A sustainable landscape for Arnhem.
The contribution energy transition has to CO2 neutrality.

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Taícia Marques and Jaime Gómez de la Fuente

Summary

Since the discovery of fossil fuels as main source for the generation of energy, the landscape has being transformed and shaped in order to accommodate these infra structures. The generation of energy by non-renewable sources is also responsible for the largest amount of greenhouse gas (GHG) emissions in the planet, with especial attention to carbon dioxide (CO2) (MacKay, 2009). The European Union defined a target of 80% CO2 reduction by 2050.

On this context, Dirk Sijmons (TU Delft and H+N+S Landscape Architects), proposed a studio which had the goal to produce the third part of an Energy Atlas, (Kleine Energie Atlas). Therefore, the present thesis focus on the case of Arnhem as the contribution for the Atlas.

The 'Five-Step Approach' (Stremke, 2010) methodology is used. First of all, we made a landscape analysis, followed by the energy and CO2 inventory and potentials. As a result we were aware about the functioning of Arnhem regarding the three energy carriers, electricity, gas and fuel and the areas with the best potentials to save, store and generate energy. By applying this information to two different socio-economic scenarios, we designed two visions and focus on two site specific interventions. As a result, we found that the potential for generation of energy in Arnhem is low. The focus on saving, storage and exchange measures should be made. The amount of CO2 to be neutralized reaches approximately 50% when the possibilities are found only inside the borders of the Municipality. The perspective of policy makers, researchers and landscape architects frame the conclusions. There is a need for cooperation between, government, private parties and social representations in order to have an effective energy transition and CO2 reduction.

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Chapter I
Introduction

The sun is known as the source for life. Plants for instance, can get energy from solar radiation in order to make photosynthesis, the essential process for its growth. Also the wind has a close relation with sun, since it is generated by the difference of temperature on the air caused by solar radiation. Therefore, when energy transition is considered the first thought is about the potentials provided by the sun. On this report, two direct means of using this source in order to generate energy will be discussed. The first is the potential to generate electricity by using solar photovoltaic cells (PV cells), the second the use of solar collectors to heat production.

Photovoltaic solar cells (PV cells) are responsible for the conversion of solar radiation into electricity. The system is made by individual PV cells organized into solar panels. The technology can be used for punctual needs (e.g. light pole on the street) or be connected to the electricity grid when a large scale implementation is necessary (e.g. solar parks). When the potential for electricity generation by PV cells is analysed in Arnhem, the national average of solar radiation per square meter of 1000 KWh/ m2 is considered. Due to the fact this number is used in many documents and is only slightly lower than the optimal condition for the region Arnhem-Nijmegen (European comission JRC) it was the base for the calculations on this report. Furthermore, the current efficiency of the system, between 10 to 20%, is used as parameter (KEMA,2009). On the map bellow it is possible to notice the availability of roofs as well as the open fields which has potential for solar parks implementation. These fields are mainly composed by agricultural plots inside the municipality borders. Another possibility is to correlate the solar panels park with wind parks on the north of the city in order to have a hybrid system.

Figure 1.1. (previous page) Wind farm in Dardesheim, Germany, (J.Gómez)

1.1 Relevance

Since the discovery of fossil fuels as main source for generating energy, the landscape has being transformed and shaped in order to accommodate these infra structures. Furthermore, large amounts of energy are spent to transport and conserve energy (Steiner, 2002). The generation of energy by non-renewable sources is also responsible for the largest amount of greenhouse gas (GHG) emissions in the planet, with especial attention to carbon dioxide (CO2) (MacKay, 2009). The global perspective of climate change, besides the depletion of fossil fuels, has receiving attention especially since the 90's. Industrialized countries promoted meetings and produced documents enhancing the necessity of invest on energy transition and the reduction of greenhouse gas emissions. Common targets have being established and resulted on the current global commitment to mitigate climate change effects. It is on this context that The Netherlands defined the goals the country should achieve during the next decades.

In 1997 the Kyoto protocol was negotiated between industrialized countries. According with this treat, greenhouse gas emissions should be decreased on 5,2% until 2010 compared with 1990. Along the years, The Netherlands established its own targets based on the international documents. In 2008, a commitment of 6% reduction by 2012 was made (Netherlands Environmental Assessment Agency, 2008). There was an emphasis that energy transition strategy and the reduction of CO2 emissions should be faced by each municipality focusing on the achievement of the national goal. Another document, the Fourth National Environmental Policy, defined 20% of the energy consumed in The Netherlands should be provided by renewable sources by 2020, next to 2% energy efficiency improvement per year since 1990. CO2 emissions should also be reduced on 30% by 2020 when compared with 1990.

The challenges for the next forty years were the focus of attention in 2009. The European Union countries together with the G8 (the eight largest economies in the world) agreed a target of at least 80% reduction of CO2 emissions by 2050 when compared with 1990 (European Comission, 2011). Hence, The Netherlands is re-defining its strategy to accomplish the global goals for 2050.

Based on this discussion, Dirk Sijmons (TU Delft and H+N+S Landscape Architects), proposed a studio to be followed by students from the Landscape Architecture and Planning department at Wageningen UR, and the Architecture and Urbanism department at TU Delft. The studio had the goal to produce the third part of an Energy Atlas, (Kleine Energie Atlas). While the first two parts, energy consumption (I) and energy sources (II), comprises basic concepts, the third, aims to investigate the meaning energy transition (III) has to spatial planning in four different locations in The Netherlands and crossing borders with Germany and Belgium.

In order to work with long term actions, two scenarios, Business as Usual (BAU) and Less is Better (Less), were introduced by the studio assuming the European Union's goal to reach 80% CO2 emissions reduction by 2050 (kWh/m2 project, 2011).

As a contribution for the third Atlas, the present thesis will attend the KWh/m2 project by redefining its main research question from the perspective of Landscape Architects. Moreover, Arnhem was chosen as the location where the project will focus on. Besides to contribute for the Atlas, our goal is also to provide the policy makers of the municipality with step advices by making them visualize how the landscape will look like in forty years when energy transition and CO2 neutrality are considered.

1.2 Theoretical Lens

When dealing with the shape of the landscape, the transition from fossil fuels to renewable sources is well explained by Stremke and Koh (2011). According to them, there is a need for 'energy- conscious planning and design'. Complementing this issue, the authors emphasize landscape architects have a challenge regarding the shift from designing 'fossil fuels energy landscape' to design sustainable energy landscapes. A sustainable (energy) landscape "comprises and is part of several energy systems that effectively utilize renewable energy and networks" (Stremke, 2010, p. 09). During this thesis, we will refer to sustainable landscape or sustainable 'energy' landscape. Both formats express the same idea.

A sustainable energy landscape comprises also the concepts of exergy and entropy. While the first law of Thermodynamics states that energy is always conserved, the second law presents exergy and entropy in order to introduce the necessity of identify and minimize losses in energy provision, conversion, storage and transport. As a result, the energy conscious landscape planning and design is challenged by three general obstacles: periodic fluctuations, low energy density and limited utilization of available energy by consumers. In order to overcome such obstacles concepts such as biorhythm, storage and differentiation of niches on site specific solutions are essential (Stremke, 2011).

Supported by these concepts, we, as Landscape Architects, will analyse Arnhem by considering the possibilities which supports the idea of designing a sustainable energy landscape. It is beyond our task to make a deep socio-economic analysis as well as to discuss in detail all the possible solutions and technologies. Our aim is to provide an overview about the possibilities to generate, store, save and be energetically more efficient in Arnhem. Even though general guide lines will be provided, the focus will remain on the landscape scale.

1.3 Research questions

The research question of this thesis was defined according with the inputs from the KWh/m2 Studio and from the municipality of Arnhem. The main question was sub-divided into more specific ones in order to guide the research.

According with the KWh/m2 studio, the major question to be answered was:

"What will the energy transition mean for spatial planning?"

For the municipality of Arnhem, the goal would be to achieve CO_2 neutrality by promoting energy transition. Based on the two requirements what we, as landscape architects, would like to know? Which are the expected outcomes of this research?

We are eager to propose a sustainable energy landscape. Our target is to design a landscape that works as a connection between the areas with highest feasibility for generating, saving, consuming and storing energy. Moreover, since the CO_2 neutrality is the main goal of the municipality, it is essential for us to know how much contribution the energy transition will have for Arnhem. Hence, the main research question is composed by two parts, as follow:

How the landscape in Arnhem will look like when energy transition is considered? and How these interventions will contribute to CO_2 neutrality in the city?

In order to answer these questions other five sub-questions were proposed:

How does Arnhem function regarding energy consumption and CO_2 emissions?

Where the near future developments are located in Arnhem and how much relevance they have for the challenges of energy transition and CO_2 neutrality?

Based on socio-economic scenarios, what kind of possible long-term developments are expected in the city?

How can we change possible futures into desired futures by designing a sustainable energy landscape?

Which desired intervention should be implemented?

1.4 Theoretical Framework

In order to frame the research question, to define our worldview and the theoretical framework is necessary.

The intension is to interpret site specific characteristics related with the generation, storage, saving and consumption of energy related with other features of the landscape. For instance, the land use and peoples activities in the city will be related with the main topic, energy. By using a theoretical framework we will define the possibilities the landscape of Arnhem has and how the potentials and limitations can be used in order to design a sustainable landscape.

Two correlated theories regarding the challenges of energy transition will compose our base, the Trias Energetica (Lysen, 1996) and the Low-Ex concept. The last will be used according with the discussion proposed by Sven Stremke et. Al. (2011) and Andy van den Dobbelsteen (2012).

Trias Energetica

When dealing with energy transition the slow long term process involved must be considered. According with Lysen (1996) the shift from fossil fuels to renewable energy sources will take from 50 to 100 years. Considering that, strategies should be laid out aiming an efficient implementation and consequent accomplishment of the energy goals regarding renewable energy sources. As a result, the author introduced the concept of Trias Energetica, based on three main strategies:

1.- Reducing the consumption by energy saving

2.- The production of energy should be as much as possible by renewable resources

3.- Use of fossil fuels should be as clean and efficient as possible

One of the main goals of the Trias Energetica is the reduction of CO2 emissions due to use of renewable energy sources and the implementation of energy efficiency measures. (Figure 1.2). These goals are closely related with the discussion Stremke et al. (2011) proposed by correlating the second law of thermodynamics and the challenges to design sustainable landscapes.

The researchers applied to the landscape design, the approach of Low-Ex which " aims to reduce exergy destruction in the built environment by facilitating and accelerating the use of low- valued and environmentally sustainable energy sources for the heating and cooling buildings" (Stremke et al., 2011, p. 163).

As well as the Trias Energetica concept, the Low-Ex approach proposes three main principles for the built environment concerning exergy:

1.- Use of high-exergy sources only for high-grade process (e.g. natural gas for metal melting)

2.- Reduce exergy destruction through efficient technologies (e.g. heat recovery systems)

3.- Find low-grade functions for waste flows from high-grade processes (e.g. room conditioning, cascading?)

Considering the large impact on land use the introduction of renewable energy sources would have, Stremke et. Al (2011) stress the necessity to improve all energy flows efficiency in order to "(...) minimize entropy production and mitigate land-use pressure". On this context the Low-Ex approach together with energy thermodynamics and industrial ecology concepts form the basis for exergy-conscious and influences the way landscape architects design sustainable energy landscapes.

Following the same line of thinking, Andy van den Dobbelsteen (2012), assumes the "full self-sufficiency is not necessarily the goal" (p.3) when we work on the scale of a city. Nevertheless the measures to turn a city less dependent of fossil fuels next to be resilient during an energy crises period is needed. Based upon this statement the author proposes three main steps:

1.- To invest on savings (reduction of consumption)

2.- Exchange and storage of energy

3.- Energy generation by renewable sources

As a conclusion, forming the theoretical framework of this research we are going to follow four steps for the energy transition:

1.- To reduce the consumption of energy by saving

2.- Focusing on measures to store and exchange energy (decrease exergy)

3.- Generate as much as energy by renewable sources

4.- Use of high-exergy sources for high-grade process

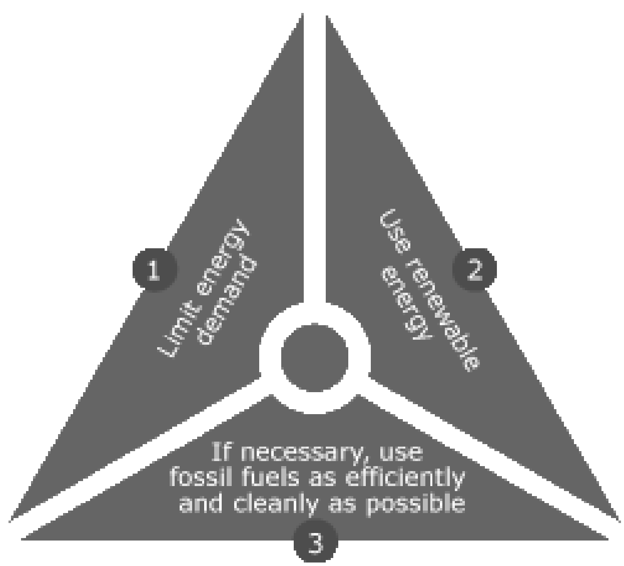


Figure 1.2. Trias energetica concept (Lysen 1996)

1.5 Methodology

In the context of this thesis, the theoretical framework will be based on a mixed method of research. The worldview will be the pragmatic (research through design). As Creswell (2009) presents, by applying a pragmatic worldview, the researchers emphasize the research problem and use all approaches available to understand the problem.

A Methodology comprises the research methods used to data collection, analysis and interpretation (Creswell, 2009). Aiming on answering the research questions and sub-questions, this thesis applies a methodology related with the integrative energy vision of the "Five-step approach" introduced by Stremke (2009) (Figure 1.3).The first two steps will be developed in cooperation between Jaime Gómez de La Fuente and Taícia Marques. The other three steps will be conducted individually based on different socio-economic scenarios. As a conclusion a comparison between the two scenarios and correlated visions (steps three and four) will be made. The comparison will use a clear criteria of evaluation and focus on the robustness of the systems. By doing so, the outcomes of the research will be explained from the perspective of policy makers, researchers and landscape architects.

The first two steps are basically related with the objective and subjective collection and analysis of data such as, maps, potentials for saving, generating and storing energy, photographs and observation. These steps are related with the followed sub-questions:

1. How does Arnhem function regarding energy consumption and CO2 emissions?

2. Where the near future developments in Arnhem are located and how much relevance they have for the challenges of energy transition and CO2 neutrality?

The introduction of socio economic scenarios on the third step will discuss how the current situation of Arnhem can be influenced for instance by the climate change while answer the sub-question:

3. Based on socio-economic scenarios, what kind of possible long-term developments are expected in the city?

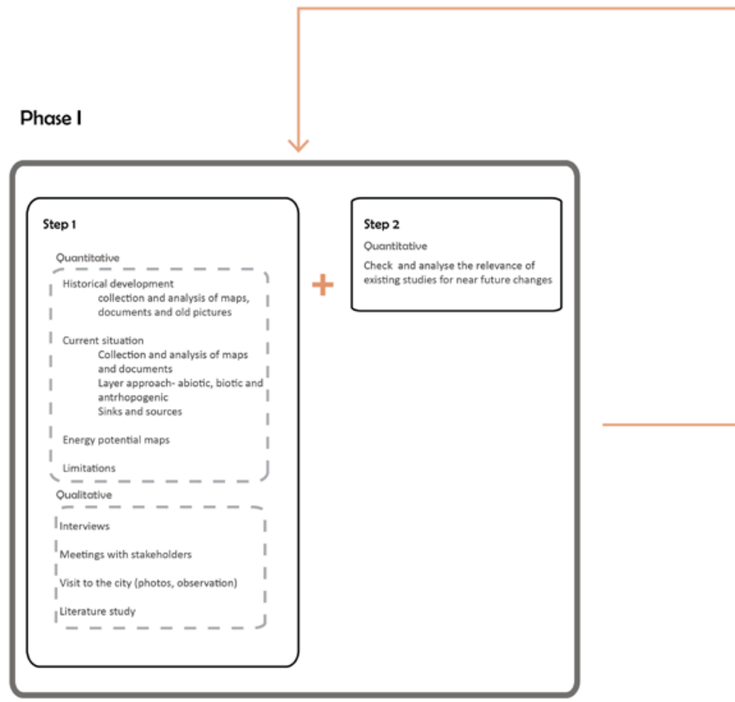
The shift from possible futures into desired futures will be made during the fourth step, when the researchers will propose visions based on the two scenarios accessing the sub-question:

4. How can we change possible futures into desired futures by designing a sustainable energy landscape?

The last sub-question will receive attention during the fifth step which comprises the design of a robust intervention.

5. Which energy-conscious intervention should be implemented?

The criteria used for the comparison will be based on the relation between the technologies used in each of the visions besides the place where they are implemented and the amount of energy generated. Furthermore, the general conclusions of each vision will be correlated and receive the focus of the three groups: policy makers, researchers and landscape architects.



