"the linear power"

Interreg North-West Europe
Climate Active Neighbourhoods
European Regional Development Fund

Climate Responsive Planning and Design
Wageningen University | December 2016

COLOFON

Written by
Rob Stuijt (950123817110)
Alex van Gelder (921014254030)
Oktaviana Miffatulani (901009572060)
Jan Willem van Veelen (941005853060)

Course
LAR36806
Climate Responsive Planning and Design

Supervisors
Sanda Lenzholzer
Sven Stremke
Gert-Jan Steeneveld

Wageningen University, December 2015

TABLE OF CONTENTS

1 | INTRODUCTION

This report contains planning and design interventions for the neighbourhood Spijkerkwartier in Arnhem. This report is written for the course Climate-responsive Planning and Design by master students of landscape architecture and forest and nature conservation from the Wageningen University.

There is a clear connection between current trends like population growth, city development and industrialization, and the effects on global warming, depletion of fossil fuel resources and climate change. (Meehl et al., 2007). These problems should be taken seriously. In order to both adapt and mitigate for a more sustainable future, spatial interventions have been specifically designed to tackle the aforementioned problems. The spatial interventions are not only applicable for providing solutions, but also implementable on a smaller including the urban heat island effect, urban wind nuisance, deteriorated human thermal comfort and the lacking transition towards a sustainable way of generating energy.

With focus on climate responsive planning and design, spatial interventions have been specifically designed for implementation in the Spijkerkwartier neighbourhood located within the Dutch city of Arnhem. Spijkerkwartier is a residential area in Arnhem. This neighbourhood is located on the northeast side of the city centre of Arnhem. Officially Spijkerkwartier consists of three areas which are Spoorhoek (red), Spijkerbuurt (green) and Boulevardkwartier (blue). The parameters of this report strictly only focus on the Spijkerbuurt and Boulevardkwartier (Figure 1).

The name Spijkerkwartier comes from two medieval storage sheds where grain was stored, that used to be located there, which were called spijkers or spiekers in Dutch. The word spijker, translated as nail in English, comes from to the Latin word spica which means storehouse. (Webteam Spijkerkwartier, 2016). At this moment Spijkerkwartier can be seen as a neighbourhood with lots of allure because of the beautiful monumental buildings, the high and large numbers of existing trees and the strong local concerned community.

Fig 1. Spijkerkwartier Neighbourhood

2 | AIMS

The aim of the study conducted is to implement energy-conscious design interventions to create a climate responsive design for Spijkerkwartier. Specific focus has been geared towards an energy neutral Spijkerkwartier. Analysis has been conducted towards the extent of the current energy demand and the actions that need to be undertaken to decrease the energy demand. Further research depicted the different methods for on-site renewable energy generation.

The key principles of the design included climate adaptation, mitigation and generation of renewable energy. During the design phase, specific attention to climate design highlighted the importance of thermal comfort within public and private outdoor spaces. Using the physiological equivalent temperature (PET) to specifically define the thermal comfortability of spaces, interventions have been created to help improve the thermal comfortably within the Spijkerkwartier.

The PET value is based on a complete heat budget model of the human being which can be ordered in different classes. Table 1 (see Appendix) is combining multiple processes, including water vapor pressure, humidity and the outside temperature, the PET is known as a highly reliable indicator for thermal comfort. (Höppe, 1999)

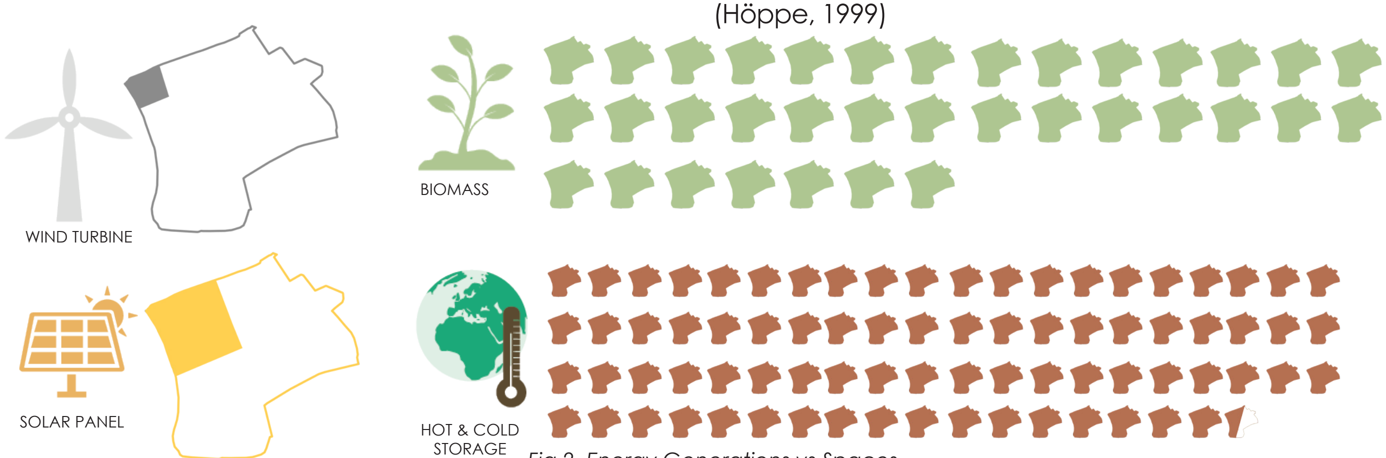


Fig 2. Energy Generations vs Spaces

With the aim to make the Spijkerkwartier energy neutral, comparison between the current energy use and the future predicted energy use has been analysed. The predictions for future energy trends are based on findings from ECN, Energie-Nederland and Netbeheer Nederland. As for Spijkerkwariter, the total numbers of the energy demand (in kWh) are depicted below in Table 2 (see Appendix).

To give an indication of how much space is necessary to generate a sufficient amount of energy, there was looked at different renewable energy sources and their efficiency. In Figure 2 is shown the amount of space that is needed (in the form of Spijkerkwartier), in order to generate to the full electricity demand of Spijkerkwartier in 2016 for households only.

The figure above highlights the sheer scale of the energy demand of the Spijkerkwartier. One can conclude that that both biomass as well as heat and cold storage are not desirable for the specific case of the Spijkerkwartier, due to the amount of space is needed. Implementation of a single wind turbine demands a miniscule amount of space. However, placing one large windmill is not realistic in the highly dense urban Spijkerkwartier. The choice of implementing solar panels resulted to be the best opportunity for this specific case.

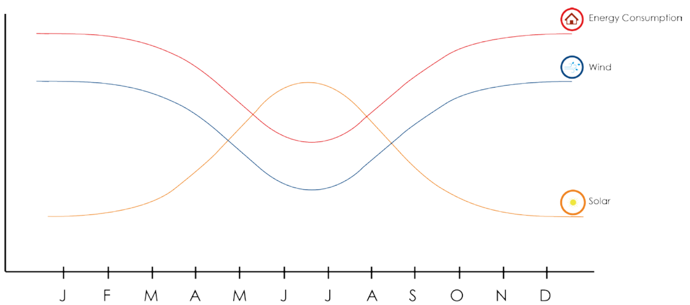


Fig 3. Energy Timeline

When focussing on making Spijkerkwartier energy-neutral, there should be looked at the total balance of energy. This consists of the demand of energy: the consumption, and on the supply of energy: the renewable energy sources (in kWh). In FIGURE 3 a timeline is shown with both the energy consumption and the energy production by different sources. Most of the energy consumption takes place during the colder months, because more gas is needed to heat up households. As for wind energy, more energy is produced during the colder months with relatively higher wind speeds than during the warmer months. Both solar- and biomass energy reach a peak during the warm months because of more and stronger solar radiation reaching the earth.

3 | ANALYSIS

After numerous site visits as well as a in depth analysis, conclusions were drawn relevant relate to the design concept of "Linear Power". Resulting with a main focus concerning urban microclimate and energy aspects.

3.1 Urban microclimate Aspect

Using the original student analysis, numerous problems related to urban microclimate have been identified. According to Lenzholzer (2015), there are three main factors that affect the urban microclimate: urban structure and temperature regimes, wind, and ambiance-experience. In the Spijkerkwartier neighbourhood, three main urban climate problems have been identified, including solar intrusion, wind direction and fluxes. As an extra, this neighbourhood is also facing flooding problems during the high precipitation. As depicted in Figure 4, four streets have been indicated with urban microclimate problems. Most of the streets that marked by the yellow line have been indicated as streets containing heat problems. They have an East-West orientation and less trees, yet they do have various height/width (H/W) ratios.

The four streets that highlighted these problems are; Steenstraat, Spijkerlaan, Parkstraat, as well as Dijkstraat. Steenstraat, with H/W ratio: 0.8, has heat problems along the street. As shown in Figure 5, the northern side contains shadows for less than three hours in the summer and a high sky view factor. Indicating that the Steenstraat seems highly vulnerable for heat stress problems. Spijkerlaan, Parkstraat, and Dijkstraat have a respective H/W ratio of 1.3, 0.8, and 0.8. The aforementioned streets have shadows for less than 4-6 hours in the summer day. In comparison to the Steenstraat one could conclude that the hours of shadow are long, yet the streets are affected by heat stress problems.

Arnhem is located on hilly terrain with some small valleys, driving the wind to create a downslope effect over the city bringing cold air into the city. However, the Spijkerkwartier is located behind a railway dyke and the other buildings of the city and won't get any benefit of these cooling valley winds. As the main wind direction is from the South West and South-South East in hot days, the occurrence of wind nuisance is mainly happening in the western part of the neighbourhood (Figure 9). The wind strength is categorized as low wind, with a wind strength ranging from 0.8m/s to 10.7m/s. The wind nuisance itself is caused by wind interaction between urban blocks, in turn creating corner streams and downwash effects (Figure 11 and 12). The wind ventilation of the Spijkerkwartier can be categorized as very weak, only recognized in private backyards, parks, and parking lots. The channelling of the urban block is quite poor, due to the highly dense neighbourhood block with extreme low street airflows.

Spijkerkwartier is located in the lower part of the Veluwe. With the average precipitation depicting that the largest amount of rain falls during summer every year. The worst rainfall effect happened on July 28th, 2014 and most of the area experienced rainfall with average 75 mm height on street level. This neighbourhood only

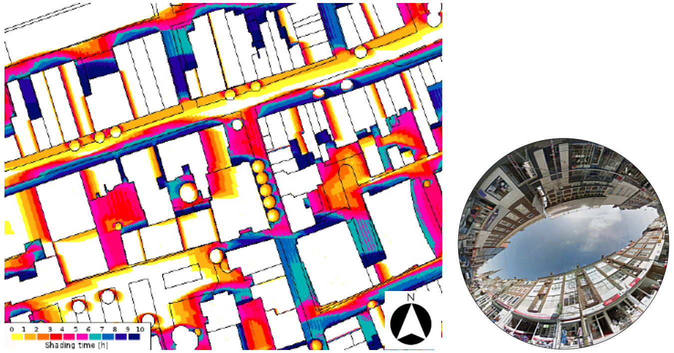
Fig 4. Problem Map

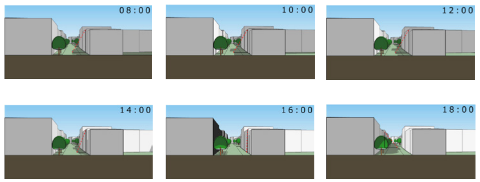
has small amount of green areas and the rest of the area is covered by buildings and hard surfaces. This makes runoff water hardly intercept the surface. The floodings that occurred in the Spijkerkwartier are categorized into two parts: in a higher part and a lower part (Figure 13). The flooding in the higher part is caused by water runoff that flows from the VeluwAe and the lower part is caused by water flows from other places in Arnhem. Supported by an outdated sewage infrastructure, this makes that the orange part cannot catch the water efficiently and turns the street into a huge water basins that collects approximately 20,618.31 m3 of water.

