 states that highrise cannot exceed 2x the average height of the surrounding (Geo1.arnhem.nl, 2016). That's why we want a maximum height of 4 floors with a basement which provides a total surface area of 13650 m2. 13650/9= 1500m2 which is doable on all of these places.

These parking lots can be used to provide electricity for businesses in the neighbourhood. Because the parking lot is four stories high, no shadow is present at this height. This gives us the following estimated production on top of the parking lots;

161 x 13650 m2 =2.200.000 kWh per year.

Steenstraat covering

Our final intervention is the roof covering at Steenstraat. For this intervention we have 2 types of PV panels; 510 m2 of semi-transparent panels and 600 m2 of vertical solar panels. The semi-transparent have a reduced factor of 0,425 and the vertical panels also supply less than normal horizontal placed panels. Due to a high sun during summer a vertically arranged collector is therefore less effective; only 68 percent (BV, 2016).
This intervention can provide:

Semi-transparent: 510m2 x 0,425 x 161 kWh/m2/year= 34.900 kWh/year
Vertical: 600m2 x 0,68 x 161 kWh/m2/year= 66.000 kWh/year
Total 100.900 kWh/year

In terms of power production it has not a great impact, but can have an impact on the great amount of people passing by. It can convince people to switch to solar power by making them more aware of the energy production (renewableenergyworld.com, 2016).

THERMAL SOLAR PANELS ON EXISTING ROOFS	2.880.000
PV SOLAR PANELS ON EXISTING ROOFS	6.700.000
COURTYARD PV SOLAR PANELS	6.790.000
PARKING LOT PV SOLAR PANELS	2.200.000
STEENSTRAAT PV SOLAR PANELS	100.900
TOTAL PRODUCTION	**18.670.900 kWh/year**

TABLE 03 // Total amount of energy generation by our interventions, see Appendix ??? for the calculations