Phase I
Step 1
Quantitative
Historical development
collection and analysis of maps, documents and old pictures
Current situation
Collection and analysis of maps and documents
Layer approach- abiotic, biotic and antrhopogenic
Sinks and sources
Energy potential maps
Limitations
Qualitative
Interviews
Meetings with stakeholders
Visit to the city (photos, observation)
Literature study
Step 2
Quantitative
Check and analyse the relevance of existing studies for near future changes

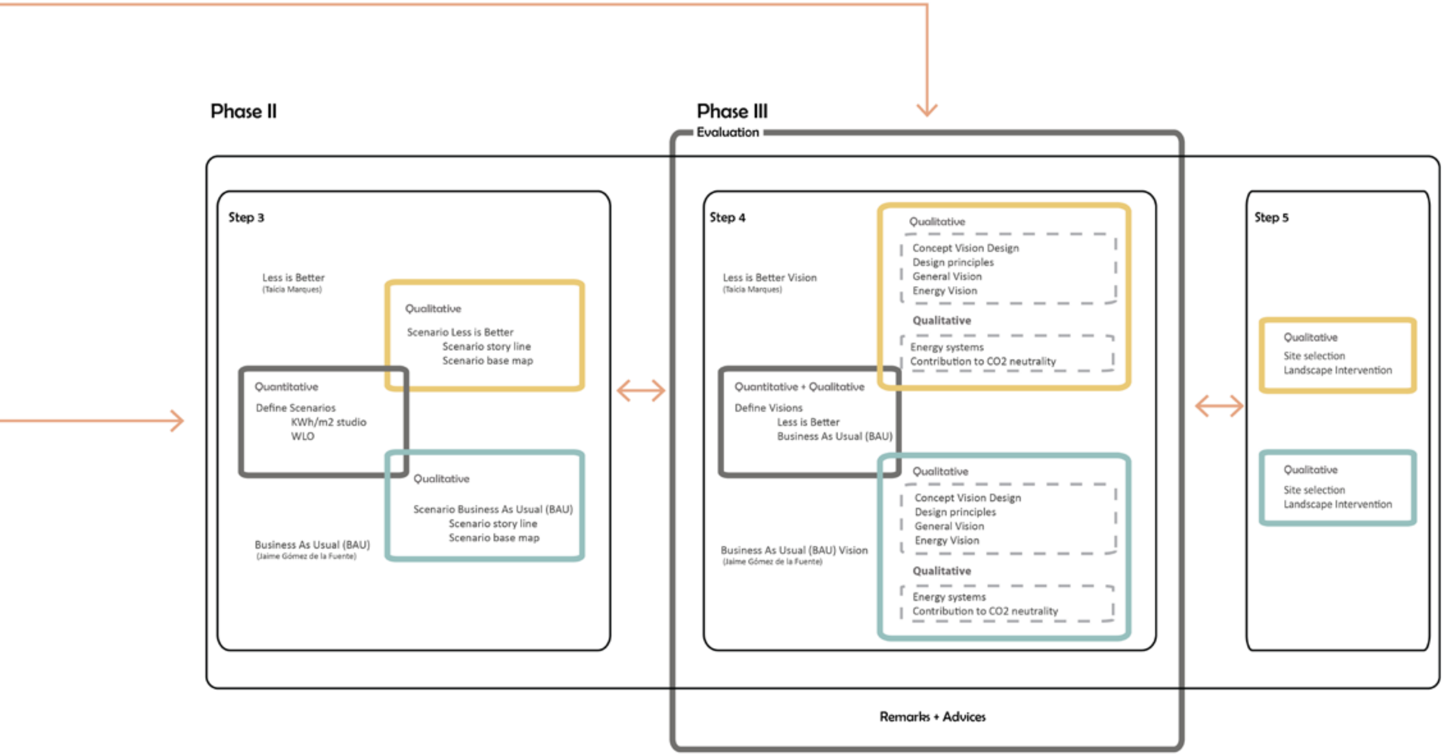


Figure 1.3. "5 Steps approach" methodology (Stremke 2010)

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Chapter II

Landscape Analysis & Site introduction

During the next three chapters (**II**, **III** and **IV**) we will explore the ***step 01*** of the methodology in order to answer the sub-question:

1. How does Arnhem function regarding energy and CO2 emissions?

The current chapter will present the historical development of Arnhem and the current situation of the city. Regarding the historical development, maps, documents and photographs form the base of our data collection and will be organized along the time until the 21st century. The first part consists on an overview since the Pleistocene Era until the 15th century. From the 15th century maps and photographs will illustrate the information presented. Energy will be included as soon as it was found on the data collected. However, considering the lack of documents regarding this topic, it was not possible to know precisely which kind, sources and the amount of energy have been used in Arnhem. After the historical perspective, three layers of the landscape, abiotic, biotic and anthropogenic will be used to detail the current situation of Arnhem. As a conclusion the limitations found on the landscape of the city according with, history, abiotic, biotic and anthropogenic features will be defined.

Figure 2.1. (previous page) Biomass - Woodchips to be used in Jühnde, Germany (J.Gómez)

2.1 Historical development

Pleistocene Era until 15th century

Arnhem is located on the slopes of the Veluwe moraines which were formed during the Pleistocene Era (2.5 million years to 10,000 years BP). Covered by a thick glacial layer, during the Glacial Period (370,000 to 130,000 years BP), the topography was deformed due to the high pressure of the ice originating the called push moraines and its glacial valleys. Moreover, the dense layer of ice worked as a barrier for the braided rivers which characterized this period. As a consequence, the river's flows were shifted from the north direction to the west. Currently this topography is identified by the presence of the Veluwe slopes (push moraines) and the river Rhine.

Another important feature of the landscape in Arnhem is the presence of sandy soils. This feature has its consequence due to events during the last stage of the Pleistocene Era, the Weichselian Glacial Period (115,000 to 10,000 years BP). The ice from the previous period melted and winds were responsible for aeolian deposition of sand on the moraines and its valleys, forming the layer of sand soils currently found in Arnhem (this feature will be better described on the **sub-chapter 2.2**).

As well as the other cities located on the region of Veluwe, the town had its origins near the water. Nevertheless, instead of have its first settlement close to the river Rhine, the main body of water, the city started its development along the brook St. Jansbeek. The brook was also at the intersection of two major trade routes which connected the north sea with the Rhine and the west with the east (Gemeente Arnhem, 2009). The first appearance of Arnhem on records dated from 893 when a church and farms could be found on the banks of the St. Jansbeek brook. Was only in 1233 that Arnhem gained its city rights (TTE, 2009). Even though Arnhem usually remained on a good position when compared with the other cities in the Veluwe, it faced periods of prosperity and decay along the centuries.

Regarding the sources of energy the existent documentation is not so precise. It is known that Arnhem was used to burn peat imported from other areas as a source of energy. Moreover, the location of the city along the brooks, make it possible to install water wheels to, for instance, grind grains. The first water wheel was built on the St. Jansbeek brook by the end of the 13th century. During the next years other ten watermills were built along this stream being three inside the fortifications and seven outside (Figure 2.2). Currently two water wheels can be seen, the Witte Watermolen and the Agnieten/Begijnenmolen. The last one was converted into the water museum and is located inside the Sonsbeek Park (Arneym, 2011).

Figure 2.2. De Witte Watermill (Panoramio : W. Gadellaa)

15th and 16th century

This period is marked by constant changes in government which affected economic, social and cultural aspects in the cities located on the Veluwe. Regarding nature, by 1500 most of the trees around Arnhem, on the Veluwe, were cut down in order to create a siege open area.

During the 16th century, even though the Veluwe was occupied by the Spanish army, Arnhem had a phase of prosperity if compared with the other cities. This fact happened due to two main reasons, the first was the joint to the Hanseatic League in 1514 and the second the gained of importance as the capital of the province of Gelders.

The Hanseatic League was an economic alliance trading between cities and their merchant guilds (craftsmen association). The monopoly of trade was extended from the Baltic to the North sea and inland achieving most parts of the northern Europe. Even though commercial interests and privileges were protected by the League, Arnhem had its own legal system.

The second main reason of prosperity is based on the fact that in 1543 Arnhem became the capital of the Gelders attracting many governmental institutions to have its seats there.

As a consequence of the wealthy period due to the economic alliance and the attraction of governmental institutions, important physical modifications were made in the city and its surroundings. Considering the prevalent sandy soil was a barrier for transportation over the Veluwe, the water bodies became responsible for the main communication between the cities in the south (along the river Rhine) and in the north (along the former Zuider zee). As a consequence of the growth of trading, around 1530 the river Rhine was dug along the city (Figure 2.3). Furthermore, few ferries linked its north and south banks. Together with other three roads, over the already existent dykes, the ferries made the accessibility to Nijmegen being possible from Arnhem and vice-versa. The first map of Arnhem dates from 1560 and already include these features.

Regarding the fortification, Arnhem followed the pattern of defences found in other cities of the Veluwe. The defence line was then composed by a sequence of walls and moats. The first wall had an inner moat and fortified gate houses. Located after the inner moat, the second wall was composed by round bastions and followed by the outer moat with dawn bridges in each gate. The first map of Arnhem dates from 1560 and already comprises the modifications (Figure 2.4).

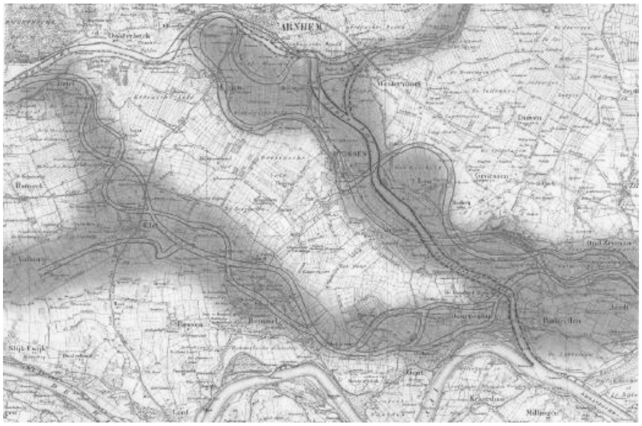


Figure 2.3. Change river course (Arneym)

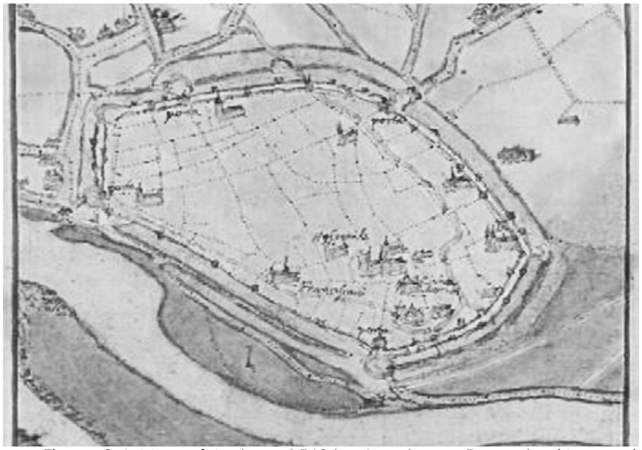


Figure 2.4. Map of Arnhem 1560 by Jacob van Deventer (Arneym)

17th and 18th century

The 17th century is marked by the definitely left of the Spaniards. In general, this fact resulted on the prosperity of the cities located in the Veluwe region. Improvements related with urban amenities such as paved streets, street light and garbage disposal received attention. However, Arnhem and Wageningen were the only two cities in the region which presented measures to reinforce its defences (Figure 2.5). During the 17th century social and cultural improvements were emphasised on the entire region. The end of the prosperity arrived in 1672, the called “Year of Disaster”, when all the cities were captured by the French army or by the bishop of Munster leading to a long period of extortion and pillaging during the 18th century.

Due to the occupation occurred in the end of the 17th century the Veluwe cities faced a situation of poverty and decay which remained until the begin of the 19th century. Public buildings and town walls were collapsing, the population was claiming for governance changes and the lack of coherence between the different levels of authorities leaded to a still worse scenario. The well-to-do class started to leave from the decadent and dirty cities looking for a better condition to live in the countryside. As an exception, Arnhem was found in a reasonable state of defence as the city had a good military fortification system. Furthermore, the city was able to show some activity especially on the cultural level, with its own Art-school and the society ‘Tot Nut van’t Algemeen’ (To the General welfare). Was also during the 18th century that a large scale planting of trees started and Arnhem received the permission to demolish its defences, nevertheless this last measure was completely only during the 19th century (TTE,2009).

With regard to energy, besides the water wheels, treadmills, step mills and windmills were built in order to process grains, paper, oil and so forth. The first dates from 1635 and was located where currently the city hall is built. During the 18th century another one was constructed where the industrial park of the city was placed (on the east side of Arnhem) (Figure 2.6).

Figure 2.5. Map of Arnhem 1652 (Arneym)

Figure 2.6. Windmills in Arnhem, XIX century (Arneym)

19th century

After the withdraw of the French domination, in the beginning of the 19th century, the cities located on the Veluwe were still found on a poverty condition. Under the command of the king William I, some measures such as transportation, demolition of defences, gas works, construction of hospitals and cemeteries were taken in order to remedy the bad situation in the cities.

Regarding transportation, road connections were improved and stimulated (Arnhem-Utrecht, Arnhem-Zwolle, Amersfoort- Deventer) beside the demolition of many gatehouses. Railways started to compose one of the most important mains of transport. Most of the train stations were placed on the periphery of the old city centres. In the case of Arnhem its station gain prominence since were located as a result of an important railway-junction (Amsterdam -Utrecht-Germany).

Even though the plans to demolish the walls were firstly made during the 18th century, this process took time, been made slowly during the 19th century. Nevertheless, Arnhem was the first town to have its defences dismantled in 1829. On this particular case, the resultant boulevard received cultural buildings, such as the 'Musis Sacrum', a concert-hall with multi-cultural function.

Followed by the demolishment of the defence walls, Arnhem initiated a strong and haphazard urban development. New disorganized residential areas could be seen spread out the boulevard. In order to control this situation an urban plan has been made in 1849 (Figure 2.7). The enormous urban extensions were then implemented until 1872 with a high control by the city council and a clever real state policy, which bought the large plots from owners who were in financial straits.

The shift to an urban character of Arnhem was reinforced by the industrial development the city faced during the 19th century (Figure 2.8). New plans were made specially focused on laying out industrial areas separated from the residential quarters, but poor slam houses spread fast through the city.

Another important implementation was the placement of a gas factory in 1844 (Figure 2.9). The industry was first settled on the Roermondsplein, close to the former harbour, moving close to the new industrial park in Westervoortesdijk by 1866. After its definitive closure during the 20th century the gas factory left behind high level contaminated soil which is currently being remediated.

Besides the large implementation during the 19th century, the last three windmills named as 'Verwachtine', 'Harmonie' and 'de Hoop' were risen along the Amsterdamseweg nearby the city centre. By 1870 the only one which remained was 'de Hoop'. Nevertheless, it was moved to the place it can be found nowadays, Klarendalseweg, and received a new name "de Kroon" (Figure 2.10).

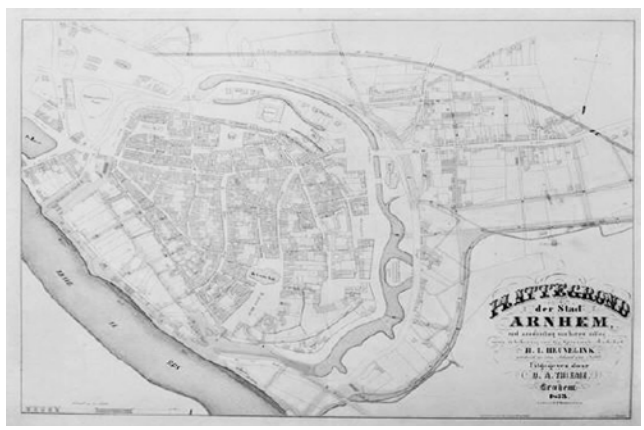


Figure 2.7. Map of Arnhem 1849 (Arneym)

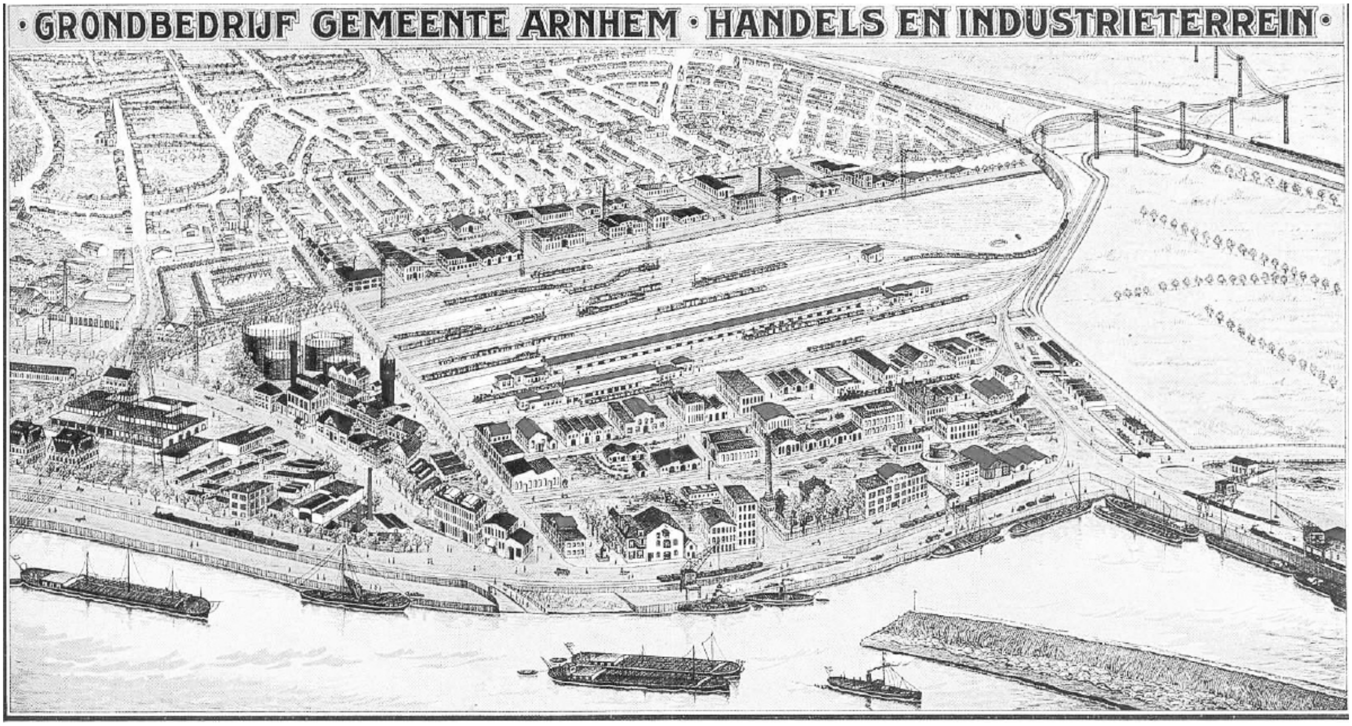


Figure 2.8. Industrial park in Arnhem (Arneym)

Figure 2.9. Gasfabriek-Roermondspelin, Arnhem, 1865 (Arneym)

Figure 2.10. "De Kroon"Windmill (Panoramio : F. van Unen)

20th century

During the 20th century Arnhem grew rapidly. Following the hygienist movement started on the end of the 19th century, new policy regarding specifications to build healthy dwellings, were applied in order to shift poor workers houses and slams into decent homes. The constructions were financed by the wealth society, interested in protect themselves from the threat of diseases, and worker's associations looking for improvement of their living conditions.

The economic crisis during the 30's caused the stagnation of the industrial park which leaded to a residential character of Arnhem rather than industrial.

During the next decade the World War II (WWII), heavily damaged the city. The battle of Arnhem left behind a city in ruins. Moreover, the main connection to the South over the Rhine, the John Frost bridge, was destroyed.

The growth of the city took place again after the end of the WWII specially during the 50's, when both, housing and industries received large investments. The construction market was based on real estate speculation founding on the International Architecture Style (modernism) the fastest, lowest budget and high profit construction. Mainly from 1945 to 1970 the landscape of Arnhem was filled with medium size towers of dwellings which faced the risk to decay during the last decades of the 20th century.

The increasing prosperity and new commuters leaded to a demand for other kind of dwelling. The shift from buildings to the wish of having more space to live, on one family houses with gardens generated different urban expansions in Arnhem. If the earlier occupations were characterized often by little more than dormitories, the new areas were equipped with schools, shops between a range of facilities. These characteristics can be found mainly in the expansions of the city through the polders area on the south banks of the river Rhine.