According to the KNMI reports the heat stress, wind and flooding problems will further increase in the future. (Hurk et al., 2014) The KNMI predict that in the future all weather events will be more extreme. This will cause longer periods of drought, higher peak precipitation and stronger winds. These extreme events have to be taken into account when designing a climate resilient Spijkerkwartier.

3.2 Energy Aspect

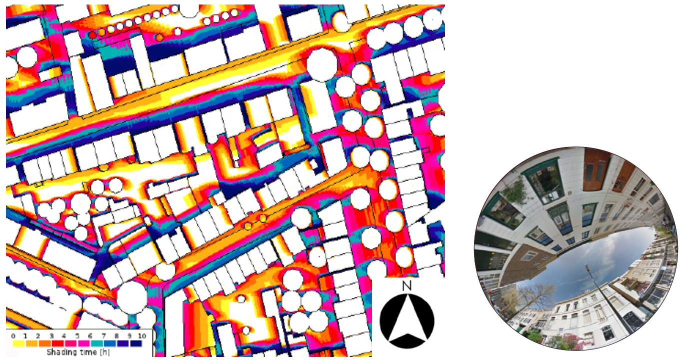
Home of 5,015 inhabitants, throughout 3,610 households the Spijkerkwartier is characterised by old buildings. Analysis from Klimaatmonitor (2016) show that the energy labels for buildings within the Spijkerkwartier are low. Pico 6.0 (2016) mentions that only 6% of the buildings are categorized as B to A++ label. All the other buildings are categorized as C-E level (38%) and F-G level (56%). Currently, the total energy consumption in this neighbourhood reaches 64,332,816.70 kWh/year for both business and housing. Gas usage (77.65%) dominates the energy usage and the other part (22.35%) is from electricity usage. In the future, in 2050, it is predicted that this neighbourhood will be able to reduce 20.81% of total energy. (See appendix)

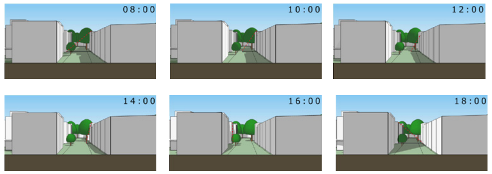




Orientation: SW-NE
Ratio: 0.8
Sky view factor: 0.502
Tmrt: 45.8 °C
PET: 34.1 °C
(Moderate heat stress)

Fig 5. Steenstraat shadow analysis & PET





Orientation: SE-NW
Ratio:0.80
Sky view factor: 0.450
Tmrt: 45.5 ºC
PET: 34.0 ºC
(Moderate heat stress)

Fig 7. Dijkstraat shadow analysis & PET

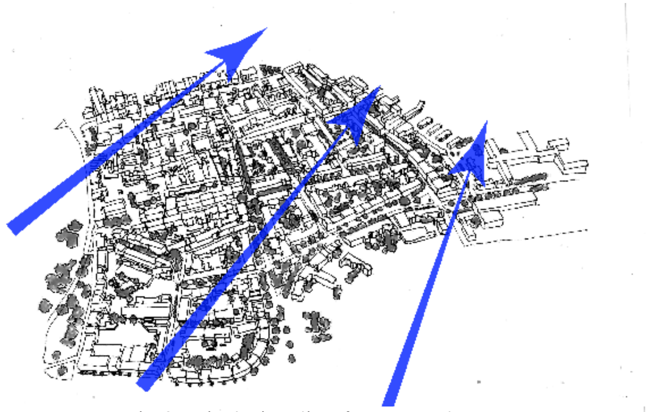


Fig 9. Wind Direction for Normal Days

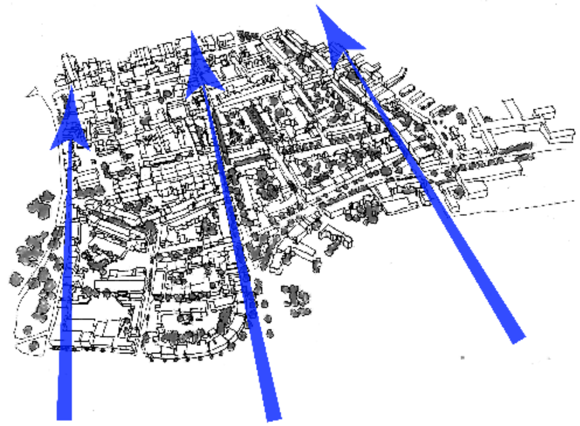
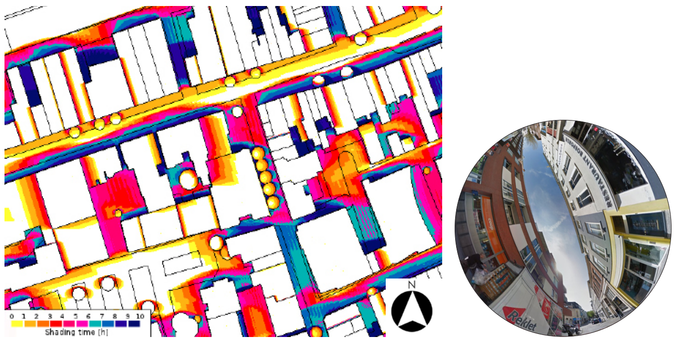
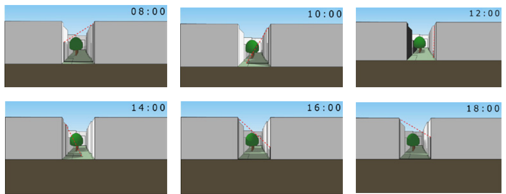


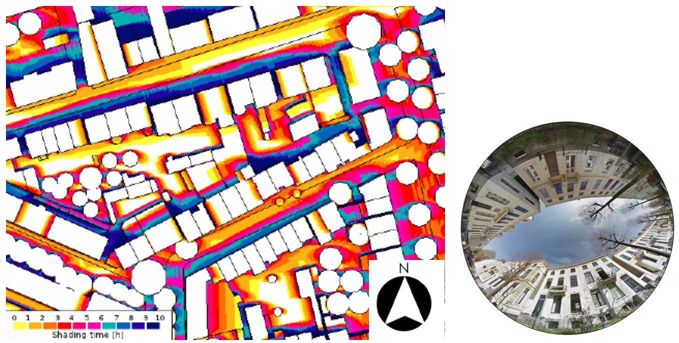
Fig 10. Wind Direction for Hot Days

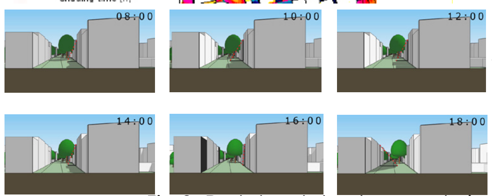




Orientation: N-S
Ratio: 1.3
Sky view factor: 0.442
Tmrt: 45.4 °C
PET: 33.9 °C
(Moderate heat stress)

Fig 6. Spijkerlaan shadow analysis & PET





Orientation: E-W
Ratio:0.58
Sky view factor: 0.439
Tmrt: 45.4 ºC
PET: 33.9 ºC
(Moderate heat stress)

Fig 8. Parkstraat shadow analysis & PET

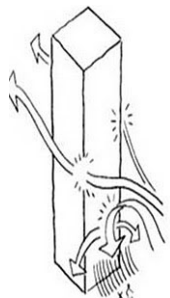


Fig 11. Downwash Wind Effect
Source : Donnelly, 2013

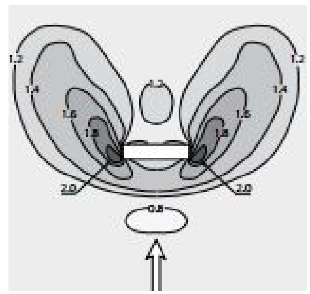


Fig 12.Corner Stream Wind Effect
Source : Lenzholzer, 2015

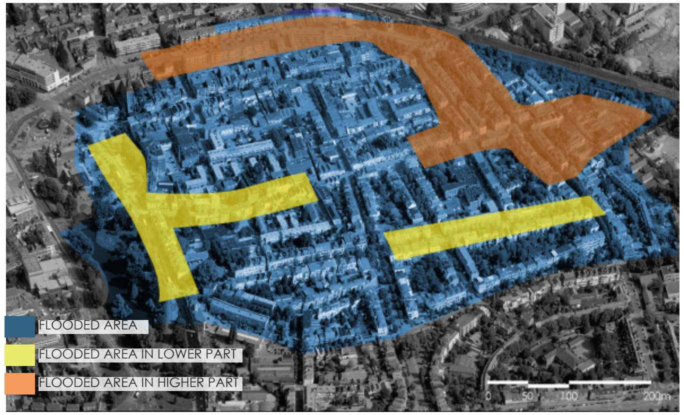


Fig 13. Problem Map

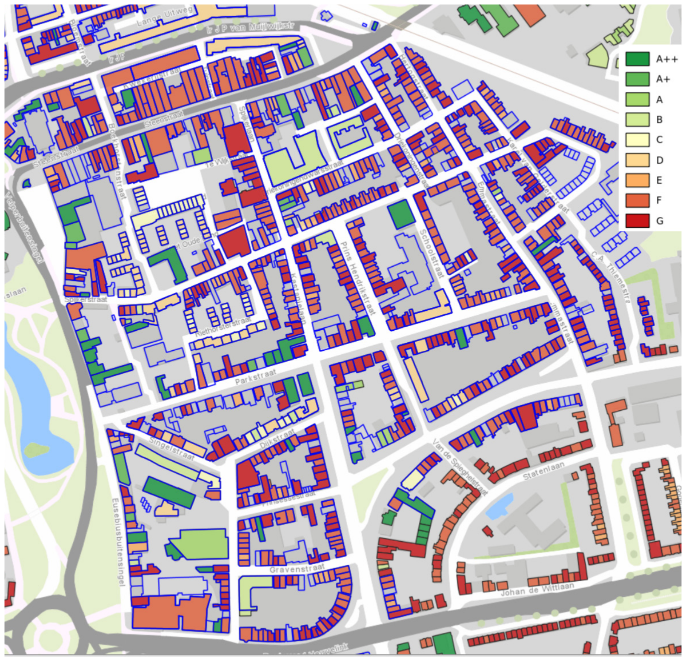


Fig 14. Energy Labels for Spijkerkwartier's Building
Source: Pico 6.0 (2016)

4 | DESIGN QUESTION

Main Question
To what extent could Spijkerkwartier be energy neutral and climate resilient by landscape design?

Sub-Questions:

- *What kind of design intervention that available to tackle this problems?*
- *How much energy could be generated by our intervention?*
- *To what extent could microclimate be altered by this design intervention?*

5 | CONCEPT

The "Linear Power" design is based on four core principles; maintaining current landscape features, providing linear park links, production of sustainable energy and reduction of microclimate effects (Figure 15). Inspired by the trias energetica in providing sustainable energy for environment while at the same time conserving energy (Figure 16), focus was put on a linear intervention that would utilize the public space as efficient as possible.

Linearity as a starting point, resulted that six different categories (Figure 17) were made based on street width and orientation in the Spijkerkwartier; 20m width of East-West orientation, 15m width of East-West orientation, 10m width of East-West orientation, 20m width of North-South orientation, 15m of North-South orientation, and 10m of North-South orientation. Using the different categorizations, interventions to produce energy and lower the heat problems at streets level were designed.

The new interventions will be mostly placed on public grounds in order to maintain the already beautiful inner courtyards. To connect these inner courtyards, we decided to depave streets. These depaved streets will provide a backbone to connect the inner courtyards and also tackle the flooding problem.

Another principle we used was keeping the current landscape features, for us these features are the beautiful houses, the large number of trees and the hidden inner courtyards. The design we implemented is very subtle and should be easy to implement. The design will not drastically change the houses and their features. However, by implementing the design the streetscape will change and the PET in the street will be lowered. This will create a more livable and better Spijkerkwartier.

The Trias Energetica concept:
the most sustainable energy is saved energy.