Regarding the industries, new large locations were necessary since accessibility by using private vehicles rose a lot after the WWII and the former industrial areas did not have enough parking lots to receive the amount of vehicles from its workers. This fact caused the shift from the periphery of the city centre, to the fringe areas of Arnhem. The former industries were then demolished or are still waiting for further developments.

The success of the large scale trees plantation during the 18th and 19th centuries provided Arnhem with large amounts of green areas along the slopes of the Veluwe. The new forest then interrupts the urban occupation downing the hill like green fingers. As a result the particular location of Arnhem, on the slopes of the Veluwe and counting with the river on its valley besides the large amount of green areas, made the city an attractive pole for tourism and recreation during the second half of the 20th century.

Besides to strengthen of the green areas of Arnhem, during the 20th century some of the most important companies related with energy have settled in the city. Even though the crises during the 30's affected the city, it was in the end of this decade, 1938, when the headquarter of Kema high voltage laboratory was installed in the city. The aim of the company was to test and certificate high voltage equipment (Kema, 2012). Just after the WWII, in 1946, was the turn of NUON De Kleef to install its structures in the industrial park Kleefse Waard supplying energy to other companies (NUON De Kleef, 2012).

Due to the presence of these headquarters together with others such as Alliander , TenneT, Essent and so forth, Arnhem was labelled as "Energy city" by the end of the 20th century. These companies are responsible for a wide range of works regarding energy, since strategic studies (e.g. Kema) until the management of gas and electricity networks (Alliander-Liander) and the generation and distribution of energy (e.g. NUON). Furthermore, innovation on new technologies is being explored by the companies. Partnerships with the municipality and research centres have being also established in order to face the new challenges of the 21th century.

2.2. Abiotic

The abiotic layer comprises the topography, soil composition, surface water and groundwater which can be found in Arnhem. Considering the location of the city, on the slopes of the Veluwe moraines, in the north, and on the polder's landscape, in the south, the height of the terrain varies almost 80m. The highest point is about 70m above NAP in the north and the lowest approximately 7.5m above NAP in the south (Figure 2.12)

The river Rhine flows on the bottom of the moraines to find its way out into the North sea. In Arnhem, the river receives the discharge of water from three main stream, Slijpbeek, Bronsbeek and Sint Jansbeek. All these brooks run partly on the surface and partly in the underground. Due to the annual flood of the Rhine, during the spring, large areas composed the flood plains along the south bank of the river. The north bank is protected by high walls on the limit of the urban settlements. In the flood plains the soil is predominantly composed by light and heavy clay rather than course sand like in the north (Figure 2.13).

Regarding the groundwater, shallow water table happens in the south. The composition of the soil besides the direction of the water flows, originate three aquifers which presents rough differences in the north and south. (Figure 2.14).

Due to the sand soils in the northern Arnhem, in general, the water can infiltrate fast. The underground water is then collected by the aquifer one, WVP1 (Water Voerende Pakket- WVP) about 15 to 20m below the surface. This feature provides a particular characteristic to the WVP1, since the aquifer gain a thickness of about 80m here. The high speed flow in the south direction causes the shallow water table in the polder areas, about 1m below the surface, when the water flows slowly. The other two aquifers do not varies so much from the south area, but keep a thickness of approximately 30m.

In the south, the level of the underground water is very much influenced by the amount which comes down the slopes in the north. Moreover the variability of the water level in the Rhine also influences the water table level in the south. The higher is the water in the river the shallow will be the water table.

The aquifers in the south, are organized according with two layers of soil and placed above a hydrological base (Figure 2.11). The first aquifer (WVP1) varies its thickness from 20 to 30m and is separated by the second aquifer (WVP2) by a discontinuous and impermeable layer of soil. The WVP2 varies its thickness in the south of Arnhem, between 30 to 40m. The last aquifer (WVP3) is the thinner one and has about 5m of thickness. The WVP3 is separated from the WVP2 by an inconstant layer of clay. Bellow all these layers, the hydrological base can be found on a depth of 80m below NAP (TTE,2009).

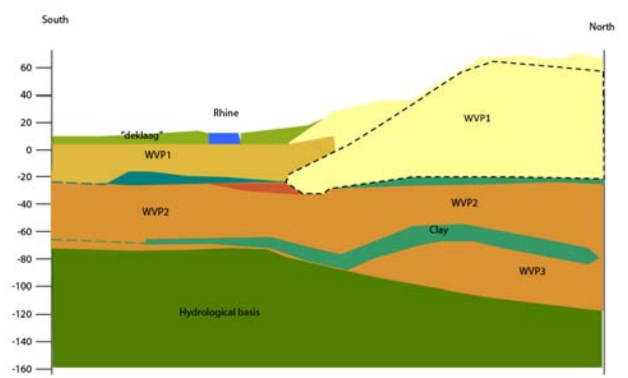


Figure 2.11. Section of aquifers (Gemeente Arnhem)

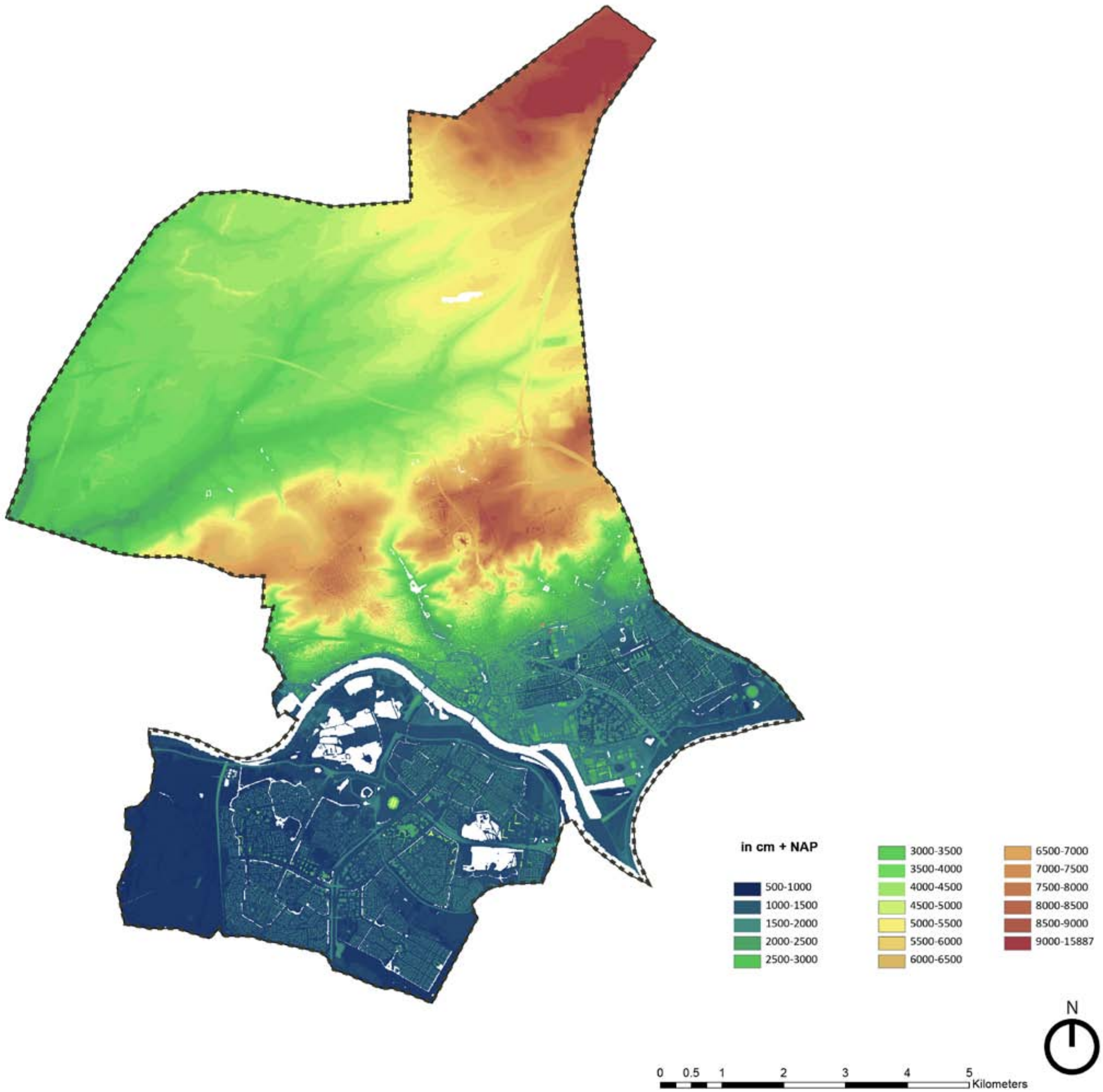


Figure 2.12. Elevation map

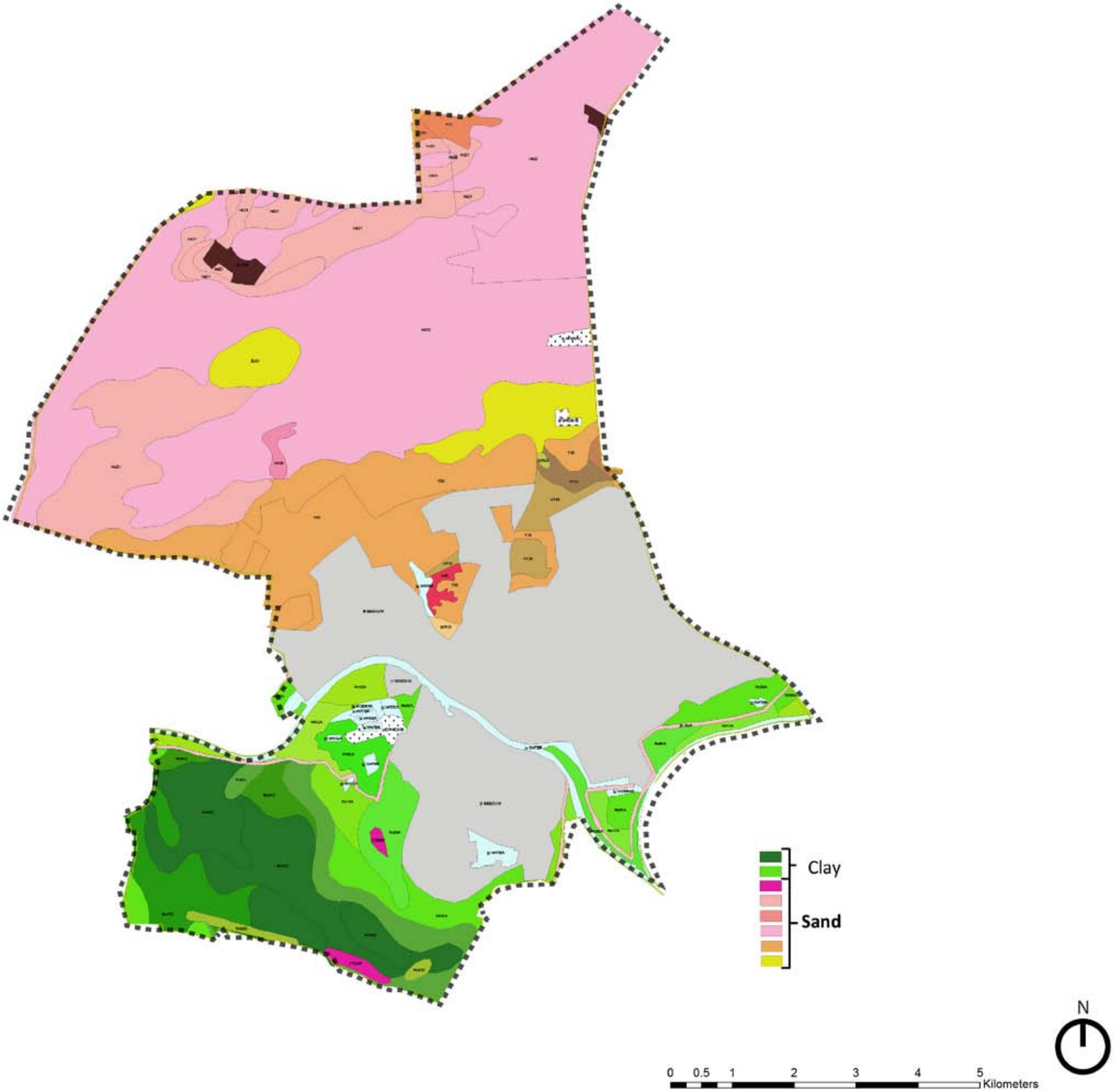


Figure 2.13. Soil composition map

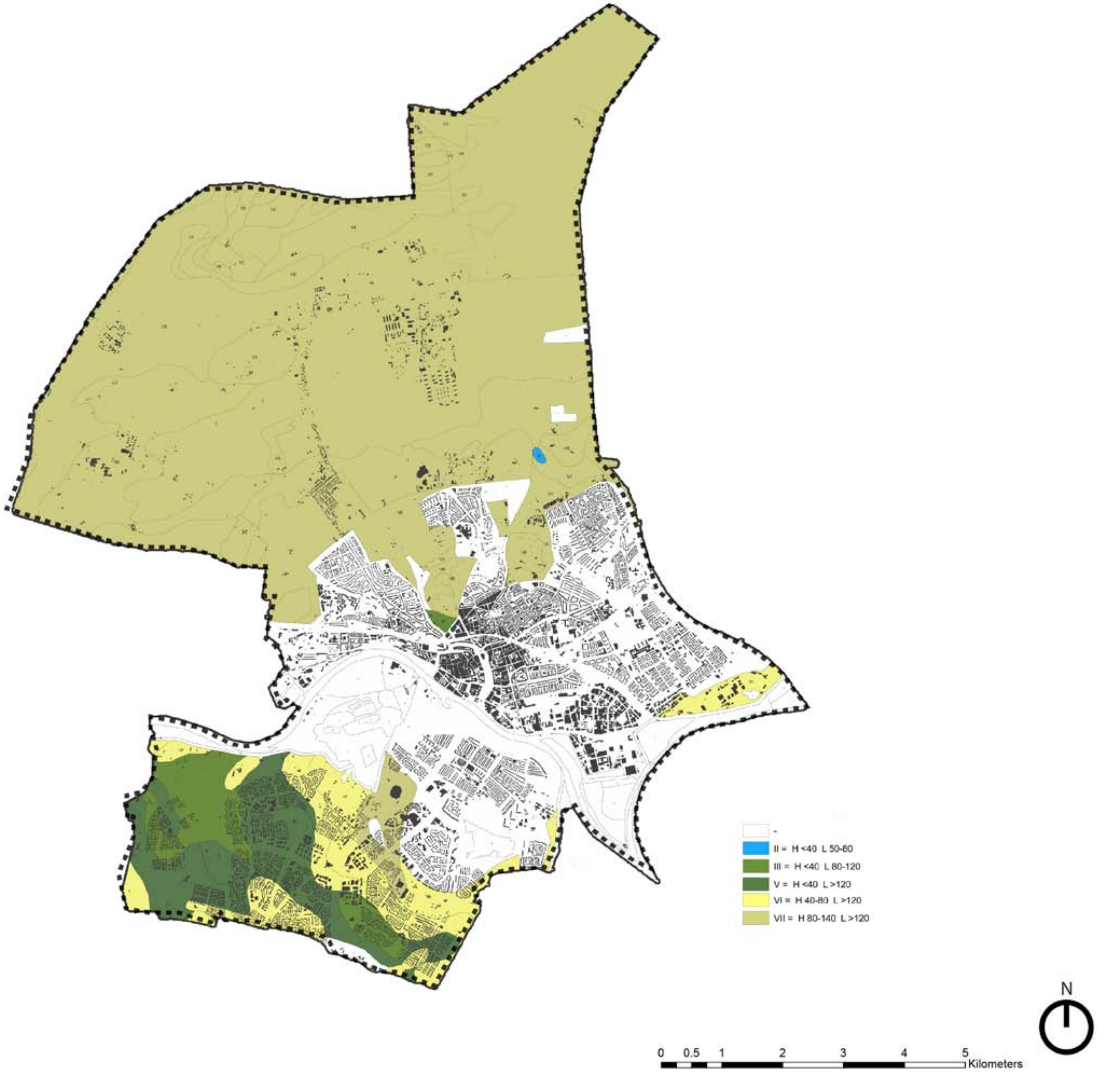


Figure 2.14. Groundwater map

2.3. Biotic

Regarding the biotic layer, fauna and flora of Arnhem will be briefly described. The green structure in the city has been one of the attractions for tourism and recreation since the middle of the 20th century. The city occupies 10,154ha of which 5,320ha are composed by green areas (TTE,2009). If the 149,395 inhabitants (Gemeente Arnhem, 2012) are considered it is possible to estimate approximately 356m2 of green surface per capita. As a result, the city received the tittle of the greenest town in The Netherlands in 2008 (TTE,2009). (Figure 2.15) Two are the largest green areas, the Veluwe moraines and the river landscapes. Furthermore, a green network formed by parks and urban vegetation along the streets and avenues penetrates the built environment. (Figure 2.16).

Regarding the Veluwe moraines, it is composed by woods and open fields with lower vegetation. This wide green area launches ‘green fingers’ in the direction of the Rhine permeating the urban fabric while provide people with recreational activities. Agriculture fields, with the potential for nature expansion, besides military sites are presented in the area. Moreover, the Veluwe moraines are located between two national parks, De Hoge Veluwe in the north and the Veluwezoom in the east. Both are part of the National Ecological Network (EHS) and follow the European policy proposed by Natura 2000 in 1992 aimed to protect natural landscapes in the continent (Gemeente Arnhem, 2008). As a result, the green areas in the north of Arnhem make a partial link between the two national parks.

The predominant sandy soil is ideal for a particular flora and fauna which creates a biodiversity and ecosystem unique in the Netherlands (Hein, 2011). The flora comprises a mixture of native and introduced plants. The majority of the forest (2,573ha) is composed by three species of trees, *Pinus sylvestris*, *Larix decidua* and *Pseudotsuga menziesii.* Besides the woods, large fields of *Phyllodoce empetriformis* (Heath) can be found in the extreme north. This particular flora provides the living condition for a variety of insets, reptiles, birds and mammals (Figures 2.17 - 2.22). For instance, several kinds of snakes, deer and the wild boar coexist along the Veluwe.

Considering the fact the forest as well as some animals have being re-introduced, the maintenance of the area is regularly made in order to keep the environment balanced. By doing so, the native species of vegetation receive priority and the hunting is strictly regulated. Due to the maintenance process, the forest assumes a productive character (Alterra, 2007). According with Probos (2007) it is possible to harvest an amount per hectare that does not exceed the annual growth of the forest, thus avoiding damage the nature. As a result, about 1t/ha/year of wood can be explored (BTG in Kema, 2009). The destination is mainly to be burned as firewood.