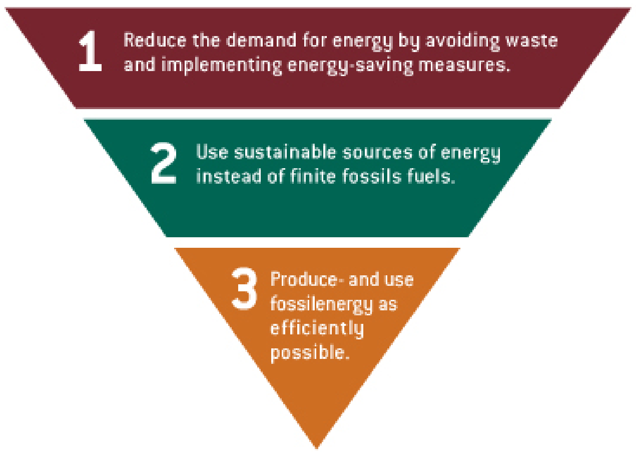


Fig 15. Trias Energetica Concept
Source : Brouwers & Entrop, 2005

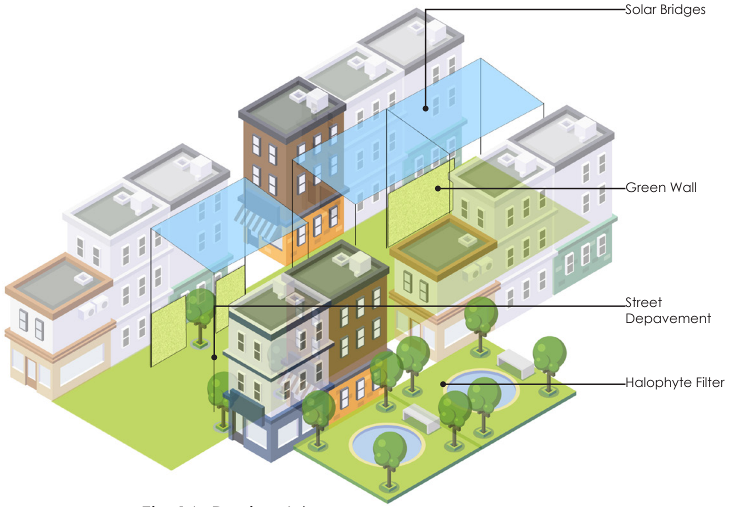


Fig 16. Design Ideas

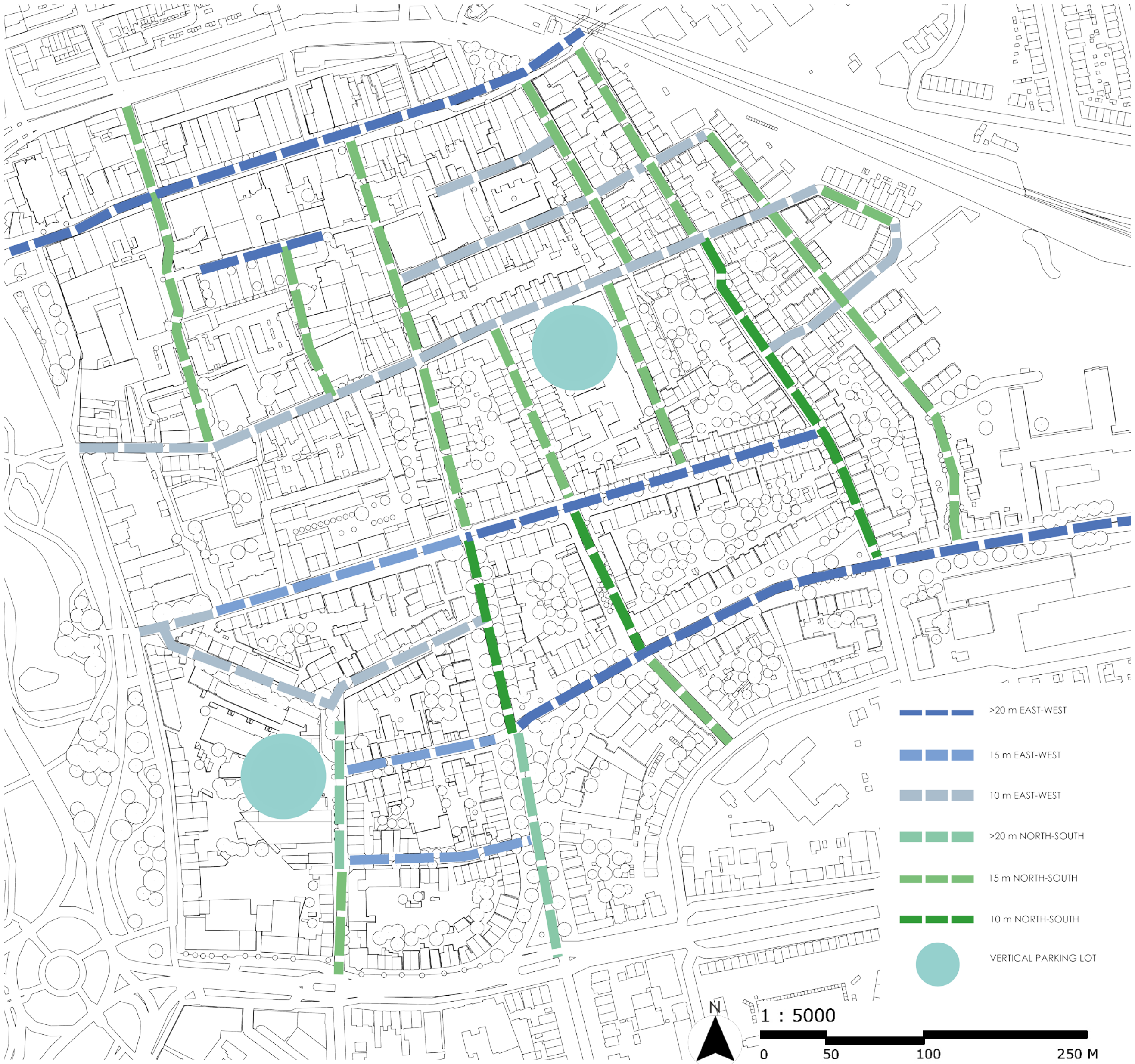


Fig 17.Street Classification

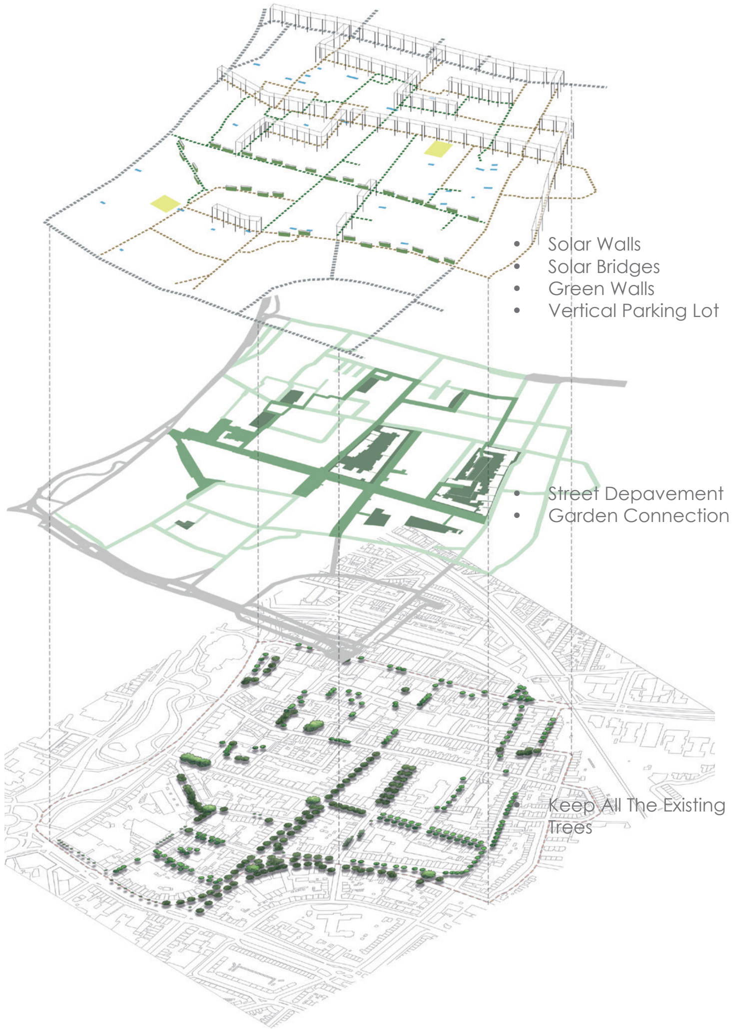


Fig 18. Conceptual Design Diagram

6 | MODELS

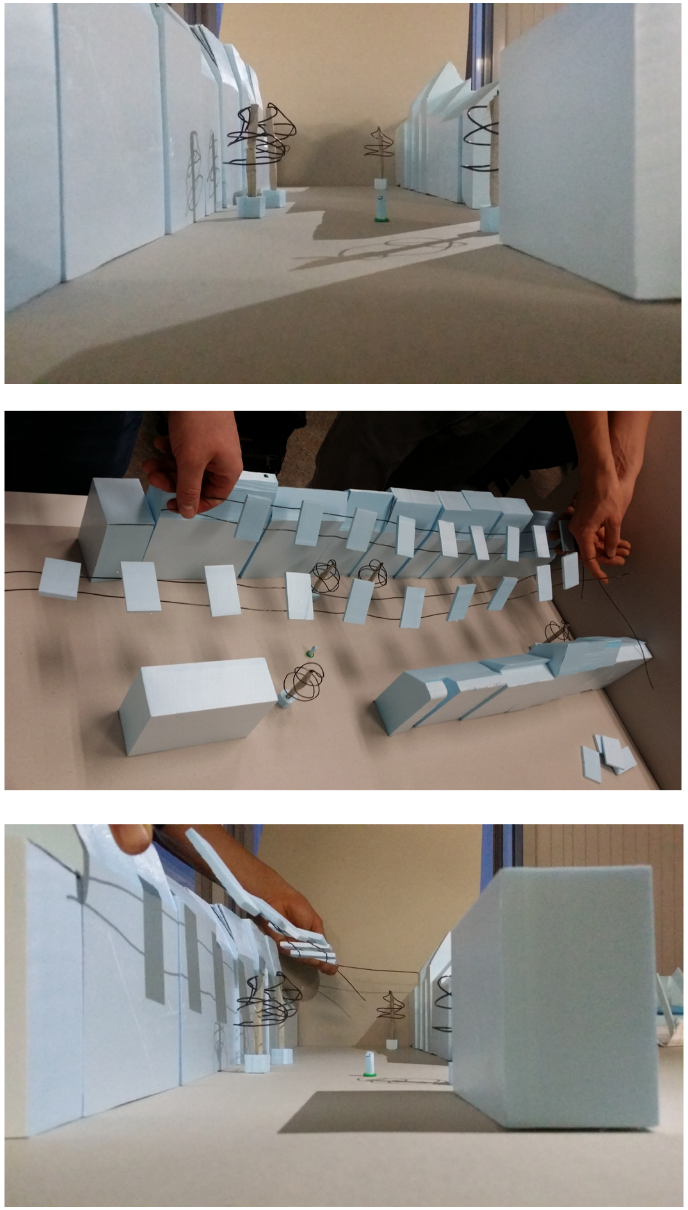
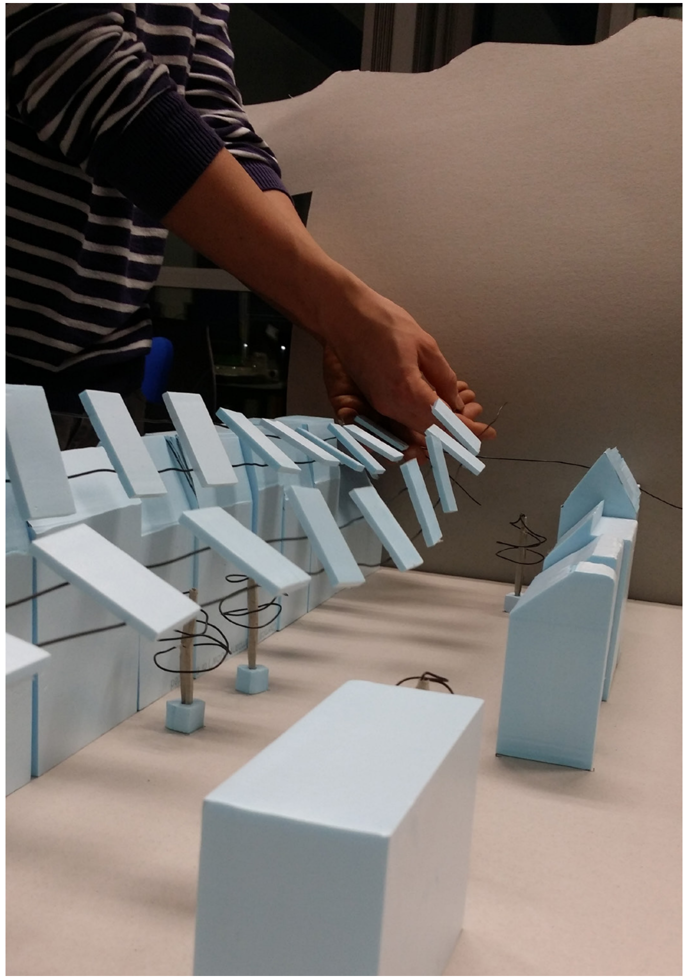


Fig 19. Pictures of Models for Shadow Study



A physical model was made with the scale of 1:100. Using the model, analysis was done to interpret the effect of the different interventions. Using a flashlight representing the sun. A sun shade film was made to highlight the effect of shade produced by the different interventions.

7 | DESIGN INTERVENTION

For the design of the Spijkerkwartier multiple interventions have been made. These interventions are either energy generating interventions, thermal comfort increasing interventions, aesthetic value increasing interventions or a combination. From the original analysis, typical streets have been identified for application of the different interventions. These resulted in different designs for the North-South oriented streets for the East-West oriented streets and designs for exceptions of these streets. The interventions are based on the width of the street and the available public space. Each of these interventions consist of modules. These modules can be repeated multiple times in a street. Streets that have high trees in them or are fully occupied by the trees are not suitable for this intervention, because of the trees affecting the amount of sunlight and the height intervening with the intervention. This module approach results in a high flexibility and makes it easier to implement in the near future.

The suspended interventions will be realized with bifacial solar panels hung between poles. To optimize the amount of absorbed radiation within the intervention module, the decision has been made to implement bifacial solar panels. Producing not only energy from direct solar radiation, but also from indirect radiation reflected off different surfaces. The amount of extra production that is generated depends on the albedo of the material. the ideal circumstances are white shiny surfaces half a metre from the PV panels. The bifacial panel chosen for the intervention has an average boosted production of 17,5%, because the materials in normal streets have a lower albedo. (Hazel, 2003) (Ortabasi, 1996)

Fig 20. Steenstraat Visualization

7.1 Steenstraat

The Steenstraat is the street that offers the most public space. This street is East-West oriented and has a width of over 20 metres. For the intervention another layer is placed on top of the already existing layers, an energy generating layer. In our design this layer mainly consists of floating solar panels above the streets. In the Steenstraat three rows of bifacial solar panels are placed on rails that are located on poles. These rails are controllable and offer the solar panels to tilt to the desired solar direction, by rolling over the arched surface of the poles. Depending on the time of year these panels can move over the round surface. This ensures that the solar panels achieve the maximum efficiency. (Spruijt, 2012)

The solar panels also provide shading on the streets and on the facades along the street. This shading will lower the PET value and thus the liveability of the street. Green walls can also be placed in between the poles to reduce the PET value and make the environment more comfortable. By implementing this intervention to Steenstraat, calculations show that a reduction of PET from moderate heat stress to slight heat stress is achieved. It can reduce 3.45°C, in average, for a summer day. The solar panels can be slide on top of each other during winter to let as much sunshine into the streets as possible.

The three rows of solar panels are placed behind each other in a way that the sun rays can still reach the bottom of the panels. The structure consists of these three rows of solar panels, with 7 panels of 2,5 by 1,5 metres of solar panels (Figure 23). This provides 78.75 square metre of solar panels per module. This produces an annual amount of 14,784.00 kWh.

These numbers apply to the Steenstraat and East-West oriented streets with a width of 20 meters or more. In streets with a smaller width it is only possible to place two rows of solar panels. (see appendix calculations)
The design of these solar bridges is intended to be subtle and functional. The design also serves the function of a lighting fixture. This makes the design more integrated in the street pattern. When implemented to the entire Spijkerkwartier it creates a more homogeneous feel to the Spijkerkwartier and provides a good option for the Spijkerkwartier in the discussion concerning the implementation of new light poles. The energy of these implementations can be stored in batteries that are "disguised" are street furniture. This integration with the street furniture makes the design easy to implement and also increases the livability in the street.

Orientation : W-E
Ratio : 0.8
Sky View Factor : 0.032
Tmrt : 52.3
PET : 36.7

Orientation : W-E
Ratio : 0.8
Sky View Factor : 0.0212
Tmrt : 43.8
PET : 33.3

Fig 21. PET Comparison Steenstraat (Left: Before Implementation & Right: After Implementation