The river Rhine and its flood plains comprise a very dynamic landscape. The open fields change a lot according with the season and the level of the water along the year. The predominant clay soils provide the good environment for grasses, shrubs and trees to grow (Figures 2.23 & 2.24). The area is important for birds, fishes and reptiles and has being modified as part of the national project “*Ruimte voor de Rivier”(*Room for the River) in order to accommodate the waters of the river while protect the city.

Both landscapes, the Veluwe and the river, are currently comprised by the environmental vision made by the municipality of Arnhem which follows the main principals established by the Natura 2000 policy (TTE,2009). The main target is to include the areas on the National Green Network by 2018.

Figure 2.15. Biotic layer map

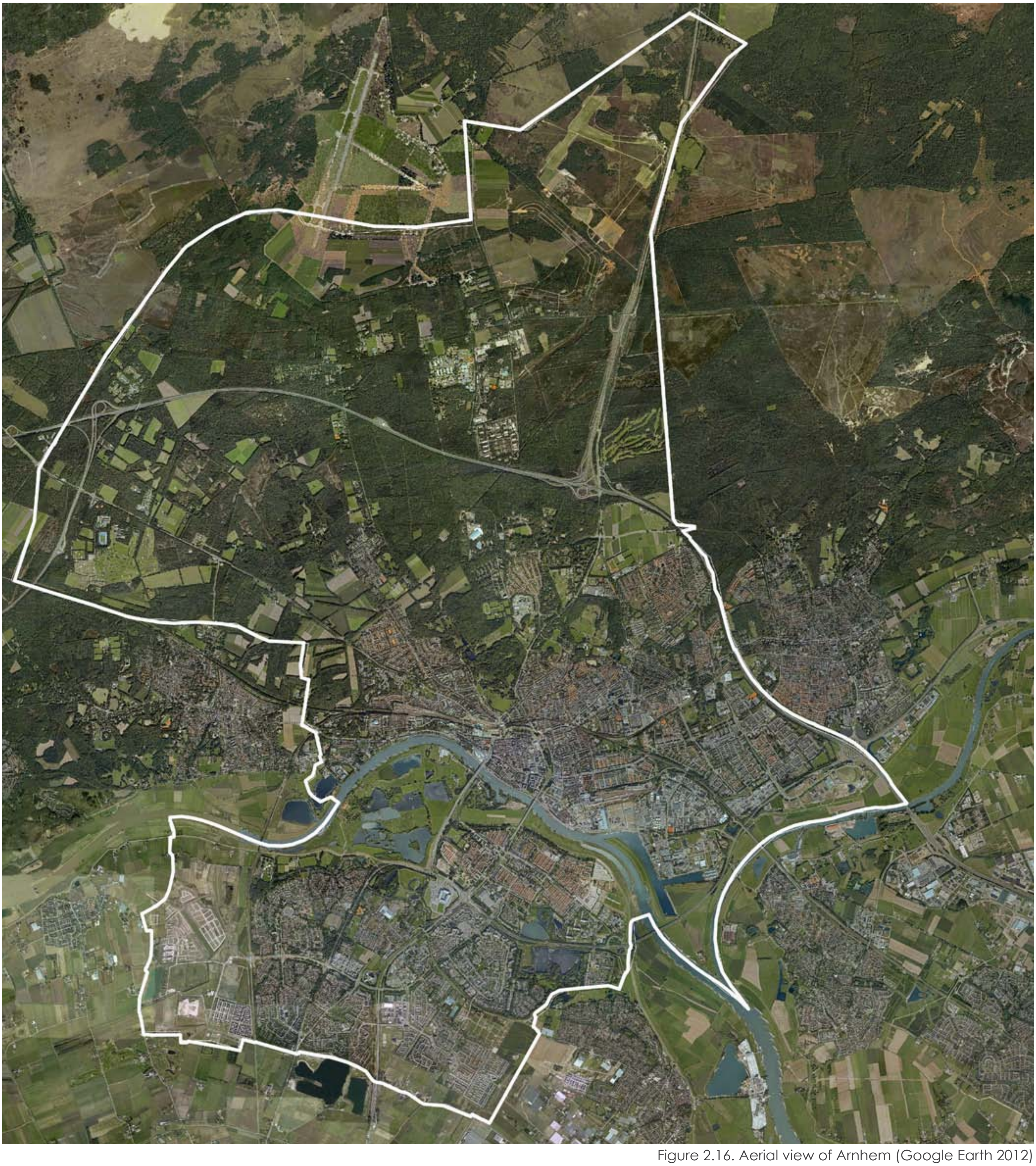


Figure 2.16. Aerial view of Arnhem (Google Earth 2012)

Flora and fauna at the nature area in the north of Arnhem (Official website Hoge Veluwe park)

Forest and heath in the North

2.17. Moufflon
2.18. Red Deer
2.19. Badgers
2.20. Douglas “Pseudotsuga menziesii”
2.21. Sundew “Drosera tokaiensis”
2.22. Heath “Erica Tertralyx”

Flora in the floodplain area in Arnhem (T. Marques)

Floodplain

2.23. Reed “Phalaris arundinacea”
2.24. Willow “Salix Hybrid”

2.4. Anthropogenic

The anthropogenic layer comprises the features Arnhem has regarding its urban development. Considering the historical overview was introduced on the sub-chapter 2.1., the present sub-chapter will focus on current data such as, demography, land use and infra-structures.

Arnhem has 149,395 inhabitants (Gemeente Arnhem, 2012) distributed into 24 districts. The urban occupation is composed by different generation of buildings and differs a lot between north and south (Figure 2.25). While in the north a radial development took place along the centuries in the south the settlements, dated from the 20th century, are not organized radially, but counting with smaller centres spread through the districts (Figure 2.26). As a result north and south can almost be understood as two separate cities.

In both cases, residential, mixed, commercial and industrial land use can be found (Figure 2.27 - 2.33). The approximately 68,350 dwellings are 57% located in the north and 43% in the south. Even though the north part of Arnhem is roughly three times bigger than the south, due to the presence of the Veluwe forest it settles only 14% more dwellings. About 12,650 new dwellings are expected to be built during the next thirty years. Almost half of them will be located in the southwest part of the city (Schuytgraaf neighbourhood) (Figure 2.34).

Companies are concentrated in five main locations besides being spread through mixed use areas in the north and south. The most important mixed area comprises the old city centre and is mainly formed by heritage buildings and post WWII dwellings. The industries are concentrated on the industry park Kleefse Waard, in the east side along the north banks of the river Rhine.

The infrastructure for mobility is composed by freeways, highways and smaller roads, railways and the fluvial transport. Three freeways cross the city, the A12, A50 and A325. The first makes the east-west connection, the second makes a direct link between north-south banks of the Rhine and the third makes the link between Arnhem south and Nijmegen.

Regarding the railways, Arnhem counts with one main station, Arnhem Centraal, for international and national destinies, and other three stations, Arnhem Zuid, Presikhaaf and Velperpoort, for stop trains. The fluvial transport is composed by a large amount of barges for the transport of goods besides the tourism cruises.

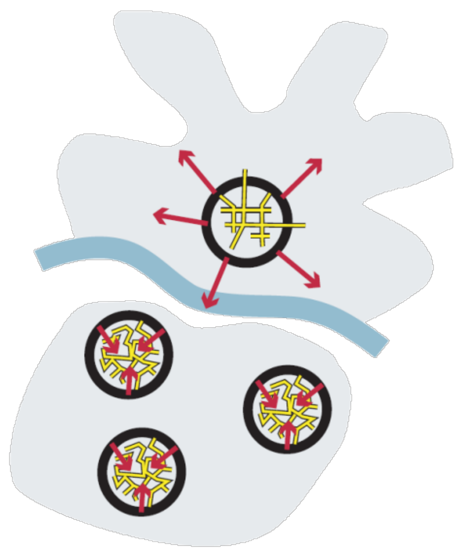


Figure 2.25. Difference between North and South

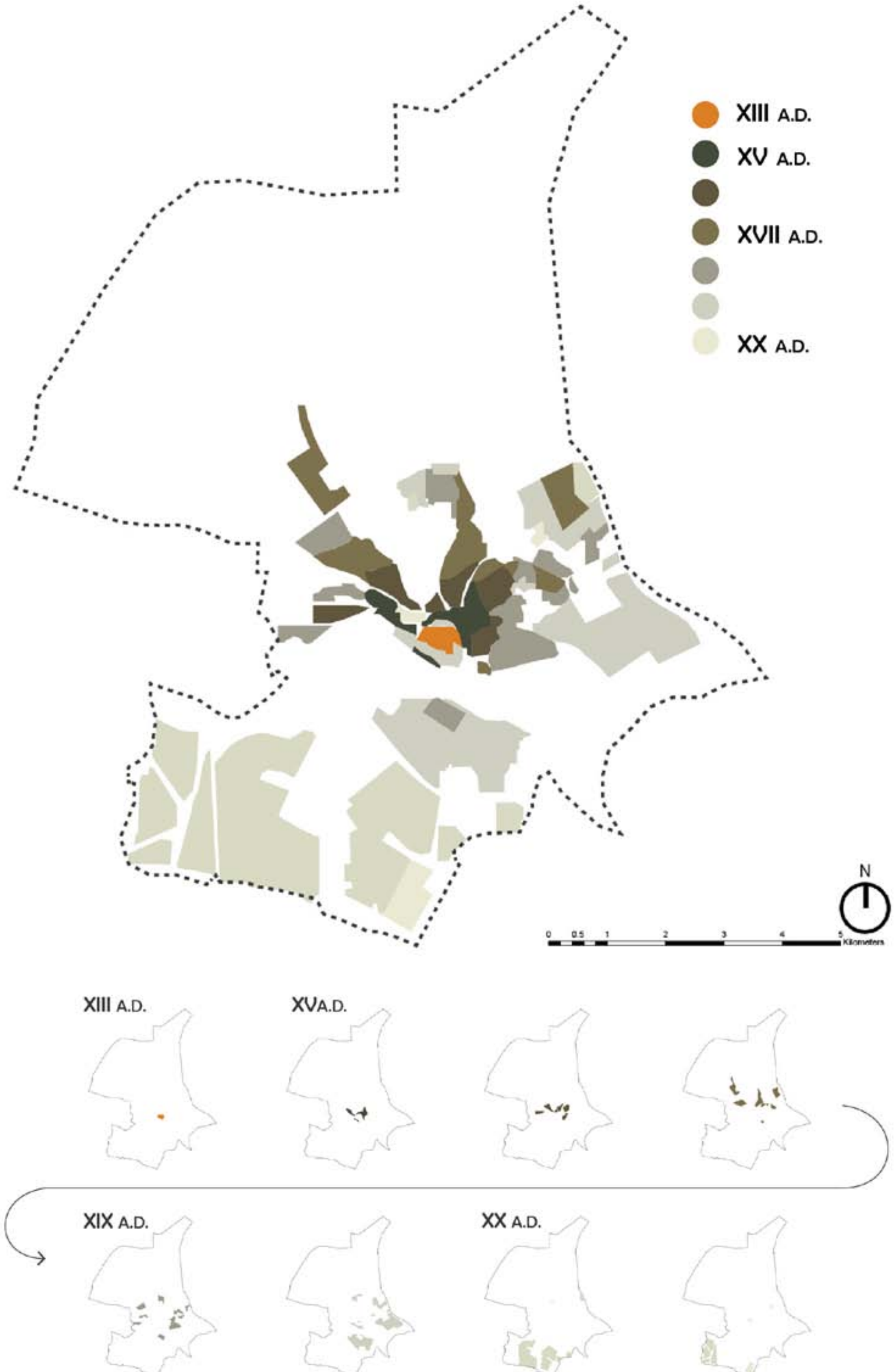


Figure 2.26. Urban development sequence

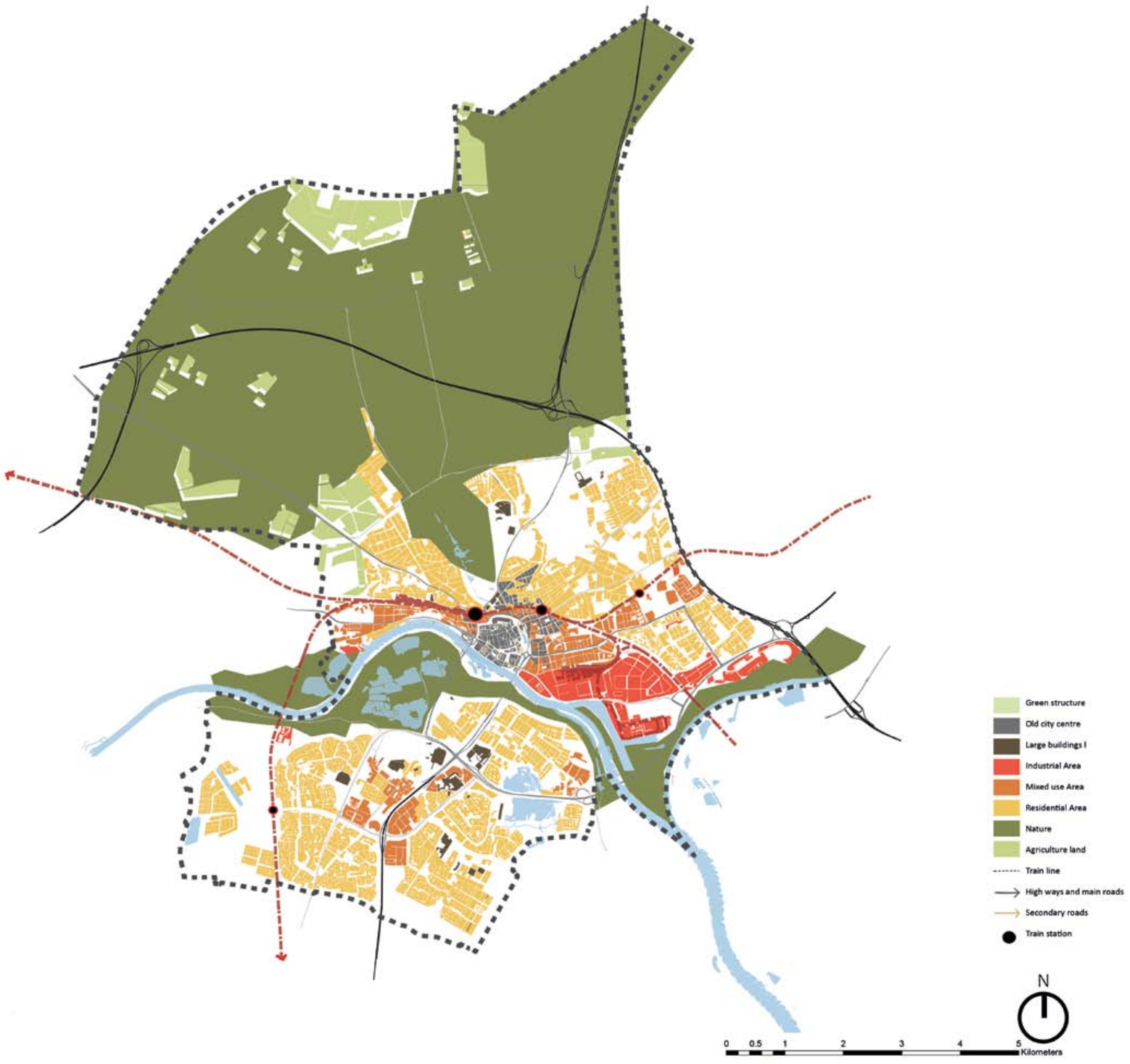


Figure 2.28. Anthropogenic layer map

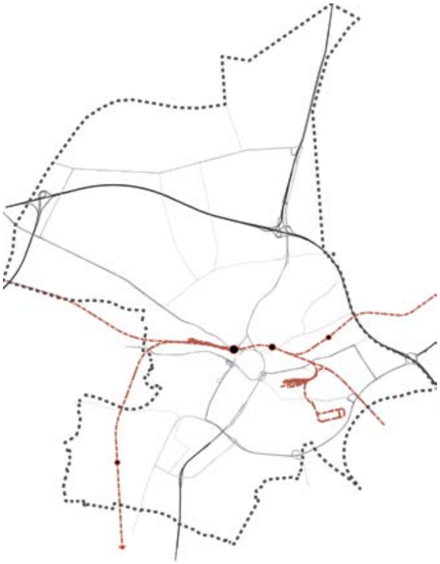


Figure 2.29. Road infrastructure

Figure 2.30. Open fields-agriculture

Figure 2.31. Mixed land-use

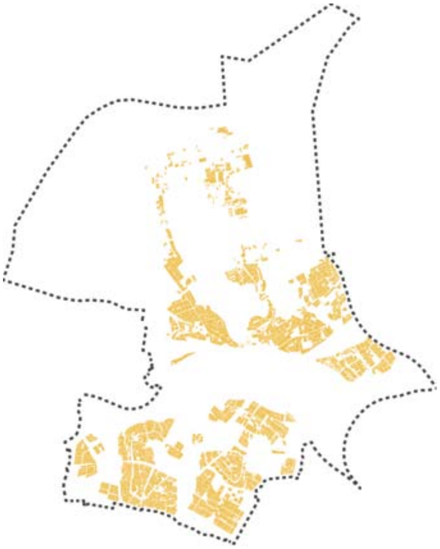


Figure 2.32. Residential land use

Figure 2.33. Industry land use

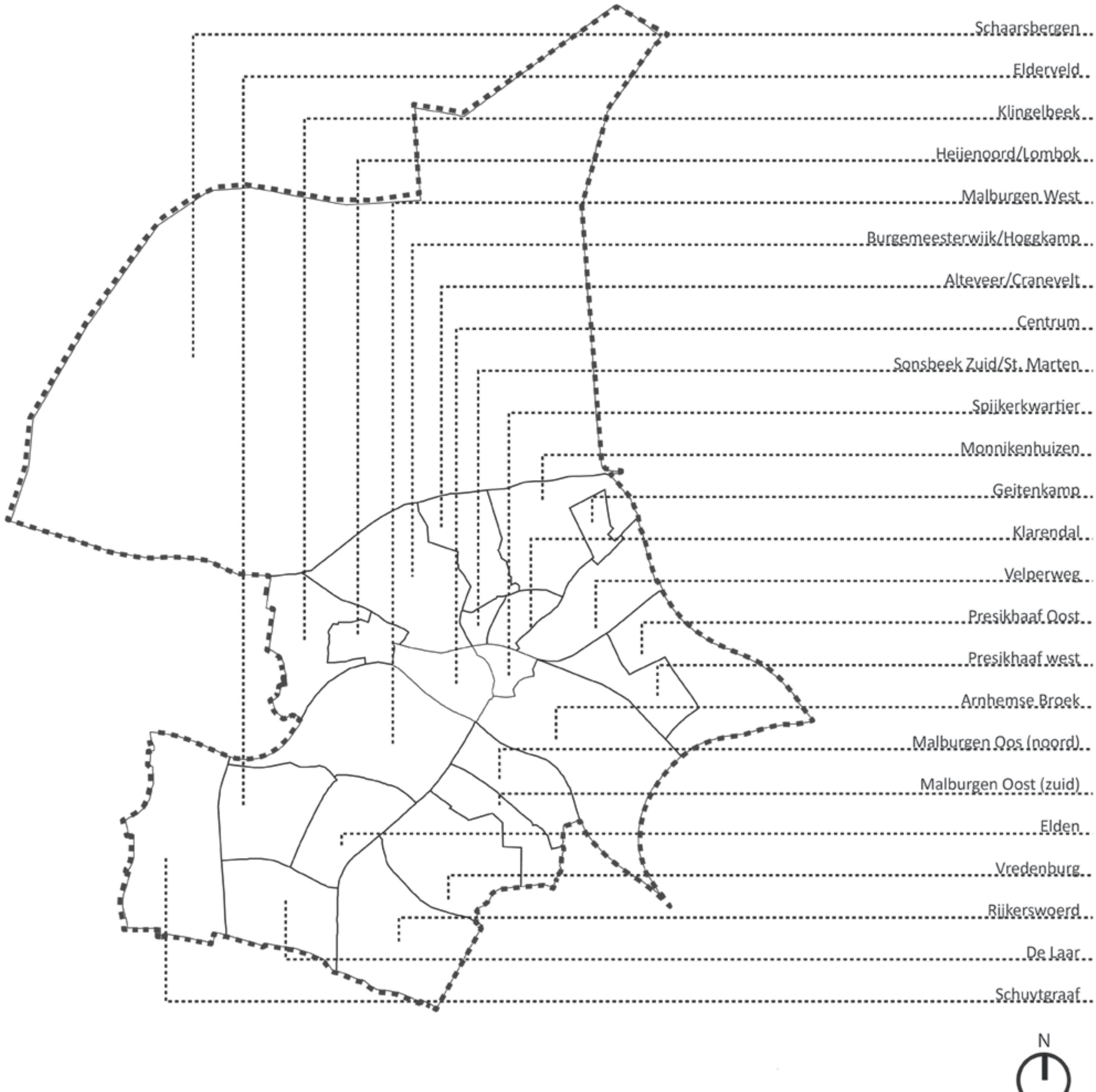


Figure 2.34. Neighbourhoods location map

Rhine river & Floodplains

2.35. Arnhem skyline from the floodplains

2.36. Oostelijk centrum and floodplains in the south

2.37. Rijnboog area and Stadsblokkers Meinerswijk

2.38. Floodplains in Stadsblokken Meinerswijk.

2.39. Railway crossing the Rhine river

2.40. Protective dyke on the floodplains in the south

2.41. Road N-325 from the floodplains

2.42

2.43

2.44

2.45

North Arnhem

2.42. Sint Jansbeek creek in Sonsbeek park

2.43. Arnhem Centraal train station

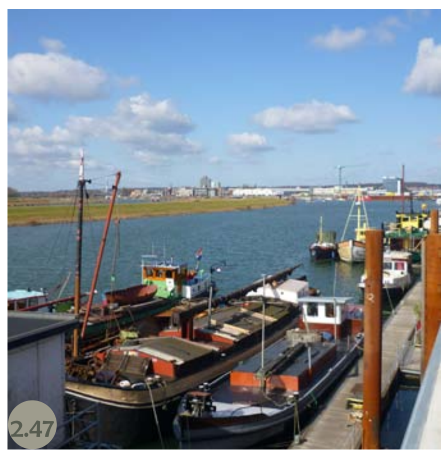
2.44. Waterfront in the old city centre

2.45. Bakerstraat, comercial area in the old city centre

2.46. Kerkplein, old city centre

2.47. Harbour at the industrial area "Kleefse Waar d"

2.46



2.47

South Arnhem

2.48. Kronenburg shopping centre, Arnhem Zuid

2.49. Schuytgraaf neighbourhood

2.50. Modern architecture and open spaces

2.51. Gelredome stadium, Arnhem Zuid

2.52. Wind turbine at the pumping station

2.53. Waste water treatment plant (WWTP)

2.5 Conclusion Landscape Analysis

As a conclusion of the historical development besides the three layers, abiotic, biotic and anthropogenic we are able to identify the limitations presented in the landscape of Arnhem. For instance, physical barriers, historical, natural and cultural values of the landscape will be distinguished. They present very different levels of relevance between the northern and southern part of the river Rhine (Figure 2.54).

In the northern part of the city, the main limitations are based on the existence of the forest and the cultural value of the landscape and historical buildings. The forest is currently protected by strict regulations (Natura 2000). Moreover, some sites require attention since they are used for leisure, recreational and military activities besides being destined to nature expansion. Regarding the cultural values, the former brooks should receive attention as well as the traditional districts. The old city centre is located inside the ring of parks (boulevard) once occupied by the fortifications of the city. Nevertheless, the blocks of buildings distributed between the edges of the old city centre and the river Rhine, usually have much less importance, since they are resulted by the fast and low quality urban reconstruction after the WWII.

Entering the river bed a special care should be taken regarding the flood plains. They are designed according to national projects in order to provide more space for the rivers protecting the city from the floods. Due to the heavy clay soil found on this area, some brick factories were settled on the area and close to the river during the 20th century and carry historical value.

The limitations in the south are less visible. Despite the old dikes, the polder landscape have most of its limitations located in the underground. There, archaeological sites can be found and should be considered when interventions on this layer are proposed. Moreover, the shallow water table, the areas of drink water extraction and the risk of contamination are limiting factors.

In general, other punctual limitations such as, historical buildings, waterwheels and a windmill can be found in the municipality. Therefore, they are relevant for small scale implementations rather than for interventions on the landscape level focusing on an energy transition.

Hence, the limitations found in Arnhem comprise a broad range of features. It varies between north and south and the three layers of the landscape. When energy transition is considered, the influence these characteristics have can also vary according with possible futures (socio-economic scenarios). This analysis will be made on the **Chapters 07** and **08**, when visions will be described.

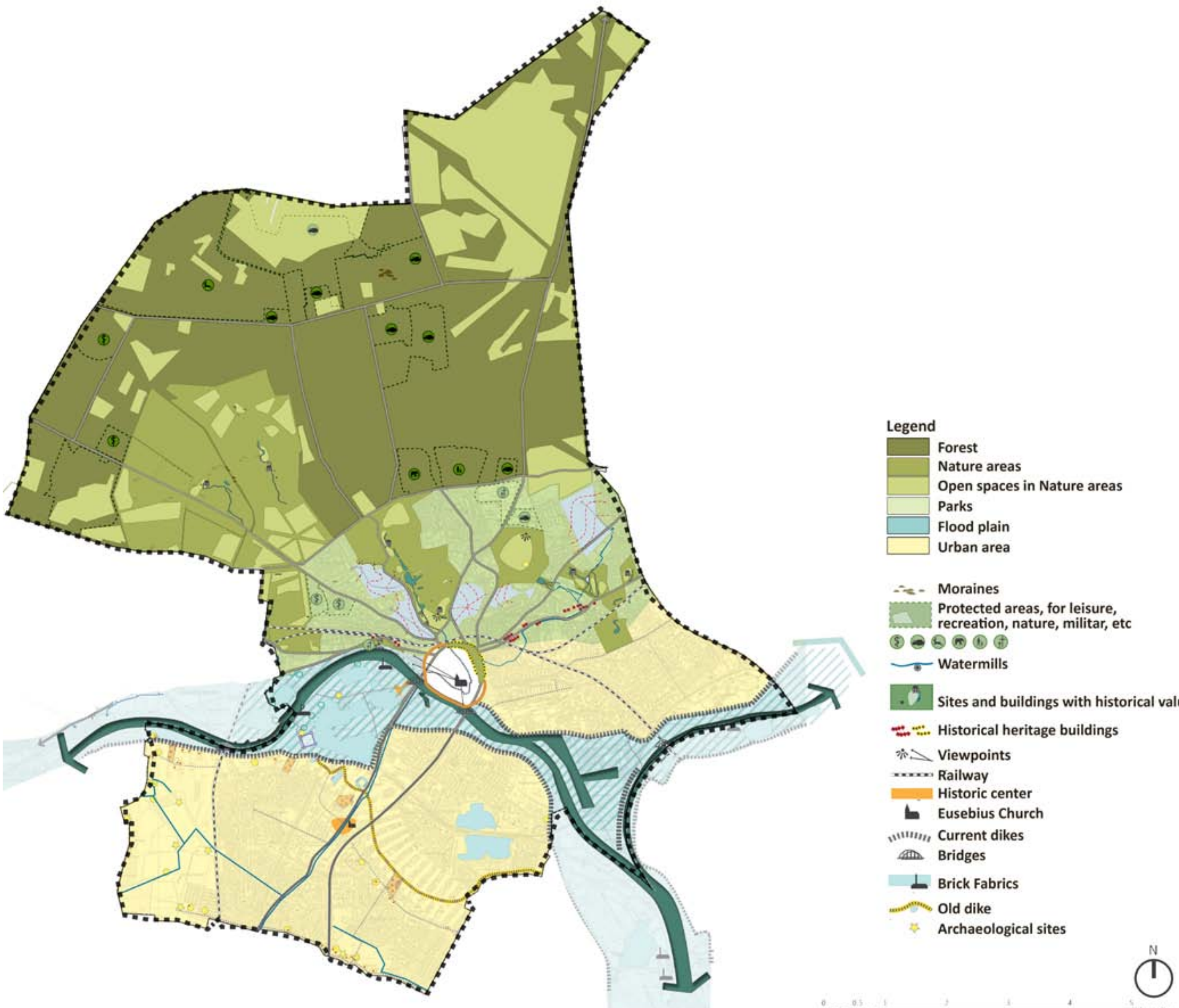


Figure 2.54. Cultural and natural limitations in Arnhem (Gemeente Arnhem)

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Chapter III

Energy and CO_2 Inventory

The challenge of CO_2 neutrality towards energy transition involves the understanding of different aspects of the landscape. On ***Chapter 2*** we presented the historical development besides the abiotic, biotic and anthropogenic layers. During the current chapter the figures of sinks and sources of energy and CO_2 in Arnhem will be described. Roughly, the sinks of energy comprise the areas where consumption exceeds the potential of generating energy while the sources represent the places which have a highest potential for energy generation rather than consumption (Stremke, 2010). With regard to CO_2 emissions, the same concept will be applied. Nevertheless, on this case the sinks are the areas where the dioxide carbon can be sequestrated rather than emitted and the sources comprise the places where the emissions due to the use of energy exceeds the amount of CO_2 sequestrated.

As a result we will be able to define how and if it is possible to re-arrange efficiently sinks and sources of energy, and consequently CO_2, in the city. Moreover, we will focus on three main energy carriers, electricity, heat and fuel. Before we indeed start the chapter an introduction of the terminology, units of measure and carbon cycle we are going to use will be briefly explained (**section 3.1.**). Once the reader is familiarized with the terms and measures, we will present how much and in which areas the three energy carriers are consumed and how they contribute to the total amount of CO_2 emitted in Arnhem (**section 3.2**.). The section 3.3. comprises the current energy sources and the **section 3.4.** the conclusions of this chapter.

Figure 3.1. (previous page) Wind turbine in Germany (J.Gómez)

3.1 Terminology, carbon cycle and measures

Terminology

Carbon dioxide emissions: refers to the amount of this gas released to the atmosphere. It can happen due to a large range of causes (e.g. burn of fossil fuels to produce energy).

Carbon dioxide sequestration: refers to the amount of CO2 which can be used by biomass (e.g. forest) in order to make photosynthesis. Therefore, it is the amount of carbon dioxide bound on biomass.

Carbon dioxide neutralization: it is achieved when the amount of CO2 emitted is the same than is sequestrated in certain area. For instance, nature, without the humans influence, is in balance regarding carbon dioxide emissions and sequestration.

Carbon = C

Carbon dioxide = CO2

Units

Energy:

1 KWh = 3.6MJ

1GJ= 1000 MJ

1TJ= 1,000,000MJ

Weight:

1t= 1000Kg

1Mt= 1,000,000t

1 t C = 44/12 t CO2

Carbon cycle

Carbon dioxide is stored in the oceans, in the ground, in the vegetation and in the atmosphere. Most of this gas is in the oceans (40,000 Gt) and the smallest quantity in the atmosphere (600 Gt) (Mackay, 2009) (Figure 3.3). The relation between all the sources of CO2 and the atmosphere have being in balance until the humans start to burn large amounts of fossil fuels in order to generate energy (mainly from the 20^{th} century). As a consequence lots of tonnes of carbon dioxide has being released to the atmosphere per year (e.g. 8.4Gt in 2005, Mackay, 2009).The problem is that natural process involved on the sequestration of this gas are not fast enough to neutralize the emission. In other words, there is no natural process or combination of natural processes able to keep the balance between CO2 emissions and sequestration when the first is so high and fast as it is being during the last hundred years (Mackay, 2009).

As an example of the carbon cycle we will briefly analyse the contribution the forest in Arnhem has for CO2 neutrality. When looking to the current map of Arnhem, it is easy to have hopes regarding the 2,573ha of forest (Figure 3.2) located in the north (almost ¼ of the total area of the city). It is well known the preservation of forests, between other reasons, has an important role regarding CO2 emissions. But how this system works? How much can the forest in Arnhem indeed contribute for the challenge of CO2 neutrality?

The forest sequestrates CO2 in order to make photosynthesis. As a result, the carbon is fixed in the plants while oxygen is eliminated to the atmosphere. Once a plant dies, the carbon is slowly released to the atmosphere, where it will meet the oxygen molecules to form CO2 and re-start the cycle. Considering the information regarding the forest on The Hoge Veluwe we found it has the capacity to sequestrate 900t C/year (Hein, 2011). Using the factor of conversion 1 tC= 44/12 t CO2, about 3280 tCO2/year can be sequestrate. The forest in Arnhem has the same characteristics than the Hoge Veluwe, thus, it

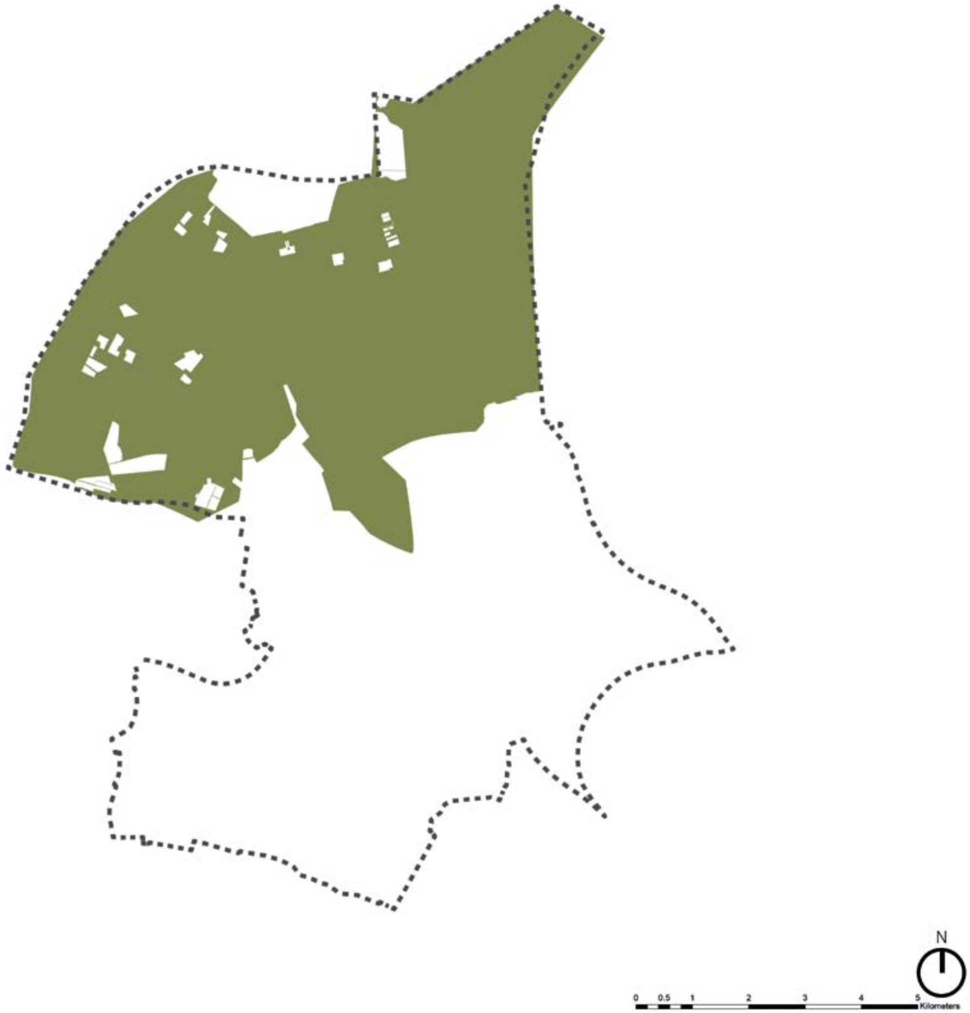


Figure 3.2. Forest surface in Arnhem

can proportionally sequestrate 1.13t CO_2/ha/ year in the city. Hence, the total amount of dioxide carbon potentially sequestrated in Arnhem is 2835t/ year. This number will be accessed on the conclusion of this chapter, in order to check how much it represents in relation with the total amount of CO_2 emissions due to energy use.

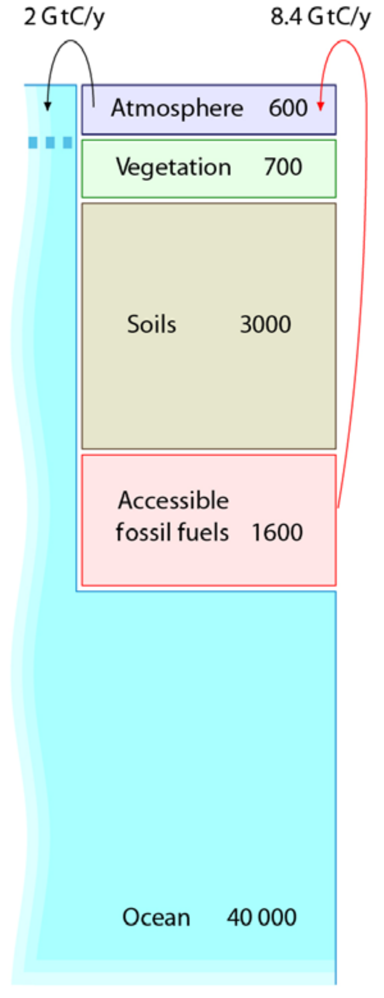


Figure 3.3. Carbon Cycle (MacKay 2009)

3.2 Energy sinks and CO_2 sources

The consumption of energy is directly related with the amount of CO2 emitted. Considering that, it is possible to identify how much carbon dioxide is emitted in Arnhem due to the use of electricity, heat and fuel. The detailed tables of energy consumption and CO2 emissions can be also found on the.