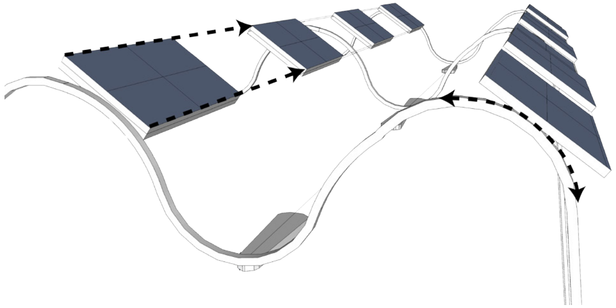


Fig 22. Panel Movements

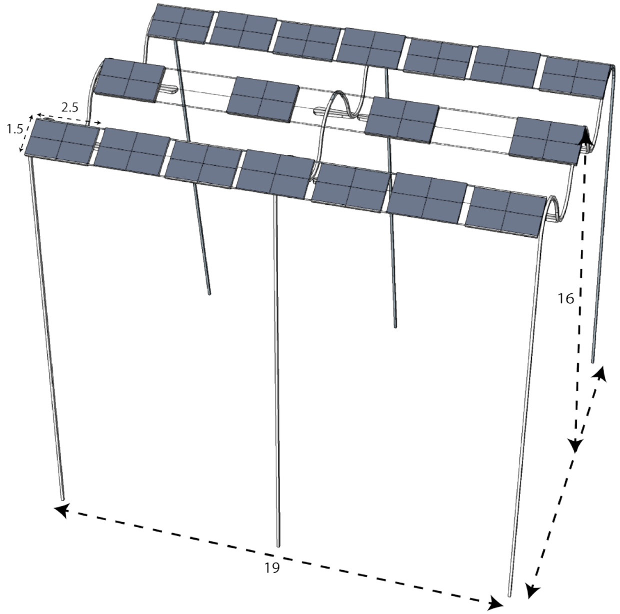


Fig 23. Technical Solar Bridge Module

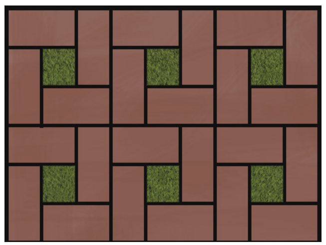


Fig 24. Interlocking Old Bricks

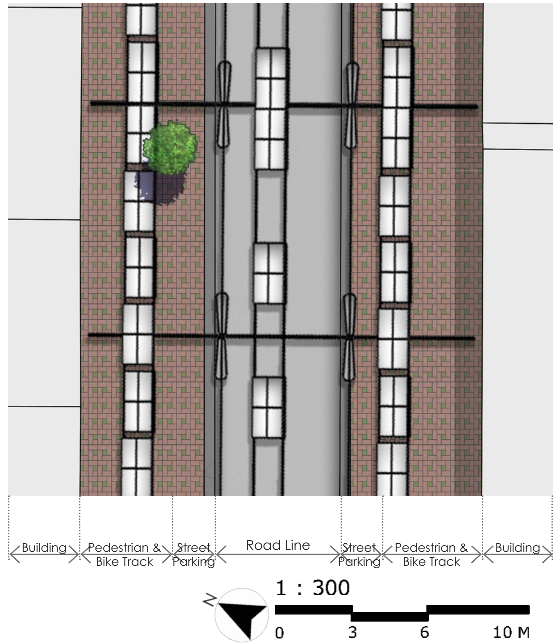


Fig 25. Typical Plan of Steenstraat

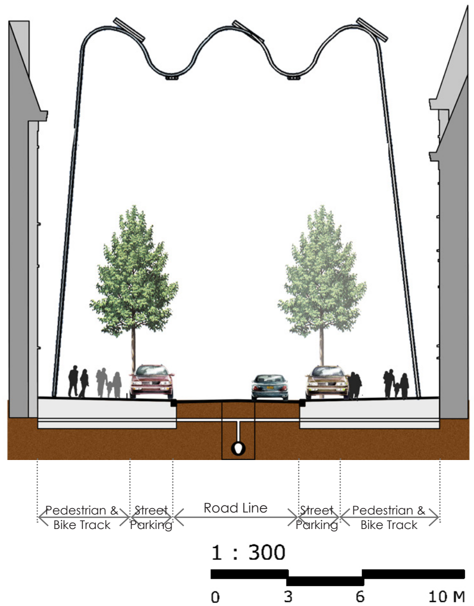


Fig 26. Typical Section of Steenstraat

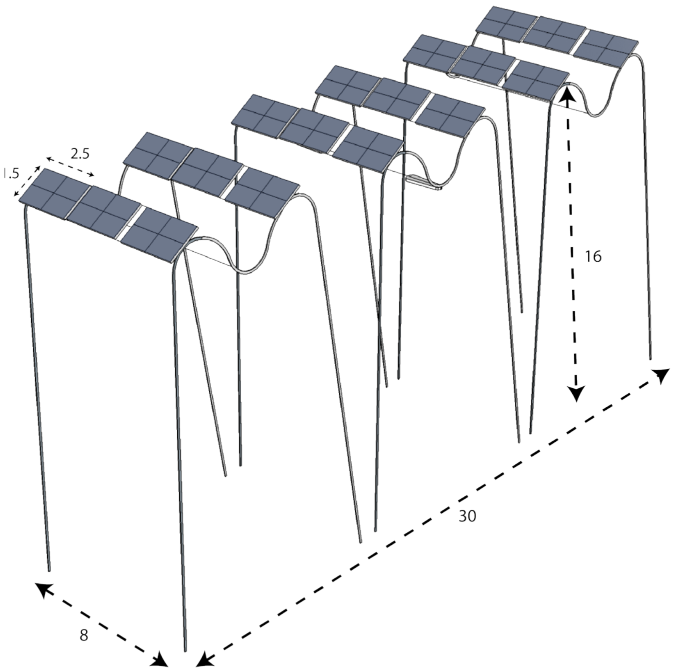


Fig 27. Technical Solar Bridge Module for Karel van Gelderstraat

Orientation : N-S
Ratio : 1.1
Sky View Factor : 0.217
Tmrt : 43.9
PET : 33.3

Orientation : N-S
Ratio : 1.1
Sky View Factor : 0.155
Tmrt : 43.4
PET : 33.2

Fig 28. PET Comparison Karel van Gelderstraat (Left: Before Implementation & Right: After Implementation)

Fig 30. Steenstraat Visualization

7.2 Karel van Gelderstraat

TThe design for the Karel van Gelderstraat is almost the same as the one for the Steenstraat. However the Karel van Gelderstraat is a North-South oriented street. This orientation makes that the design has to be turned in order to be south orientated. The same principles of the solar panels from the Steenstraat apply to this street. Per module are 18 solar panels of 2.5 by 1.5 metre. This gives us 67.5 square metres of solar panels, which produce an annual amount of 12.672,00 kWh.

This intervention also contributes to PET reduction. In average, it reduces 2.59°C, on a summer day, if the solar bridges and green walls along the street are implemented.

For the Karel van Gelderstraat the decision was taken to make the streets more permeable. This was done by reusing the old brick, but putting them back in a different bond. (See Figure 24) This bond allows room for a patch of grass or pebbles in which the rainwater can infiltrate. This ensures during peak rainfall the amount of water that is taken up by the soil is increased and the sewers are less likely to flood.

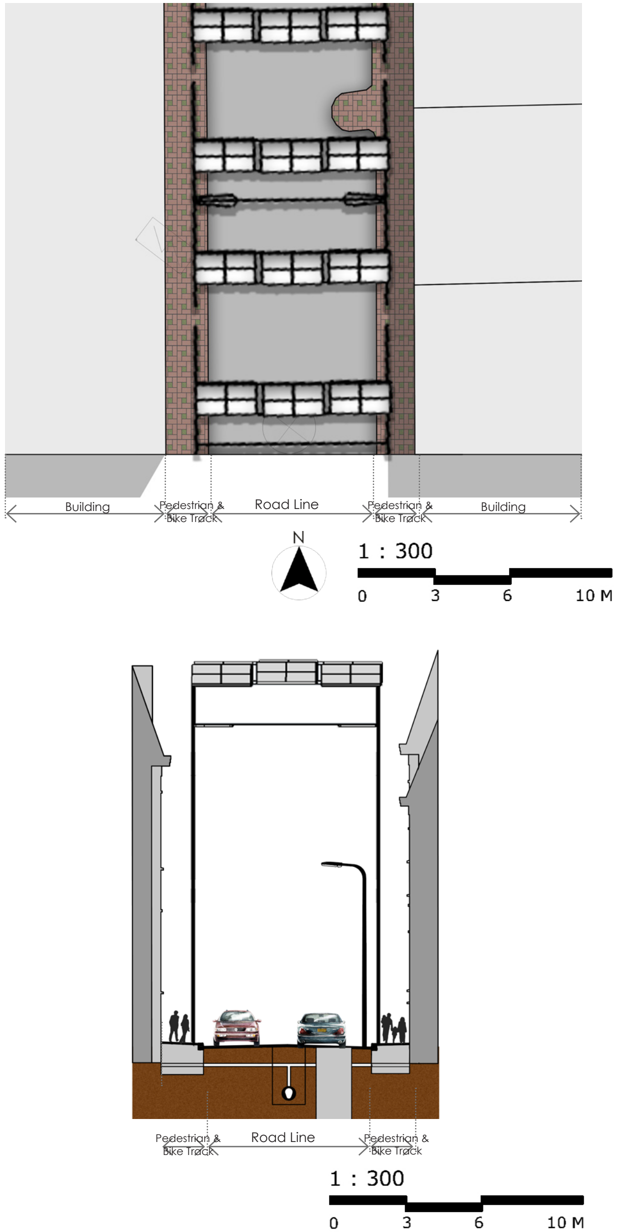


Fig 29. Typical Plan (Above) and Section (Bottom) of Karen van Gelderstraat)

7.3 Parkstraat

For the Parkstraat, a different kind of construction was used to mount the solar panels, by using poles to fix the solar panels on. This is done by using the available trees in the street. These trees are too high to put our solar bridge over. However the tree branches are cut every year making it still possible to harvest the solar energy. The poles will be about 11 metres high and will also include street lighting. Green walls can be implemented in between the poles to lower the PET (average: 3.22°C) on the street level.

Fig 30. Parkstraat Visualization

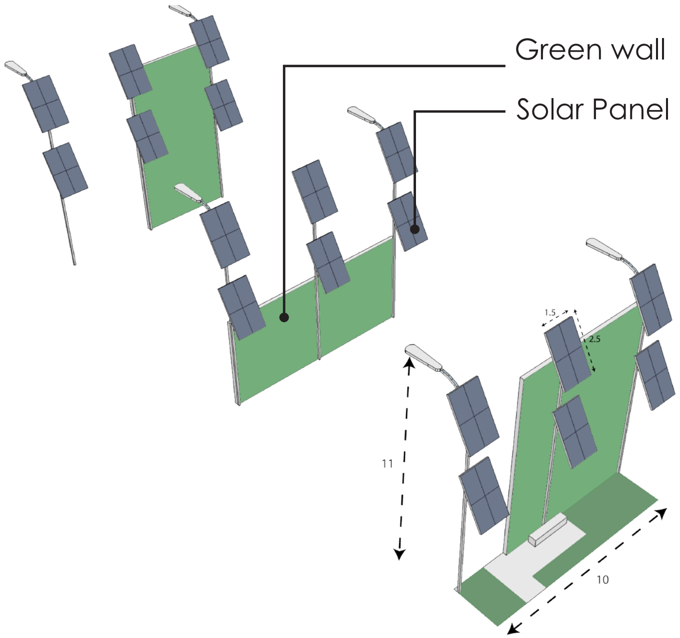


Fig 31. Technical Solar Pole & Green Wall Module for Parkstraat

Fig 33. Parkstraat Visualization & Street Depavement

Orientation : W-E
Ratio : 0.58
Sky View Factor : 0.244
Tmrt : 44.0
PET : 33.4

Orientation : W-E
Ratio : 0.58
Sky View Factor : 0.241
Tmrt : 44.0
PET : 33.4

Fig 32. PET Comparison Parkstraat (Left: Before Implementation & Right: After Implementation

Another way to decrease the PET in the street is by depaving the street, thus it can decrease the heat on street level if another material is used that has a lower albedo. In this case, we are going to remove the current paving, concrete block which has 0.20-0.4 albedo value (Wikipedia, 2016), into grass which has lower albedo value (0.25). The choice to depave the Parkstraat and some other streets in the Spijkerkwartier has been made, in order to enhance the precipitation during peak rainfall. This makes that the area is less likely to flood. By depaving the street a new linear park in the Parkstraat is created, bringing back the park in the Parkstraat! This linear park offers more green space close to the people their homes and provides nice areas for children to play and get in touch with nature.

The biodiversity in the area will increase, as Parkstraat will become the new green connection between the already existing courtyard gardens. This connection makes it easier for small wildlife to travel from one place to the other without interrupting traffic.