The information contented on this chapter is based on the amount of electricity and gas delivered by Liander (Liander, 2009), the administrator of these energy networks in Arnhem. The numbers related to gas consumption were converted on unities of heat (TJ) consumed, since this is the main use of the gas delivered. The data shows the consumption of energy and CO2 emissions according with each one of the twenty four districts in the Municipality and seven different sectors: households, companies, industry, catering, education, healthcare and retail. Even though we are not focusing on the sectors, an overview of the highest consumers will be presented. Further, the seven sectors will be arranged into two groups, buildings and industries, to receive attention of general measures. A third group will comprise transportation.

Regarding the amount of fuel used we collected the data from Kema (2009). Three sectors, industry, transportation and agriculture are responsible for the consumption of this carrier. The calculation of CO2 emissions due to the use of this source was based in CO2/liter of fuel (Mackay, 2009). Moreover, in order to take future decisions, regarding transportation, we included the calculation of kilometres driven by private and commercial vehicles in Arnhem (CBS, 2010) and they consequently contribution for CO2 emissions.

Even though we are not focusing on the sectors, an overview of the highest consumers will be presented. Further, the seven sectors according with Liander (2009) will be arranged into two groups, buildings and industries, to receive attention of general measures. A third group will comprise transportation.

3.2.1 Electricity consumption and CO2 emission

The total amount of electricity consumed in Arnhem is 2789TJ. Following the calculations made by Liander the amount of TJ was converted into KWh and multiplied by the factor 0.597. As a consequence, we were able to directly know how much CO2 is emitted due to electricity consumption.

As a result of the analysis, five districts, which presented the highest numbers by summing all the sectors will be highlighted (Figure 3.4). Moreover, some other areas deserve attention because of its expressive numbers by a particular sector and/or by punctual buildings.

1.- Centrum: companies, retail and catering represent 90% of the electricity consumption and the respective CO2 emissions in the district. Each one of the three sectors presents the highest consumption and emissions in Arnhem. The expressive numbers in this area occurs due to the concentration of old buildings, which require more energy, next to the fact that many companies and business, are settled there. The consumption of electricity and the CO2 emissions due to the use of this energy carrier in the Centrum represents 14.67% of the total in the municipality

2.- Arnhemse Broek: Companies, industries and retail are responsible for 92% of the electricity consumption and CO2 emissions in this district. From the 92%, about 60% refers to companies and 20% to industries. Even though industries do not represent the highest amount of CO2 emissions in Arnhemse Broek, this sector has there, the highest contribution for carbon dioxide emissions in Arnhem. Arnhemse Broek represents 14.60% of total electricity consumption and CO2 emissions in the municipality.

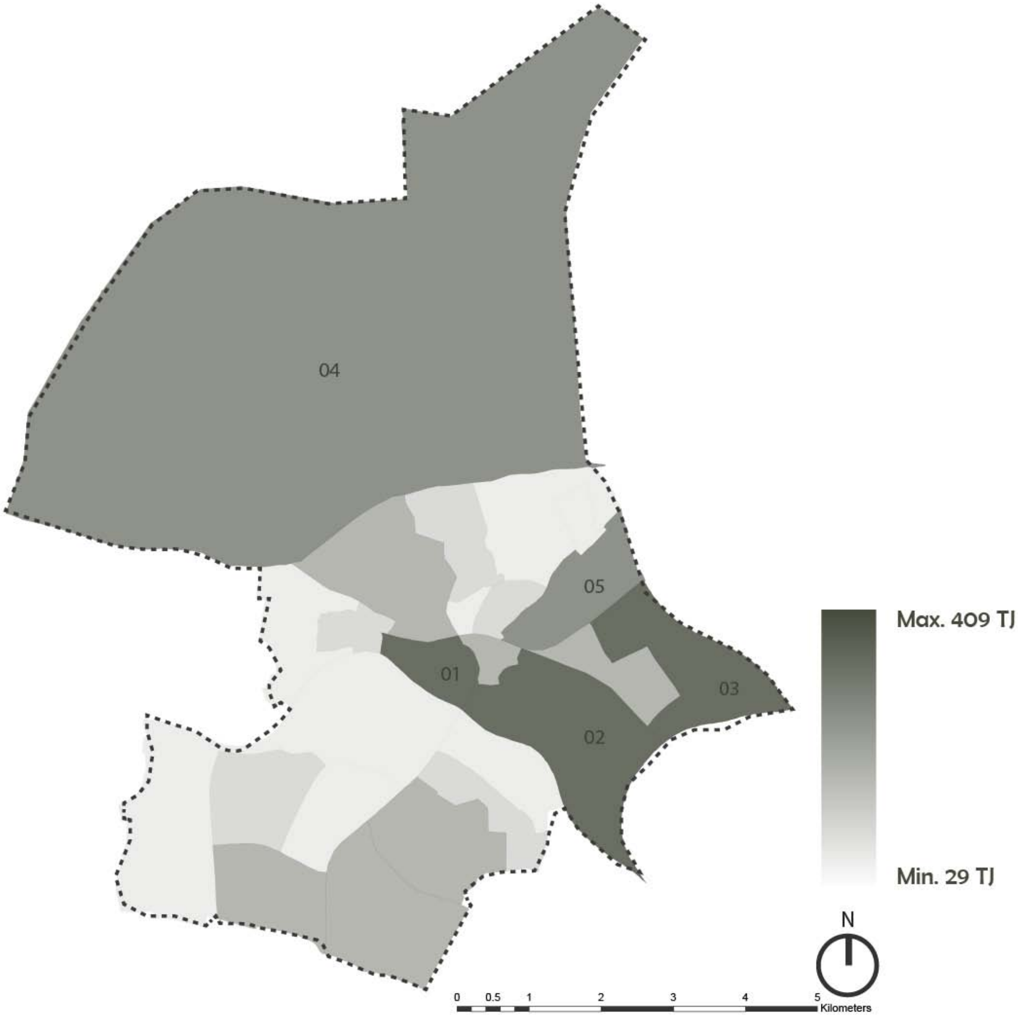


Figure 3.4. Electricity consumption map

3.- Presikhaaf Oost: companies, households and education represent 89% of the electricity consumption and CO2 emissions in the district. Companies alone are responsible for three times the emissions of households (58% of the total). Furthermore, a special attention should be paid to the educational sector, since this district counts with the highest consumption and emission by this sector in the city. It happens because of large educational buildings are placed there such as, the (HAN) Hoegeschool van Arnhem en Nijmegen and the Arentheem College. The contribution this district has for the total amount of CO2 emitted by electricity consumption in Arnhem is 6.75%. As noted, this percentage is already less than half of the numbers showed by the two first districts, Centrum and Arnhemse Broek.

4.- Schaarsbergen: companies and catering are responsible for 89% of the electricity consumption and CO2 emissions in the district. An important remark is that the companies sector represents already about 85% of the CO2 emissions (electricity consumption) in Schaarsbergen. Even though the area is mainly occupied by nature (e.g. forest), large complexes of buildings such as the Burger Zoo, Papendal sports centre (NSO NSF), Nederlands Openlucht Museum and military complexes are settled there. Since these companies have restrictions regarding the exact numbers of energy consumed, we were not able to precisely define their contribution for the total electricity consumption. Schaarsbergen represents 6.68% of the total amount of CO2 emitted in Arnhem due to electricity consumption.

5.- Velperweg e.o.: companies, households and healthcare. These three sectors consume 85% of the total electricity delivered in the district. As a result, they emit 85% of the CO2 in the area. Companies represent 68% of the total emissions in Velperweg e.o. In the context of the Municipality, the district represents 6.50% of the CO2 emissions due to use of electricity.

Even though other districts did not rise with the highest consumption of electricity and CO2 emissions, they deserve attention since some sectors concentrate in these areas the highest percentage in the city. For instance, in Alteveer/Cranevelt the healthcare sector represents 32% of the electricity consumption and consequently CO2 emissions. Even though healthcare does not represent the highest consumption of electricity inside the district it does represent the highest number found on this sector in Arnhem. This fact can be explained by the existence of the Rijnstate Hospital (Rijnstate Ziekenhuis) in Alteveer/Cranevelt. Regarding the household sector, three districts, Rijkerwoerd, De Laar and Elderveld have the highest electricity consumption and CO2 emissions in the city. Due to the fact that these districts have high concentration of dwellings, they contribute with 6.30% of the total use of electricity and CO2 emissions referred to this energy carrier in Arnhem.

The final contribution by electricity use to the CO2 emissions in Arnhem is about 44%. The difference between Centrum and Arnhemse Broek compared with the other districts is impressive, being at least about two times higher than the others. This happens mainly because of the large amount of companies located on the two districts. Furthermore the Centrum counts with the oldest and most energy demand buildings in the city.

3.2.2 Heat consumption and CO2 emission

The consumption of gas in Arnhem is 6368 TJ (Liander, 2009). The largest majority of this amount (about 94% according with Kema, 2009) is used in order to generate heat rather than to be used for other ends. Therefore, we will consider the whole number, 6368TJ, as heat in order to make the calculations and measures regarding energy transition more simple. The total amount of CO2 emitted by the use gas will be considered according with the factors applied by Liander (2009). As well as with to electricity, the five districts, which presented the highest consumption of gas and CO2 emissions, by summing all the sectors, will be presented (Figure 3.5). Also, the areas with relevant numbers by a particular sector or punctual buildings will receive attention.

Highest emission of CO2 due to gas consumption:

1.- Arnhemse Broek: companies, households, retail and industry are responsible for 99% of the CO2 emissions in the district due to gas consumption. Companies alone represent 49%. Even though the numbers presented by the industries are the highest in the city, it represents only 11% of the total of CO2 emitted by the district. The use of gas for high temperature heat on industrial processes besides the high demand of heat by companies can be understood as the main reasons why this district showed up as the highest consumer of gas. On the context of Arnhem, the carbon dioxide emission of Arnhemse Broek represents 8.1%.

2.- Centrum: companies, households, retail and catering are responsible for 98% of the CO2 emissions due to use of gas in the district. Companies are again responsible for the highest percentage of emissions. With 60% it represents the second highest number of this sector in the Municipality. The old age of most of the buildings in the Centrum is the main factor why the gas consumption is so high. Since the buildings are not well insulated, the need for heating is much higher than in the newer developments. Considering the total of CO2 emissions due to consumption of gas, the Centrum contributes with 8%.

3.- Alteveer/Cranevelt: companies, healthcare and households. These three sectors are responsible for 98% of the gas consumption and CO2 emissions in the district. Companies are responsible for 40% of the total while other 30% regards the healthcare sector. As well as with regard to electricity consumption, the Rijnstate Hospital (Rijnstate Ziekenhuis) presents a significant consumption of gas for heating in the area. Regarding CO2 emissions due to gas

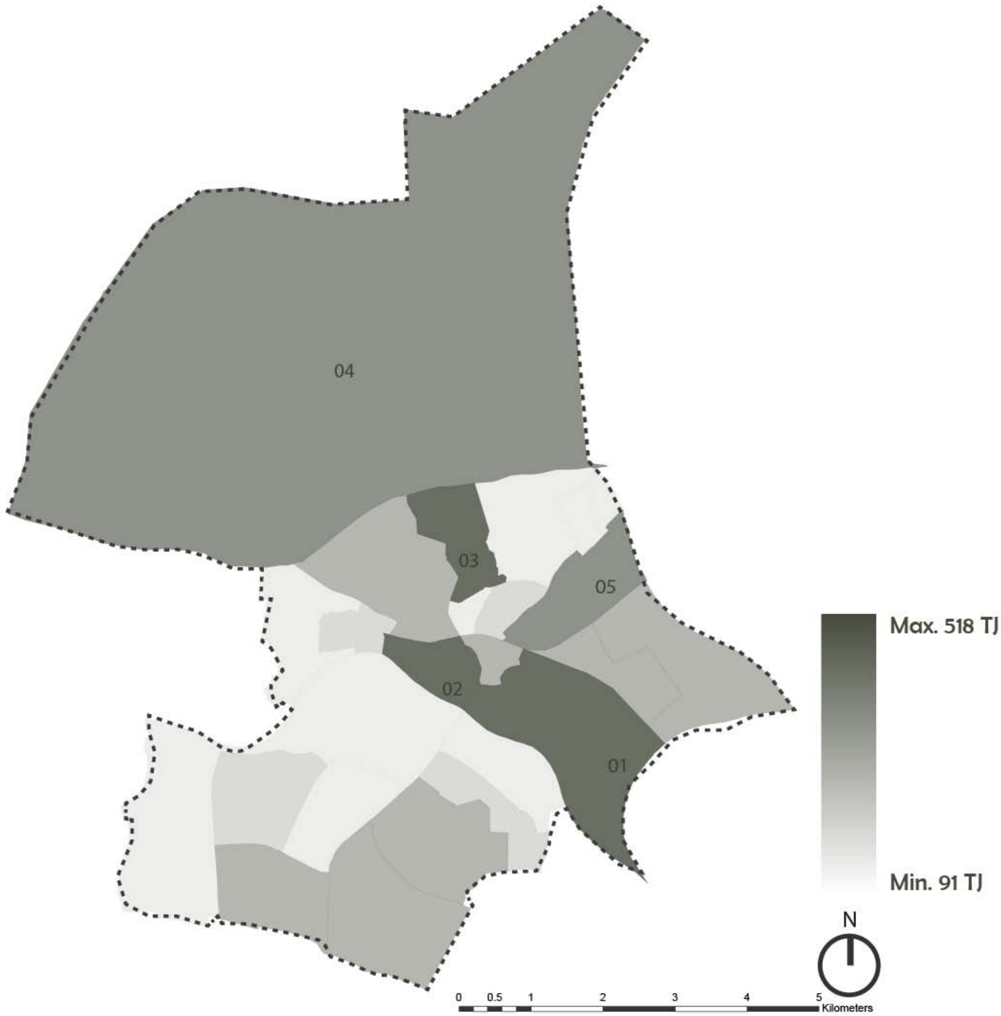


Figure 3.5. Gas consumption map

consumption in Arnhem, the district contributes with 7.21%.

4.- Schaarsbergen: companies, household and catering represent 96% of the emissions on this district. Companies correspond to the highest amount of emissions by this sector in the city being responsible for almost 78% of the CO2 emitted in Schaarsbergen. Again the high number on this district are assumed to be the result of large complexes of buildings such as the Burger Zoo, Papendal sports centre (NSO NSF), Nederlands Openlucht Museum and military complexes. The district contributes with 6.9% of the CO2 emissions because of gas consumption in Arnhem.

5.-Velperweg e.o.: households, companies and healthcare are responsible for 94% of the gas consumption and CO2 emissions in the district. Households are responsible for 50% of the total in the area. The district represents 6.4% of the total CO2 emissions in Arnhem due to gas consumption.

Regarding the consumption of gas and CO2 emissions, some attention has to be paid to certain sectors and districts since they represent the highest numbers in the city. For instance, the health sector is responsible for large amount of gas consumption and consequently CO2 emissions in Klingelbeek e.o disctrict. Another example is the educational sector in Presikhaaf Oost and Vredenburg which represents the two highest percentages of CO2 emissions by this sector in the city. A third case will receive attention too. The districts of De Laar, Burgemeesterswijk/Hoogkamp and Rijkerswoerd rise as the highest consumption of gas by households in the city being responsible for about 12% of the total CO2 emissions due to gas consumption in Arnhem (average of 4% per district).

In total, the contribution of gas consumption to CO2 emissions in Arnhem is approximately 31%. Regarding this source of energy, special attention should be paid for insulation of buildings and self-sufficient systems in the highest consumers such as the Rijnstate hospital.

3.2.3 Fuel consumption and CO2 emission

Regarding the consumption of fuel, the total amount used in the city was converted in TJ in order to facilitate the calculations. According with Kema (2009), 4041 TJ of fuel are consumed per year by industries, agriculture and transportation. The amount of CO2 emitted due to the use of this energy carrier was calculated by relating how much kilograms of dioxide carbon are emitted per litter of fuel used (Mackay, 2009). As a result, 0.04Mt CO2 is launched to the atmosphere per year due to industrial processes and agriculture, where the later has a very low contribution. Transportation is responsible for the larger amount of emissions, about 0.22Mt CO2 per year. This amount was related with the Dutch national average of kilometres driven per day by private and commercial vehicles, respectively 33 Km and 68 Km (CBS, 2011). Finally, the number of vehicles of each kind was considered in Arnhem (CBS,2011). By relating the amount of CO2 emitted with the average of kilometres driven and the kind of vehicles, we will be able to define guide lines for further interventions on this sector regarding energy transitions and CO2 neutrality.

As a result the contribution fuel consumption has to the total of CO2 emissions in Arnhem is about 25%.

3.2.4 Electricity consumption and CO2 emission per hectare

When the relation between energy consumption and CO2 emissions per hectare of each district is taken into consideration, impressive numbers grabbed our attention. For instance, Centrum and the Arnhemse Broek districts are responsible for the largest amount energy consumption and CO2 emissions in Arnhem. Nevertheless, when the area covered by each district is correlated with the energy consumption and CO2 emissions, the Centrum rise up with a value of about 7.63TJ and 777 tCO2/ ha, while the Arnhemse Broek shows about 1.8TJ and 183 tCO2/ ha.

It is interesting to notice that those districts with the highest CO2 emissions per hectare are located in the oldest quarters of the city. This fact occurs due the oldest constructions are concentrated there. The buildings are usually bad insulated and sometimes bad orientated to receive efficiently the sunlight. Another reason is the predominant mixed use of these areas, mainly companies and households, the sectors which consume most of the electricity and gas delivered in Arnhem. As a conclusion, the oldest areas deserve special attention regarding energy savings and the efficient provision of energy. Moreover, due to historical limitations the areas have few potential to generate energy, as it will be explained on the **Chapter 04.**

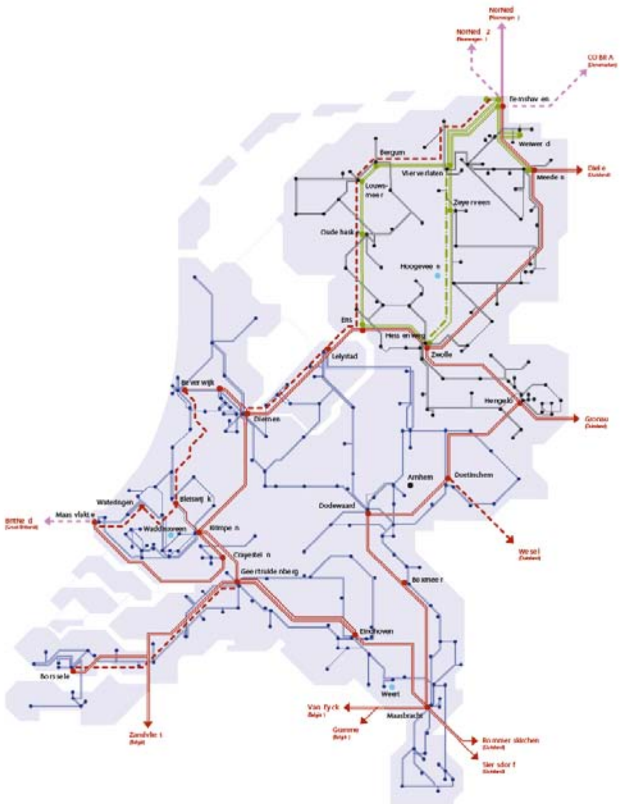
3.3 Energy current sources

Arnhem is connected with the national grid network of electricity and gas. Inside the borders of the municipality, as well as in a large part of The Netherlands, Liander is responsible for the management of these networks (Figure 3.6). Working as a separate branch from Liander since 2009, NUON is the company responsible for part of the generation and supply of energy in the city. This network includes electricity, gas and heat between other products.