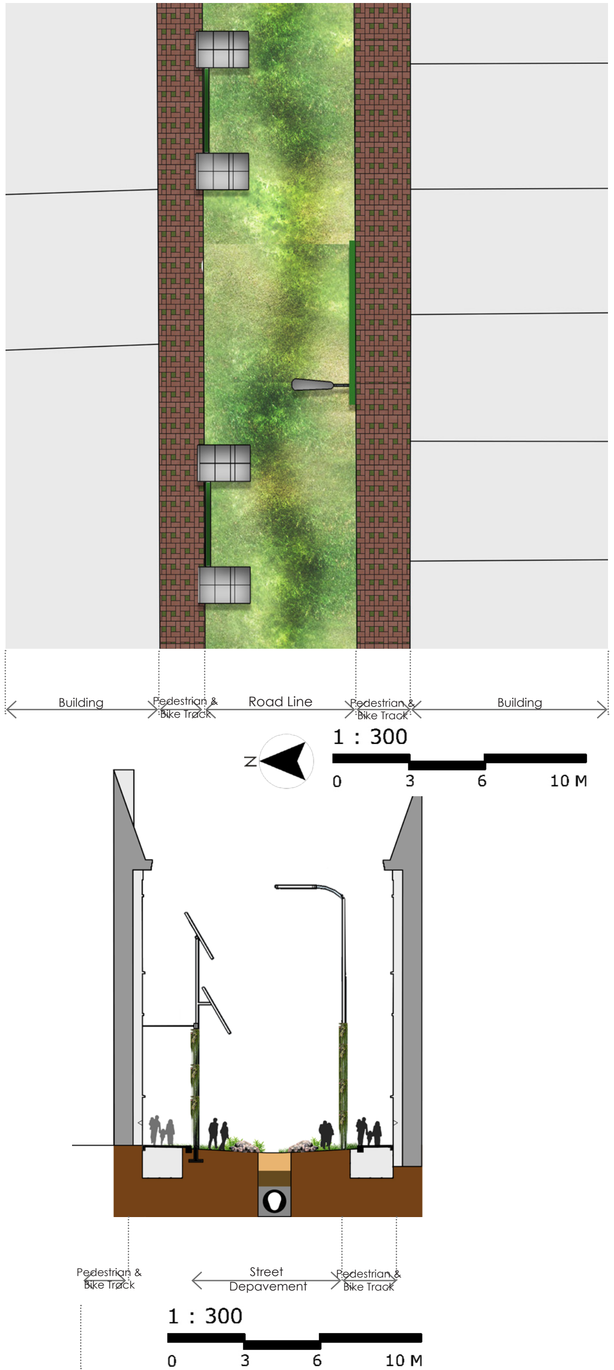


Fig 34. Typical Plan (Above) & Section Bottom of Prkstraat

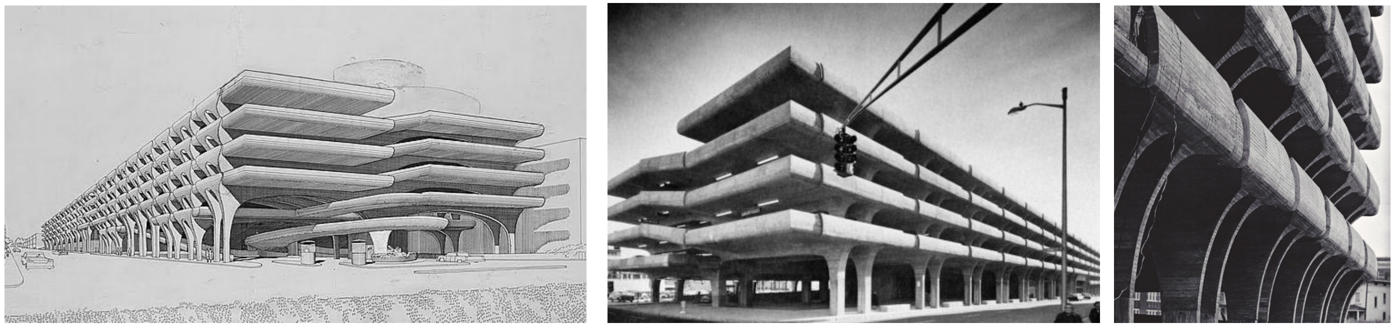


Fig 35. Image Refferences of Vertical Parking Structure
Spurce : paulrudolph.blogspot.nl

Fig 36. Vertical Parking Lot Visualization

7.4 | Vertical Parking Lot

In order to accommodate the lost parking space by the depaving of the streets we had to construct two parking garages. These garages were based on a design of a parking garage in New haven by Paul Rudolph. The parking garage offers space for around 100 cars. The ground floor of the parking garage is reserved for the storage and infiltration of water. This makes it an interesting site for animals, but also for people. To ensure that there is enough light for plants to grow several light tunnels will be placed. Ivies and other hanging plants can grow from the sides of the parking garage, making it greener and also reducing the PET. The parking garage also offers a space to store the energy that is generated by the solar panels. This battery can release the energy when needed. On top of the parking garage are solar panels that also generate energy. These panels work the same as the ones used in our interventions and can be opened, closed and tilted. The South facing side of the parking garage also generates energy. This wall is covered with bifacial PVT panels to have an optimal result.

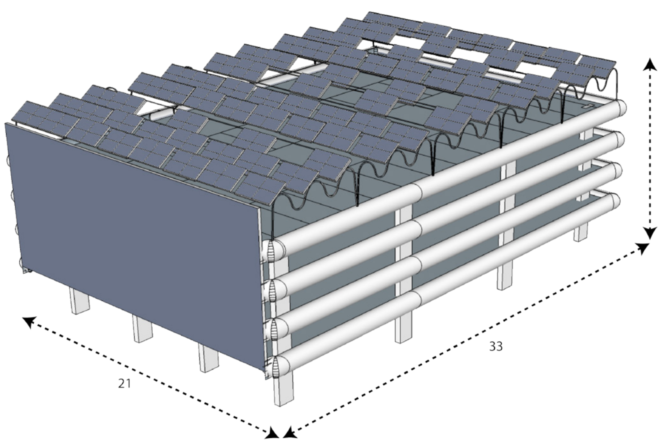


Fig 37. Technical Module Vertical Parking Lot

7.5 Vertical Solar Wall and Roof

The Rooftop interventions have mainly been realized by means of Photovoltaic (PV) panels. Suitability of rooftops within the area of focus has been analyzed based on aerial photos in comparison with the Dutch website www.zonatlas.nl. For a roof to be applicable for PV panels it is of uttermost importance that the panels are faced in a southern direction. By using bifacial PV panels the production is boosted with an average of 17,5 %. (Hazel, 2003)(Ortabasi, 1996)

To generate more energy some buildings will be cladded with vertical solar panels. For the vertical orientated interventions the choice has been made to implement combined heat and power systems. This will be realized with the use of Photovoltaic thermal hybrid solar collectors (PVT) placed on a rail structure. In comparison to PV panels, PVT panels can convert solar radiation into both thermal- and electrical energy. To optimize the efficiency of the PVT elements they will be placed 30 cm away from the building façade. This allows an airstream to flow between the PVT elements and the façade of the building, creating a bubble of cool air. With a distance of 30 cm and a white surface it is said the the PVT panels will have a boosted efficiency of 45%, when using bifacial PVT panels. (Chow, 2010) The generated warm water can be used for household purposes supplying warm water for showers, heating, etc.

7.6 Additional energy generating sources

One of the characteristics of the Spijkerkwartier are the elegant, large and monumental houses which are relatively old. The age of the buildings result in high energy demands as well as high energy losses due to

Fig 38. PVT Wall Visualization

poor insulation. With the modern advances of energy technologies, one can assume that future implementations will be focused on reduction of energy consumption on household basis as stated in Introduction. Neighborhood initiatives throughout the Spijkerkwartier have started with green residual collection collaborations, with the aim to use green residuals for either the production of heat or biogas.

With a scope broader than that of the Spijkerkwartier analysis has been done. The environmental friendly industrial park Kleefse Waard, located to the southeastof the Spijkerkwartier is known for utilizing reserves and by-products. Currently a heat combustion plant located on the industry park planned by the energy supplier Veolia, aims to participated to fulfill the demand of both households and enterprises in the districts of Arnhem. As for 2015, the in Duiven based waste incineration plant has been added to the existing district heating network, leading to a broad range of opportunities for extension of Arnhem's district heating network.

Further opportunities could be exploited in combination with the municipal plan of "Buiten Gewoon Beter" that has been developed with the aim to fulfill restoration and resiliency goals to restore outdated wastewater infrastructures. One could propose the use of a sewage heat recovery system, used to capture the warmth of domestic wastewater and transfer it to a clean water source that in turn can be used for heating purposes.

8 | MASTER PLAN

The masterplan of the Spijkerkwartier includes all interventions for the Spijkerkwartier.

In total, 3056 metres of solar bridges will be placed. Most of these bridges are located in the Northern part of the quarter, because there are less trees located there. The Northern part was also the most vulnerable in terms of thermal comfort, which is also tackled by the solar bridges and green walls.

The solar panels on poles are places in streets with bigger trees and will totally cover 169 metres of the streets. These poles will add another 100 solar panels (of 4 x 300 wp) to the calculation.

The PVT walls will be implemented in 396 m2. Some of these walls have already a white background, boosting the bifacial PVt with 45 %.

The biggest amount of energy is generated by solar panels on the rooftops. The calculation was made using the Zonatlas website. In total there is around 46000 m2 of solar panels that can be placed on the roofs.

In total 7% of the total area will be depaved. All the other roads will receive a more permeable pavement, allowing water to infiltrate.

Fig 39 Spijkerkwartier Neighbourhood Master Plan

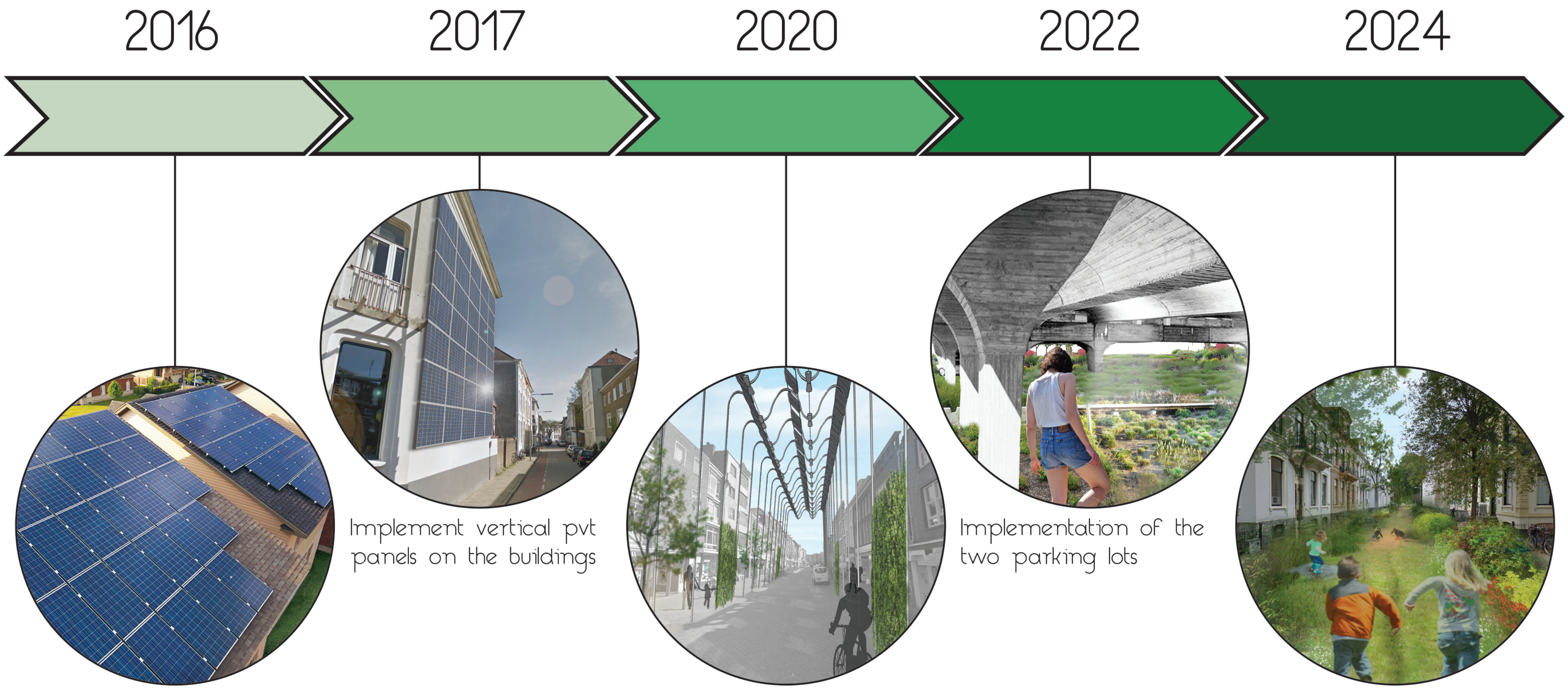


Figure 40. Estimated Project Implementation Timeline

The design can be best implemented in certain phases. These phases can be implemented in relatively short time of each other, because of the modular way the design is built up.