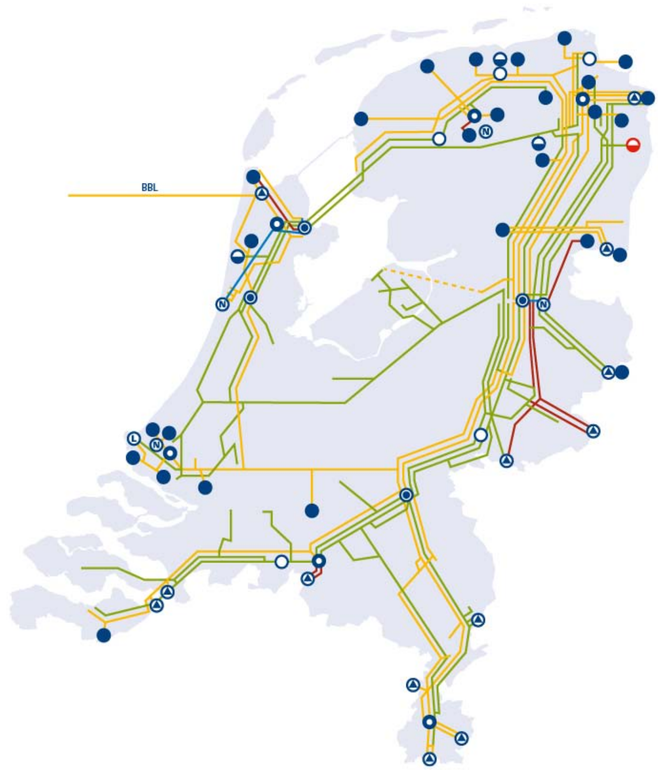
Since 1993, NUON managed the Cogenerate Heat Power Plant (CHP) De Kleef, located in the Kleefse Waard, the industrial park of Arnhem. This plant is able to provide heat (60MW/h capacity) and electricity (45MW/h capacity) to the industries located in the neighbourhood (Nuon, 2012). Besides the CHP Plant De Kleef, NUON manage the auxiliary district heating plant in Schuytgraaf (56MW/h capacity). The last one runs by biofuels and is activated in case of high pick demand of heat. The heat resulted by the two plants is distributed through mainly four districts: Centrum, Presikhaaf West, Elden and Schuytgraaf. Furthermore, the possibility to connect the heat network of Arnhem with the CHP Plant in Duiven and the district heating power plant Westervoort would contribute to the extension of the network. Even though the generation of energy inside the city represents 23% of the electricity and 13% of the heat consumed the fuel used on the conversion process (e.g. gas) is imported from other areas.

Next to the companies responsible for the management, generation and supply of energy, Arnhem counts with a number of laboratories, institutes, research and strategic studies centres interested on innovative measures to deal with the challenges of energy transition. For instance, KEMA high-voltage and high-power laboratories are testing different components such as cables, power transformers and insulators to be used on electricity networks worldwide. Another example is the HAN University of applied sciences, which directs its research to topics related with climate change and renewable energy sources.

Currently the researchers are focusing on the challenges of transportation as the main goal in order to achieve the CO2 neutrality in Arnhem. As a result, cooperation is taking place between the government, research institutions and private companies. The projects vary from the installation of electrical recharge stations to the possible use of green gas and hydrogen to run vehicles (Gemeente Arnhem, 2011). Besides that, energy studies have been conducted during the last decade based on the shift to renewable sources for energy in the city as a condition for CO2 neutrality.



Electricity



Natural Gas

Figure 3.6. Map of National grid of electricity and natural gas (Energie in Nederlands 2011)

3.4 Conclusion

In order to facilitate the advices regarding energy transition and CO2 neutrality, the sixth initial sectors presented by Liander (2009) will stay grouped into buildings (households, companies, catering, education, healthcare and retail) and industries. Moreover, transportation will receive attention as the third group. Some special cases such as the Rijnstate hospital will receive attention, but the conclusions of the present chapter besides the advices during the next chapters will follow that separation.

As a conclusion of the third chapter, Arnhem consumes more energy that is produced inside its borders. Buildings are responsible for 98% of the consumption of electricity and heat. Regarding fuel, transportation rises as the biggest consumer with 82%. As a consequence these groups, buildings and transportation, are responsible for the vast majority of CO2 emissions in the city. The total of CO2 emissions due to the use of the three energy carries sums 1.06Mt CO2/ year.

The Centrum and Arnhemse Broek deserve special attention in order to reduce the consumption of energy. Punctual buildings, such as the Rijnstate hospital, the Burger Zoo and other large buildings should emphasize self-sufficiency measures regarding energy and CO2 neutrality.

When compared with the average of emissions per capita in The Netherlands, 14.89t/ year, Arnhem presents less than half of this amount, 7.09t/per year. Nevertheless, the European Union target to reduce 80% CO2 emissions by 2050 is also applied to the city. It is also the time to evaluate 'How much can the forest in Arnhem indeed contribute for the challenge of CO2 neutrality?'.

In the begin of this chapter we calculated the forest is able to sequestrate 2835t CO2/ year. When compared with the 1.06Mt emitted annually in Arnhem it represents only 0,27%. Therefore, we indeed cannot count with the green areas of the city as a sink of CO2.

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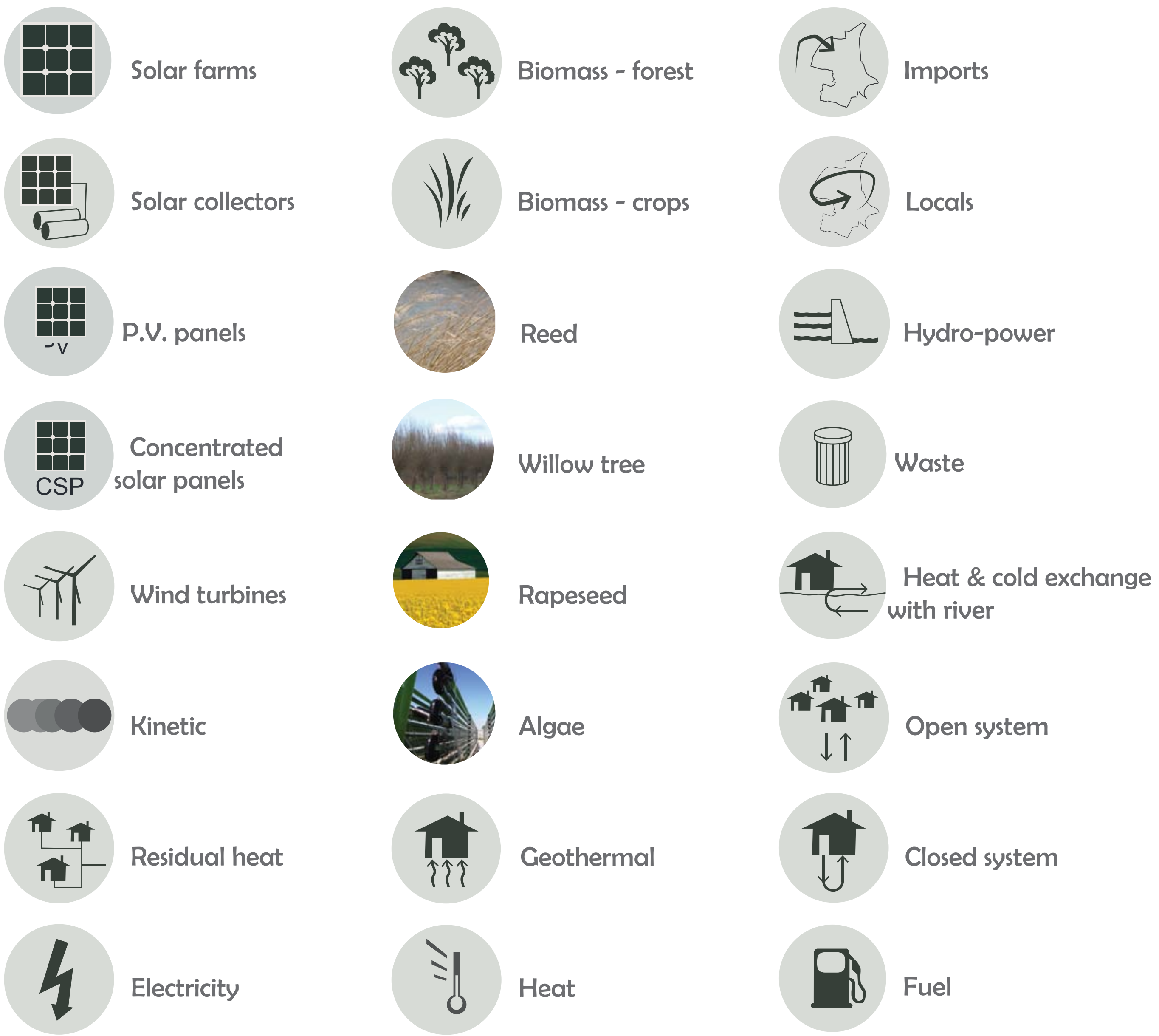

Figure 4.1. Infographic legend of energy potentials

Chapter IV

Energy Potentials

During the **Chapters II** and **III** we have being analysing the landscape of Arnhem from different layers besides to identify the current sinks and sources of energy and CO2. The **Chapter IV** comprises the energy inventory, where the potentials for energy saving, storage and generation will be presented. The chapter gains relevance since by understanding the potentials found in the study area (Arnhem) we will be able to better design a sustainable energy landscape where distances between energy sinks and source might be reduced in order to reduce energy degradation (Stremke and Koh, 2008). Moreover an overview of the EROEI (Energy Returned On Energy Invested) will be made in the end of the chapter. As a conclusion we will access the sub-question:

How does Arnhem function regarding energy consumption and generation related with CO2 emissions?

In order to define the potential sources of energy saving, storage and generation the three layers described on the ***Chapter 02*** (abiotic, biotic and anthropogenic) will be revisited from the energy perspective. The explanation will follow the three first stages for energy transition described on the ***Chapter 01***, the theoretical framework:

1. To reduce the using of energy by saving
2. Focusing on measures to store and exchange energy (decrease exergy)
3. Generate as much as energy by renewable sources

As a conclusion of the potentials found in Arnhem we will generate a map highlighting the areas were saving, storage and generation should be emphasized.

4.1 Energy Saving

In order to have an efficient energy transition, the first step should comprise energy saving measures (Dobbelsteen, 2012). To reduce energy consumption will be extreme important in order to make Arnhem less dependent of imports. According with Dobbelsteen (2011), the building scale leads when the focus remain upon the reduction of energy demand, especially heat (Figure 4.2). Considering that, even though this research focus on the landscape interventions, general potential to building savings will be described. Furthermore, the possibilities for industry and transportation will be presented regarding the three energy carriers, electricity, heat and fuel.

4.1.1 Buildings

The buildings (commercial, dwellings, health care, retail and catering) are responsible for about 95% of the electricity and almost 100% of the heat consumed in Arnhem (Liander, 2009). Therefore, energy savings are very much influenced by them. Different typologies, materials and date of construction are the main influential factors when energy consumption is analysed. In Arnhem centenary buildings coexist with 21st century constructions following a radial expansion in the north. In the south, large urban development varies the decade of construction during the 20th century (Gemeente Arnhem, 2011).

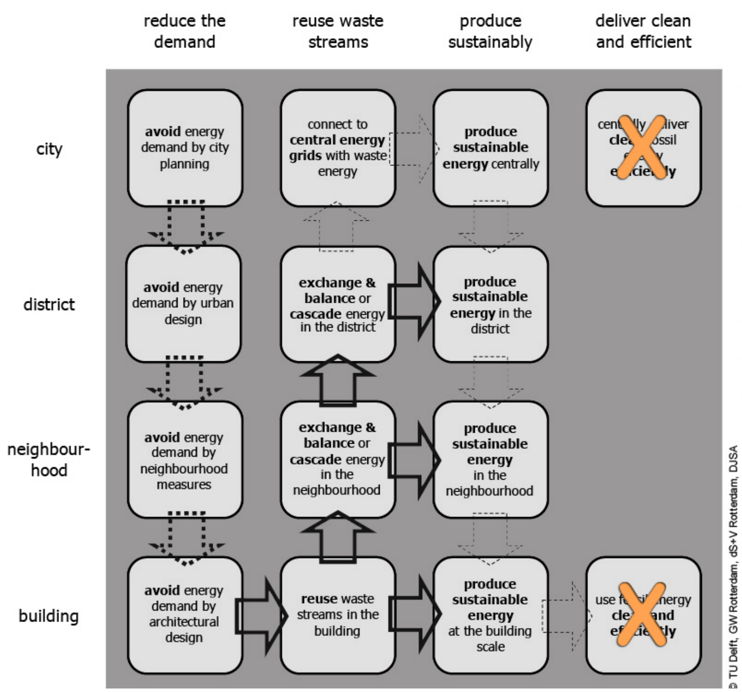

Figure 4.2. The Rotterdam Energy Approach & Planning, REAP (Tille et al. 2009a)

The potential each building has to be insulated will define how much the heat demand will decrease. The percentage of reduction varies from 30% to 50% in buildings constructed before 1990 and is able to reach about 95% in new constructions (e.g. passive houses) (XCO2, 2012). Therefore, a strategy for energy saving in buildings should be made based on the typology, age and materials. In Arnhem, we are able to have an overview of how much can be saved according with the age of each district. Nevertheless, we will work with general potentials rather than analyse carefully each area of the city from the building scale.

Besides the use of technologies for insulation, change in behaviour is considered another influential factor for researchers. Once people are aware about the consumption of energy they can actively contribute for the reduction of use especially in dwellings. Awareness can also lead to the change of appliances and the consequent contribution to decrease the energy demand.

Focusing on the landscape scale, measures to mitigate the urban heat island effects (UHI) in the city can contribute for energy savings in buildings. For instance, the introduction of vegetation and water besides the change of materials and the inclusion of elements which direct the wind, can result on the decrease of air co need during warm days for buildings .As a consequence, energy consumption might decrease. Even though currently some studies are focusing on this topic, precise numbers of reduction by applying these measures are still imprecise.

4.1.2 Industries

Even though Arnhem does not have a very expressive industrial park, this sector might be also responsible for a large amount of energy savings on the three energy carriers. Ambitious refurbishment of existing plants and the use of the Best-Available- Technology (BAT) should be done (Ecofys, 2011).

4.1.3 Transportation

Regarding transportation low consumption vehicles and alternative fuels might be developed. The increase of public transportation and the reduction of distances should also contribute for the reduction of fuel consumption by this sector. Another measure is the shift of the light fleet of vehicles from fossil fuels to electric engines. The reduction of CO_2 emissions will be very representative since electrical vehicles are around 63% more efficient than the ones running by fuels (AVTA in Nelson, 2009). Moreover, considering the bio-fuel production demands large areas of land, the partial shift to electric fleet would result on less competition for land, since some of the potential renewable sources of electricity has a higher productivity per hectare, as the **section 4.3.**

4.2 Energy storage and exchange

Following the theoretical framework, the second measure regarding energy transition should be the analysis of the potential for energy exchange and storage. First of all we will describe general measures comprising the three groups, buildings, industries and transportation. Secondly we will focus on the heat and cold exchange potential (e.g. heat and cold exchange with water bodies) and the third part will comprise the potentials for Heat and Cold Storage (HCS) found in the underground of Arnhem.

4.2.1. Buildings, Industries and Transportation

When buildings and Industries are considered, measures to reduce the exergy (2nd Law of Thermodynamics), are considered. Regarding industries, the reduction of waste should be accompanied by the reuse of energy, improvements of material efficiency and the possibility of heat cascading and energy exchange between this sector and related with the surroundings neighbourhoods. According with Ecofys (2011) in general, by applying saving, energy exchange and reuse of waste initiatives in light industries about 50% of the three energy carriers consumed by this sector can be reduced. Regarding heavy industries, the primary sources of energy should be used only to offset losses due to dissipative use (Ecofys, 2011). In order to know the precise potential for these kinds of interventions in Arnhem, a more detailed study has to be done. Nevertheless, go in depth on these topics are beyond the aim of the present thesis. Researchers such as Dobbelsteen (2011, 2012) involved on the project Rotterdam Energy Approach Planning (Van Djik, 2009) or case studies, for instance the Eco-Industrial Park in Germany (ECN, 2004) should be accessed.

With regard to transportation, the shift to electric vehicles can be used as a measure to store electricity. Once there is the need for extra electricity, the fleet would be connected to the grid in order to discharge the electricity to be used in other places.

Heat and Cold Exchange

The potential for heat and cold exchange in Arnhem can be found mainly along the river Rhine (Figure 4.3). The exchange is based on low temperature of heat and cold. The cold water is collected from the bottom of the river to be used on cooling systems in buildings located on the banks of the Rhine. The final warmer water is discharged on the upper layers of the river (Figure 4.4). During the winter the system works on the opposite way, and the low temperature of the water is up graded by electrical heating pumps. An example of this system can be currently found in Rotterdam along the river Mass (van Djike, 2009).

Even though the feasibility of this technology in Arnhem still requires economic and ecological studies (KEMA, 2009) the system can be integrated with the heat and cold storage (HCS) in the underground. According with documents from the municipality (TTE, 2009) it is possible to save about 100 million m3 of gas by using all the potential content on the water bodies surface (e.g.rivers, brooks, lakes). On the other hand, approximately 0.9TJ (250MWh) of electricity would be necessary to run the system. Thus, the investment on renewable sources for electricity generation should be considered for the implementation of the system.