Firstly additional solar panels are added to the roofs that are suitable. This will already generate a lot of energy. In the meantime additional insulation can be added to the houses. These simple interventions could be implemented in a short amount of time and would increase the energy generation of the Spijkerkwartier.

Next the vertical PVT walls and suspended PV panels could be added to the street. These implementation will further increase the energy production and lower the PET in the streets as well.

In order to already cope with the parking problem the new parking garages will be added. After this step the depaving of the streets can begin and will change the Spijkerkwartier into a more lush green linear oasis.
This whole process would take about eight years to complete, because of the small scale of the interventions. The process could also take place in the future. In this case the solar panels and PVT panels probably would have an increased energy production.

9 | CONCLUSION & DISCUSSION

9.1 Conclusion

The goal to make the Spijkerkwartier energy neutral seems to be impossible without enormous interventions. The charm of the current design is that the created interventions are of small scale yet easily implementable. Due to the modular characteristics of the design, the interventions can easily be implemented on the larger scale throughout the Spijkerkwartier. The design interventions resulted in a generation of 22% of the total demand of energy for the Spijkerkwartier. That said, the design furthermore shows the impact it has on the microclimate. The microclimate is positively influenced by the design and will raise a level in thermal comfort. This makes the outdoor space a better place to be and makes the Spijkerkwartier more liveable.

Peak precipitation was also a topic of interest throughout the design. Opening up the streets, by reducing the amount of paved surface, resulted in an increase of water that can infiltrate into the soil. The design resulted in paved surface coverage of 7% of the total surface.
By implementing the intervention the park is brought back to Parkstraat. This ensures the amount of traffic in the area is reduced and the liveability is increased.

The interventions are easy to apply, due to the modular characteristics from their design. This makes the interventions multi applicable. Therefore the interventions used in the Spijkerkwartier could be used in other cities and other neighbourhoods. This make the Spijkerkwartier a pilot project for other neighbourhoods that aim to be energy neutral and climate resilient.

We can conclude that the current layout of the Spijkerkwartier does not offer enough space to generate enough energy to fulfil the demand. This is mainly because of the high density of the buildings and the mainly inhabitants that live in the area in apartments. This makes that multiple households are inside one building, which makes the population density really high.

9.2 Discussion

In this discussion we want to elaborate things that could be different in order to achieve the goal of fulfilling the total energy demand of the neighbourhood.

Firstly, from the calculation of the energy numbers of 2050 a decline can be seen in the total energy demand, this main variable seems to be better insulation of the houses. Furthermore the numbers show that the energy demand of the companies doesn't reduce as much. To decrease this number of consumed energy one could analyze the option for the businesses and how to reduce their energy demand. This will lower the target and will be more easy to achieve. The other way around will happened to climate.

According to KNMI scenario, heat stress, wind and flooding problems will further increase in the future and weather phenomenon will be more extreme. This will cause longer periods of drought, higher peak precipitation and stronger winds. Thus, more climate design and planning approach will be needed not only in Spijkerkwartier, but also all over the world

Secondly, the solar panels used in the calculations expect to be more efficient in the future. The calculations made in the paper show the amount of electricity that can be generated with current solar panels. However, in the last years solar panels have greatly improved. If the efficiency is boosted the number of generated energy will also directly increase.

Thirdly, the calculations for the energy demand have been based on the assumption that not every house will achieve higher energy label level than the current situation. Future advancements in insulation materials and other new energy saving options could then even further reduce the demand of energy.

Lastly, in the design the decision was taken to not use the private gardens for any design intervention. Initial focus resulted in interventions that could be easily applicable for in the public space, and as the private gardens are very valuable the decision was taken to maintain the current state of the private gardens. However, if these spaces could be used for energy generation the amount of generated energy would increase as well.
The Spijkerkwartier proves to be a very difficult area to make energy neutral and climate resilient. However, the sheer strength of involvement within the community and strong initiatives might lead to achievement of the goal in the future.

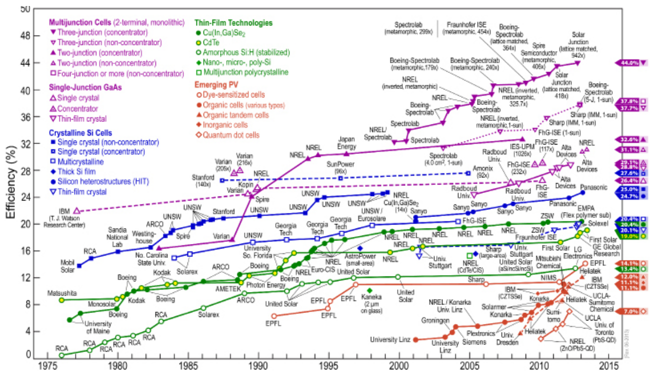


Figure 41. Projected Energy Efficiency Level

APPENDIX

Video 1. Steenstraat Sun & Shadow Study Video for 24 hour on Summer Day*
Video 2. Karel van Gelderstraat Sun & Shadow Study Video for 24 hour on Summer Day*

*All videos are attached together with the digital files

Table 1. PET classification values

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

Table 2. Solar bridge energy production

street	implementation	available metres in Spijkerkwartier (without trees)	numer of implementations	number of pv panels	amount of energy generated	amount of energy generated when using bifacial pv
East-West						
20 m	hanging solar panels 3 rows, 19 m long 21 x 4 x 300wp pv panels	475	25	525	554400	651420
15 m	solar panels on poles, 10 m long 6 x 4 x 300wp pv panels	169	16.9	101.4	107078.4	125817.1
10 m	hanging solar panels 2 rows, 19 m long 14 x 4 x 300wp pv panels	1131	59.52632	833.3684	880037.1	1034044
North-South						
20 m	hanging solar panels 3 rows, 10 m long 12 x 4 x 300wp pv panels	82	8.2	98.4	103910.4	122094.7
15 m	hanging solar panels 2 rows, 10 m long 6 x 4 x 300wp pv panels	1019	101.9	611.4	645638.4	758625.1
10 m	hanging solar panels 2 rows, 10 m long 6 x 4 x 300wp pv panels	349	34.9	209.4	221126.4	259823.5
				total kWH	2512191	2951824

produced energy by 4 x 300wp pv panels: 1056 kWh

Table 3. Total energy consumption 2016-2050

		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

Table 4. Energy Production of Vertical Parking Lot

	kWh	kWh with bifacial
80 x 4 x 300wp pv panels	84480	99264
193 m2 pvt	69480	100746
	total kWh	200010

Table 5. Energy Production of Vertical PVT Panels

	kWh per m2	m2	m2 regular	m2 white pavement (+45%)
Vertical PVT panels	360	396	236	164
			84960	85608
		total		**170568 kWh**

Table 6. Energy Production of solar panels on roofs

	m2	panels
roof surface	46867.59	6249.012

	6598957	kWh from pv on the roofs
total	7753774	kWh with bifacial pv panels

Table 7. Total Energy Balance

intervention	kWh	Spijkerkwartier 2050			
vertical pv	2951824	total gas consumption	35050137		
vertical pvt	170568	total electricity consumption	15886960		
parking garage	400020				
rooftops pv	7753774				
total kWh	11276186	total	50937097	total balance	-4E+07
				22.13747 %	of the total energy demand
				70.97762 %	of electricity demand

Table 8. PET Calculation for Each Intervention in The Hot Days

					STEENSTRAAT									KAREL VAN GELDERSTRAAT									PARKSTRAAT						
						TMrt				PET					TMrt				PET					TMrt			PET		
DayOfYea	Temp (deg C)	Rel. Humidity (%)	wind speed (m	cloudc	Temp (deg C	Befor	After	with gre	Differer		After	with gre	Differen	Temp	Before	After	with gre	Differer	Befor	After	with gre	Differen	Temp	Before	with green	Difference	Before	with green wall	Difference
173	19.3	85	3	7	17.8	29.4	25.5	24.3	5.1	17	16	14.5	2.5	17.3	25.5	24.5	18.7	6.8	16	16	12.8	3.3	16.8	25.7	23.4	2.3	16.2	13.4	2.8
174	14.6	90	3.1	7	13.1	25.1	21	19.8	5.3	11.7	8.9	9.2	2.5	12.6	21	18.4	13.6	7.4	11	10	7.5	3.3	12.1	21.3	18.9	2.4	10.9	8.1	2.8
175	13.4	92	3.1	8	11.9	21.8	18.5	17.3	4.5	10.2	9.2	7.6	2.6	11.4	18.4	17.3	12.4	6	9.2	9	6.2	3	10.9	18.7	16.3	2.4	9.3	6.5	2.8
176	20.9	75	2.8	6	19.4	33	28.4	27.1	5.9	19.4	18	16.7	2.7	18.9	28.3	27.5	20.6	7.7	18	18	14.7	3.6	18.4	21.9	26.2	-4.3	28.5	15.6	12.9
177	24.2	68	2.2	4	22.7	40.6	34.3	33.1	7.5	26.3	24	22	4.3	22.2	34.3	33.7	24.8	9.5	24	24	19	5	21.7	34.4	32.2	2.2	24.1	20.6	3.5
178	24.8	66	1.9	7	23.3	34.6	30.7	29.5	5.1	25.2	24	21.8	3.4	22.8	30.7	29.8	24.1	6.6	24	24	19.6	4.2	22.3	30.9	28.6	2.3	23.9	20.4	3.5
179	22.5	73	3.8	4	21	38.5	32.6	31.4	7.1	21.5	20	18.3	3.2	20.5	32.6	32	23.1	9.5	20	20	16.2	3.8	20	32.7	30.5	2.2	20	17.2	2.8
180	22.2	74	2	6	20.7	34.4	29.6	28.4	6	22.3	19	18.9	3.4	20.2	29.6	28.8	27.1	2.5	21	20	19.4	1.2	19.7	35.5	27.5	8	20.4	17.8	2.6
181	24.6	71	2.1	3	23.1	43.3	36.2	34.9	8.4	28	25	23.2	4.8	22.6	36.1	35.6	33.9	2.2	25	25	22.3	3	22.1	36.3	34.1	2.2	25.3	21.9	3.4
182	27.1	60	2.3	0	25.6	36.9	42.9	41.7	-4.8	33.6	30	27.9	5.7	25.1	42.9	42.5	40.8	2.1	30	30	27.1	2.9	24.6	42.9	40.8	2.1	30	26.5	3.5
183	33.9	48	4	0	32.4	56.6	48.4	47.1	9.5	40.8	38	35.6	5.2	31.9	48.3	48	46.3	2	38	38	35	3.1	31.4	48.4	48.3	0.1	38.1	37.8	0.3
184	36.2	62	4	2	34.7	54.2	47.5	46.3	7.9	42.9	41	38.6	4.3	34.2	47.5	47.1	45.4	2.1	41	41	37.7	3	33.7	47.6	45.4	2.2	40.7	37.1	3.6
185	30.3	76	2.5	2	28.8	50	42.5	41.3	8.7	36.1	33	31.3	4.8	28.3	42.5	42.1	40.4	2.1	33	33	30.4	2.9	27.8	42.6	40.5	2.1	33.4	29.9	3.5
186	33.7	64	3.4	3	32.2	33.7	44	42.7	-9	39	37	34.8	4.2	31.7	44	43.5	41.7	2.3	37	37	33.9	3	31.2	44.1	41.9	2.2	36.9	33.3	3.6
187	28.1	74	2.9	5	26.6	41.4	36.3	35	6.4	30.1	28	26.3	3.8	26.1	36.2	35.6	33.8	2.4	28	28	31.3	-2.9	25.6	37.7	34.1	3.6	28.2	24.8	3.4
188	23.8	70	3.3	2	22.3	44.2	36.7	35.5	8.7	25.5	23	20.8	4.7	21.8	36.7	36.2	34.5	2.2	23	23	20.1	2.9	21.3	36.8	34.6	2.2	23.1	19.7	3.4
189	27.6	63	4.1	5	26.1	40.6	35.7	34.4	6.2	28.1	27	24.4	3.7	25.6	35.6	33.7	33.2	2.4	27	18	23.4	3.2	25.1	35.8	33.5	2.3	26.7	22.8	3.9
190	18.9	84	5.2	8	17.4	26.7	23.6	22.4	4.3	14.8	14	12.6	2.2	16.9	23.6	22.5	20.6	3	14	14	11.9	2.4	16.4	23.9	21.5	2.4	14.3	11.5	2.8
191	17.9	74	3.8	4	16.4	34.4	28.3	27.1	7.3	16.2	15	13.2	3	15.9	28.3	27.7	25.9	2.4	15	15	12.5	2.3	15.4	28.4	26.2	2.2	14.9	12.1	2.8
192	22.6	63	2.3	1	21.1	46	39.6	36	10	26.4	30	21	5.4	20.6	37.2	36.8	34.9	2.3	23	23	20	3.1	20.1	37.3	35.2	2.1	23.1	19.8	3.3
193	28.8	53	2.8	3	27.3	46.1	39.5	36.8	9.3	32.4	30	26.6	5.8	26.8	39.5	39	37.3	2.2	30	30	27	3	26.3	39.6	37.4	2.2	30.1	26.5	3.6
194	19	82	4.2	8	17.5	26.8	23.7	22.5	4.3	15.4	15	13.1	2.3	17	23.7	22.6	20.7	3	15	15	12.3	2.4	16.5	23.9	21.5	2.4	14.8	12	2.8
195	18.7	93	4.1	8	17.2	26.5	23.4	22.2	4.3	15.1	15	12.9	2.2	16.7	23.4	22.3	20.5	2.9	15	14	12.1	2.4	16.2	23.7	21.3	2.4	14.6	11.8	2.8
196	21.9	86	3.7	6	20.4	33.5	29	27.8	5.7	19.8	19	17.2	2.6	19.9	29	28.2	26.4	2.6	19	19	16.4	2.4	19.4	29.2	26.9	2.3	18.8	16	2.8
197	21.8	92	2.6	4	20.3	29.5	26.5	25.3	4.2	19.7	19	17.3	2.4	19.8	26.5	25.4	23.5	3	19	19	16.4	2.6	19.3	26.7	24.3	2.4	19	16.2	2.8
198	25.2	70	1.8	4	23.7	41.2	34.9	33.7	7.5	28.3	26	23.9	4.4	23.2	34.9	34.3	32.6	2.3	26	26	23	2.9	22.7	35.1	32.8	2.3	26	22.6	3.4
199	26.7	73	5.3	4	25.2	41.4	35.9	34.7	6.7	26.5	25	22.6	3.9	24.7	35.9	35.4	33.6	2.3	25	25	21.7	3	24.2	36.1	33.8	2.3	25	21.1	3.9
200	22.5	74	3.3	5	21	35.9	30.9	29.6	6.3	21.1	20	18.3	2.8	20.5	30.8	30.2	28.4	2.4	20	20	17.6	2.3	20	31	28.7	2.3	20	17.2	2.8
201	19.7	85	2.7	6	18.2	31.6	26.9	25.7	5.9	18.2	17	15.4	2.8	17.7	26.9	26.1	24.3	2.6	17	17	14.6	2.4	17.2	27.1	24.8	2.3	17.1	14.3	2.8
202	21.6	87	2.5	5	20.1	35.4	30.1	28.9	6.5	21.3	20	18.1	3.2	19.6	30.1	29.4	27.6	2.5	20	20	17.3	2.4	19.1	30.2	28	2.2	19.7	17	2.7
203	25.1	73	4.5	4	23.6	40	34.4	33.2	6.8	24.6	23	20.7	3.9	23.1	34.4	33.8	32.1	2.3	23	23	20	2.9	22.6	34.5	32.3	2.2	22.4	19.6	2.8
204	23.7	70	3.6	4	22.2	38.9	33.2	32	6.9	23.3	22	19.7	3.6	21.7	33.2	32.6	30.8	2.4	22	21	19	2.5	21.2	33.3	31.3	2	21.5	18.6	2.9
205	22.4	66	2.5	5	20.9	36	30.7	25.6	10.4	22.1	20	17.8	4.3	20.4	30.7	30	28.2	2.5	20	20	18	2.4	19.9	27.1	28.5	-1.4	19.5	17.7	1.8
206	24.6	71	2.5	8	23.1	31.9	29	27.8	4.1	23.3	22	20.3	3	22.6	29	28	26.1	2.9	22	22	19.5	2.9	22.1	29.2	26.8	2.4	22.4	19.2	3.2
207	18.7	91	6.5	8	17.2	29.9	25.7	24.5	5.4	14.7	14	12.4	2.3	16.7	25.7	24.9	23.1	2.6	14	14	11.7	2.3	16.2	25.9	23.6	2.3	14.1	11.3	2.8
208	21	80	3.9	5	19.5	34.3	29.2	28	6.3	18.9	18	16.2	2.7	19	29.2	28.5	26.7	2.5	18	18	15.5	2.4	18.5	29.4	27.1	2.3	17.9	15.1	2.8
209	19.2	87	6.7	8	17.7	26.5	23.6	22.4	4.1	14.6	14	12.5	2.1	17.2	23.6	22.6	20.7	2.9	14	14	11.7	2.4	16.7	23.8	21.4	2.4	14.2	11.4	2.8
210	19.3	81	6.3	8	17.8	26.6	23.9	22.5	4.1	14.8	12	12.7	2.1	17.3	20.1	22.6	20.8	-0.7	14	14	11.9	1.9	16.8	23.9	21.5	2.4	14.3	11.6	2.7
211	18.1	81	5.4	5	16.6	31.3	26.4	26.2	5.1	14.8	14	13.6	1.2	16.1	19.4	25.7	23.9	-4.5	13	14	11.6	1.1	15.6	26.6	24.2	2.4	13.9	11.1	2.8
212	17.8	71	3.3	3	16.3	35.9	29.1	24.9	11	16.9	15	13	3.9	15.8	19.7	28.6	26.7	-7	13	15	12.9	0.3	15.3	29.2	27	2.2	15.3	12.6	2.7
												averag	3.448								averag	2.588						average	3.2225
												range	1.2-5.8								range	0.3-5.0						range	0.3-3.9

Skyview factor

Steenstraat	Before	0.366	
	After	0.218	reduce 1.5C for green wall placement
Karel van Gelderstraat	Before	0.217	
	After	0.171	reduce 2.0C for green wall placement
Parkstraat	Before	0.229	
	After	0.229	reduce 2.5C for green wall placement

REFFERENCES

-Meehl, G. A., Stocker, T. F., Collins, W. D., Friedlingstein, P., Gaye, A. T., Gregory, J. M., ... & Raper, S. C. (2007). Global climate projections. Climate change, 3495, 747-845.

-Site-design : Webteam Spijkerkwartier Site-bouw : Webteam Spijkerkwartier, i. (2016). Spijkerkwartier/Spoorhoek - Website van de meest dynamische wijk in Arnhem. [online] Spijkerkwartier.net. Available at: http://www.spijkerkwartier.net/ [Accessed 20 Dec. 2016].

-Höppe, P. (1999). The physiological equivalent temperature–a universal index for the biometeorological assessment of the thermal environment. International journal of Biometeorology, 43(2), 71-75.

-Lenzholzer, S. (2015). Weather in the City-How Design Shapes the Urban Climate. Amsterdam: nai010 publishers.

-PICO 6.0. (2016). Pico.geodan.nl. Retrieved 21 December 2016, from http://pico.geodan.nl/beta3/

-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

-Klimaatmonitor.databank.nl. (2016). Jive. [online] Available at:https://klimaatmonitor.databank.nl/Jive [Accessed 21 Dec. 2016].

-Brouwers, H. J. H., & Entrop, A. G. (2005). New triplet visions on sustainable building.

-Hezel, Rudolf. "Novel Applications Of Bifacial Solar Cells". Progress in Photovoltaics: Research and Applications 11.8 (2003): 549-556. Web.

-Ortabasi, Ugur asi,. "BIFACIAL LIGHTWEIGHT ARRAY FOR SOLAR POWER". 1996: n. pag. Print.

-Spruijt, Jojanneke. "Zonneweide Energierijk : Resultaten 2011-2012." (2012) Lelystad : ACRRES - Wageningen UR (PPO-526) - 25 p

-Albedo. (2016). En.wikipedia.org. Retrieved 21 December 2016, from https://en.wikipedia.org/wiki/Albedo

-Chow, T.T. "A Review On Photovoltaic/Thermal Hybrid Solar Technology". Applied Energy 87.2 (2010): 365-379. Web.


Lee