Figure 4.3. Map of the areas with optimal potential for heat and cold exchange with the river

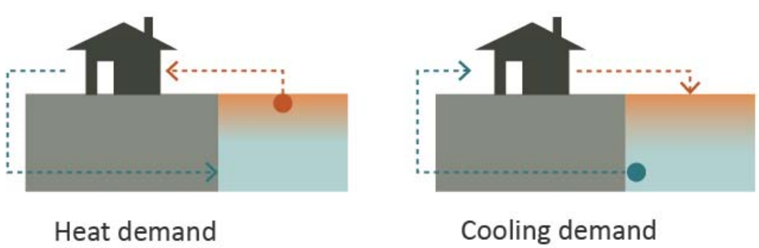

Figure 4.4. Diagram of heat and cold exchange with the river

Heat and Cold Storage

Heat and Cold Storage (HCS) systems can be divided into closed or open technologies and its implementation depend on the characteristics found on the abiotic layer, analysed on the ***Chapter 02***. Both systems, closed and open, work by storing low temperature water, from 5◦C to 20◦C, on a maximum depth of 250m. When dealing with Heat and Cold Storage systems, three main features should be taken into consideration, the risk of contamination in the aquifers, the feasibility to extract drinking water and the complex web of cables and pipes (Figure 4.5). Despite these features, for each particular technology some other characteristics should be previously identified.

In the case of closed systems (e.g. vertical heat storage) the geological and spatial features are almost indifferent. This is possible because closed pipes are vertically installed making with the circulating water in the system does not have contact with the underground layers (Figure 4.6). In the case of Arnhem, an analysis was made on a depth of 30 m, where it was possible to identify areas which have very good, good or moderate potential for closed systems (Kema, 2009) (Figure 4.8). Another feature is the need of certain quantity of pipes in order to be efficient which might lead to a lot of disturbance in the underground, such as, the sticking through subsurface layers and aquifers (Krogt,2011).

The open system on the other hand, works by using the availability found in the aquifers in order to store hot and cold water. The potential depends on groundwater pressures, velocities and resistance, thickness of the aquifers, policy restrictions and so forth. The basic principle is the use of an electric pump to inject water into two pipes, one cold and another hot, both connected to a heat exchanger (Figure 4.7). This system can also generate disturbances in the underground caused for instance by the high circulation of groundwater and the difficulty to keep the energy balance (thermal pollution). However, lots of research are being made with regard to implementation, functioning and possible disturbance of the system (Krogt,2011). Furthermore, open systems have the advantage to be instead in large areas (e.g. neighbourhood scale) rather than individual solutions besides the possibility to be integrated with urban water cycles, surface water bodies and heat cascading from industries. These possibilities make the system more versatile and robust than the closed systems.

In the case of Arnhem, the potential for Heat Cold Storage in aquifers differs according with their characteristics in the north and in the south banks of the river Rhine. Furthermore limiting areas with risk of contamination and the extraction of drink water should be considered when the viability of the system is analysed (Figure 4.9).

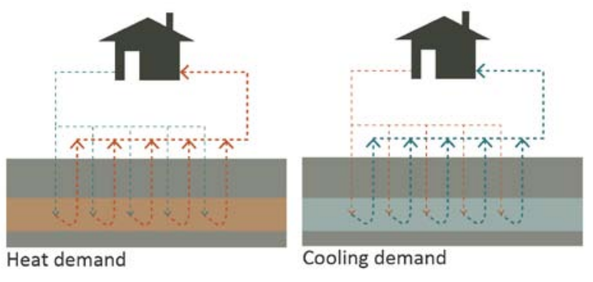

Figure 4.6. Diagram of a closed system

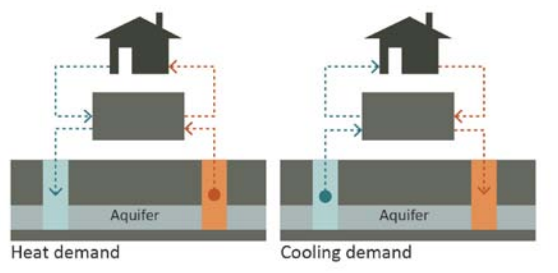

Figure 4.7. Diagram of an open system

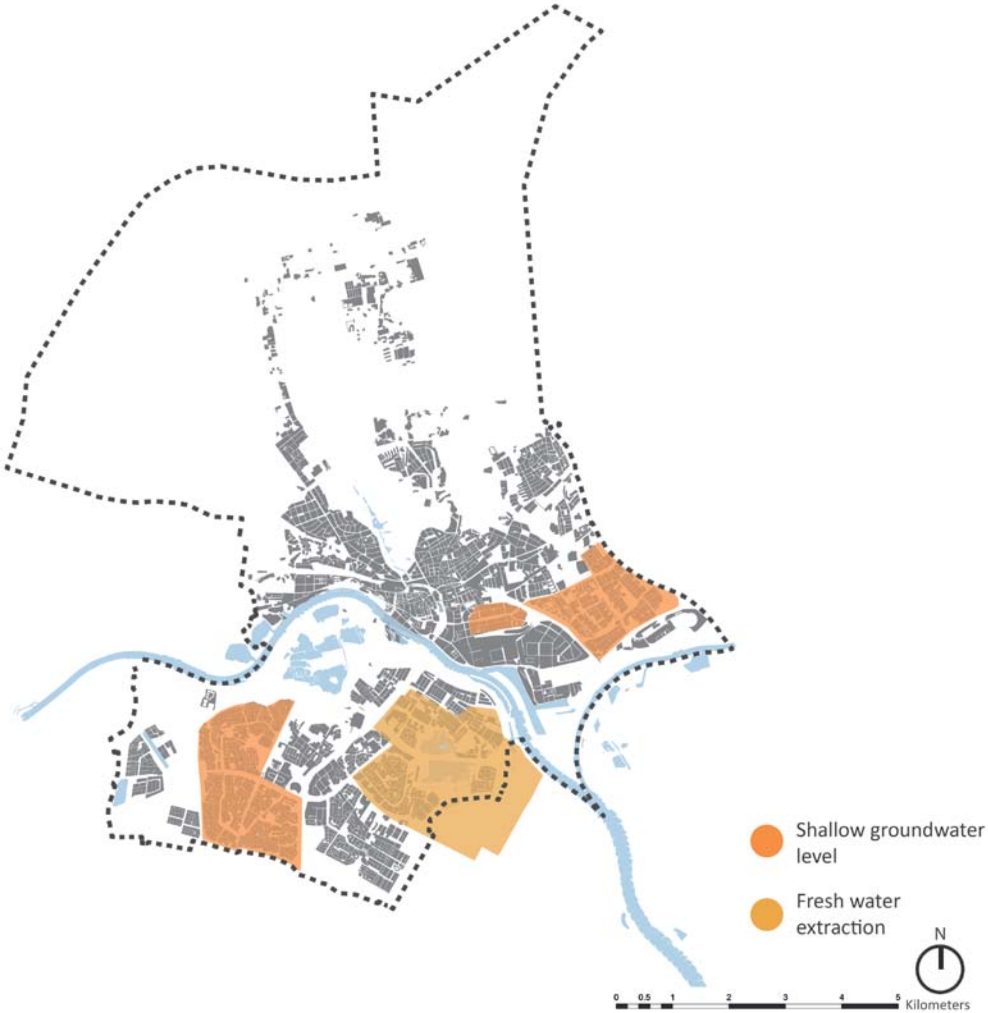

Figure 4.5. Map locating the restricted areas for heat and cold storage

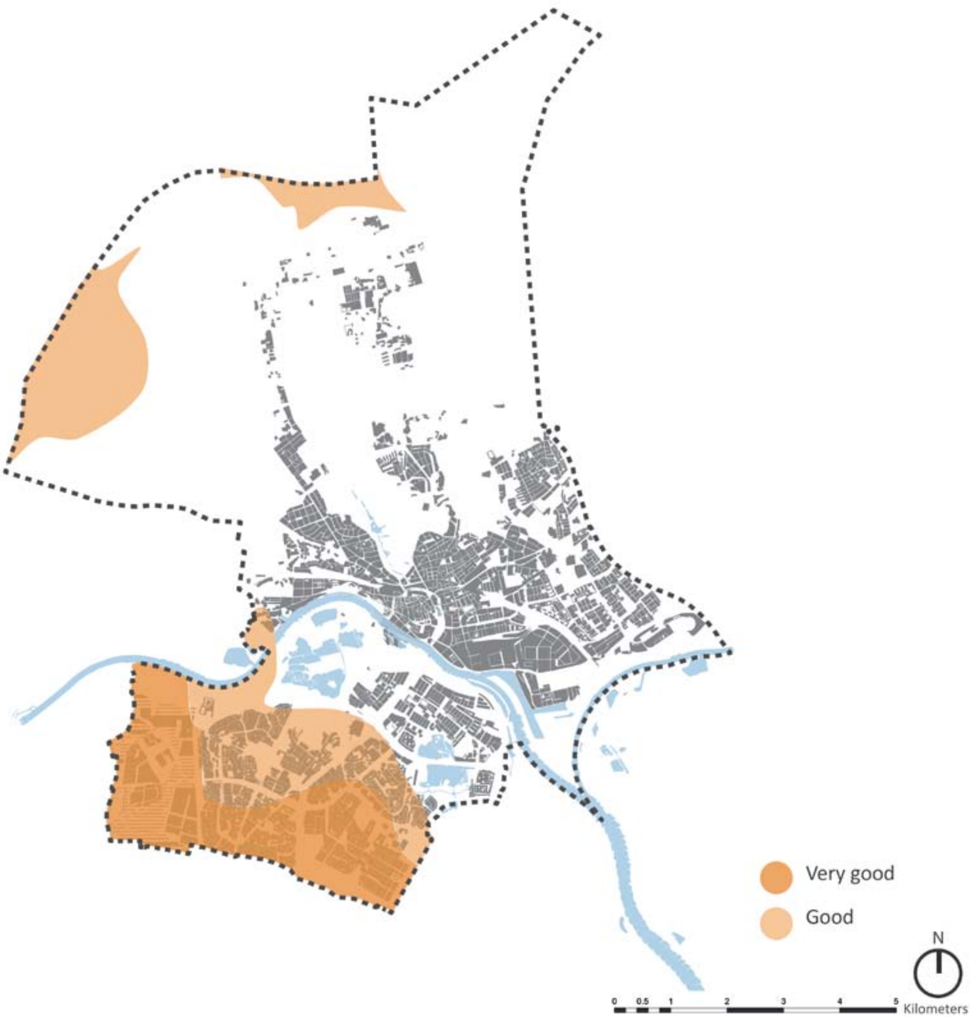

Figure 4.8. Map of the areas with optimal potential for closed systems

In the north part of Arnhem the aquifers WVP1 and WVP2 are not suitable for HCS installation due to the high flow velocity of the underground water. Moreover the first aquifer presents impermeable layers which makes it difficult for the HCS system implementation. Therefore, the third aquifer is the most suitable in the northern of the city being able to receive installations enough to supply about 30 to 50 dwellings per hectare. This calculation is based on the available space on the aquifers (FSI in TTE, 2009).

Regarding the south area, the WVP2 presents the best potential due to its good thickness and permeability. The average of the area is to supply 50 dwellings per hectares or 10,000 m2 of offices per hectare. The first aquifer has a limited potential for HCS and could be used for small installations while the WVP3 is too thin to be able to store a desired amount of heat (TTE,2009). Roughly, Kema (2009) evaluate the final potential for HCS on aquifers as 160TJ per year in Arnhem.

As well as the closed system, the open system has advantages and disadvantages. On the other hand, open systems are carried by lots of research and the feasibility of the system seems much better than the first option.

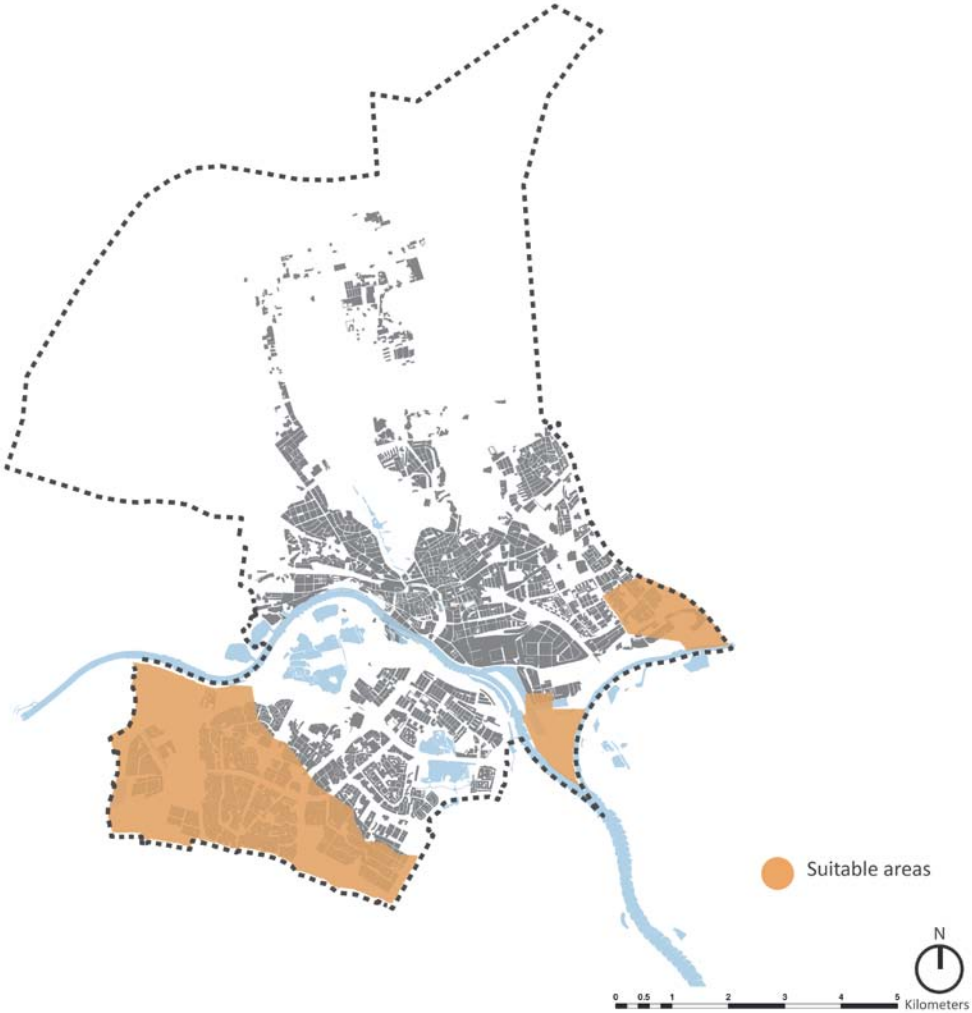

Figure 4.9. Map of the areas with optimal potential for open systems

4.3 Energy generation

The third measure to have a successful energy transition regards the potential to generate energy by using renewable sources. The target in the potentials found inside the city and in some cases in correlation with existent systems in the surroundings of the city. In Arnhem, even though the potentials for energy generation by renewables sources are very limited, diverse kinds of technology have the potential to be implemented. They were studied based on the characteristics of the three layers abiotic, biotic and anthropogenic of the landscape. Considering the obstacles to design a sustainable energy landscape faces, periodic fluctuations (also known as intermittency), low energy density and limited utilization of available energy by consumers (Stremke, 2011) the coexistence of diverse technologies should be emphasized.

Therefore, each technology will be presented individually, and once we propose our vision, **chapter 07 and 08**, the systems will be correlated. The data collection regarding energy generation was based on the energy study made by Kema (2009), specific webpages and interviews with professionals. The amount of energy the technologies can potentially generate will be compared with the national average consumption of electricity, 3,500 KWh, (Kema, 2009) and heat, 11,000 KWh per household per year. Also, we will inform how much CO2 neutral each technology is considered. The detailed calculations can be found on the annex III.

Solar potential

The sun is known as the source for life. Plants, for instance, get energy from solar radiation in order to make photosynthesis, the essential process for its growth. Also the wind is influenced by the sun, since it happens due to the difference of temperature in the air caused by solar radiation. Therefore, when energy transition is considered the first source one would thing about is the potential provided by the sun (MacKay, 2009). Even though other potentials, such as biomass and wind are related with the sun, we are going to focus on the two possible direct use of solar radiation. The first is to generate electricity by implementing solar PV cells and the second is to generate heat by installing solar collectors. The other sources, will receive particular attention along this chapter.

Photovoltaic solar cells (PV cells) are responsible for the conversion of solar radiation into electricity. The system is made by individual PV cells organized into solar panels. The technology can be used for punctual needs (e.g. Solar tree, Figure 4.10) or to be connected to the electricity grid, when a large scale implementation is necessary (e.g. solar parks- Figure 4.11). The current efficiency of the system, varies between 10 and 20% (MacKay, 2009), therefore we used the average efficiency of 15%. The feasible area on roofs was taken from the evaluation made by Kema (2009). Moreover, some open fields in the north showed up as potential areas for solar farms implementation (Kema, 2009). The national average of solar radiation per square meter of 1000KWh/ m2 (Figure 4.12) (JRC, 2011) was then used in order to evaluate how much electricity can be provided by this source in Arnhem

On the map on figure 4.12, the roofs and the open fields are identified. From the total area of roofs, only 24% can indeed receive PV cells (Kema, 2009). The open fields are mainly composed by agricultural plots. Due to the favourable inclination of the Veluwe slopes to the south, the potential

Figure 4.10. Solar tree in Vienna, Austria by Ross Lovegrove (Inhabitat)

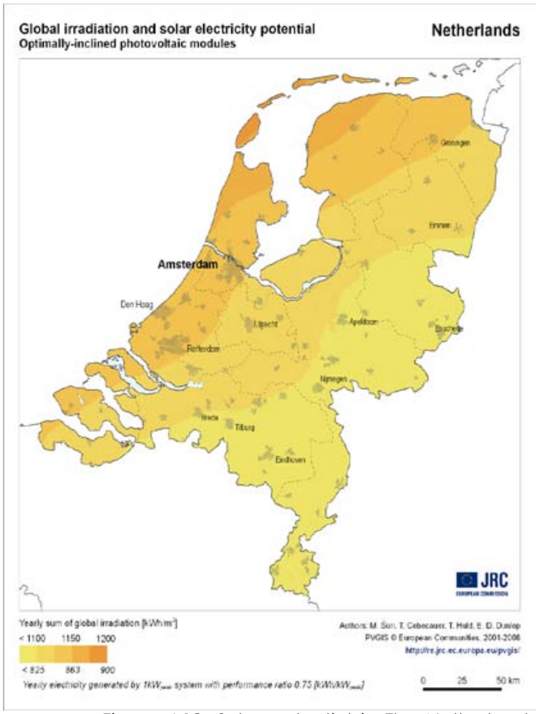

Figure 4.12. Solar potential in The Netherlands (JRC, European comission)

Figure 4.11. Solar farm Les Mées, France (B. Horvat, The Guardian)

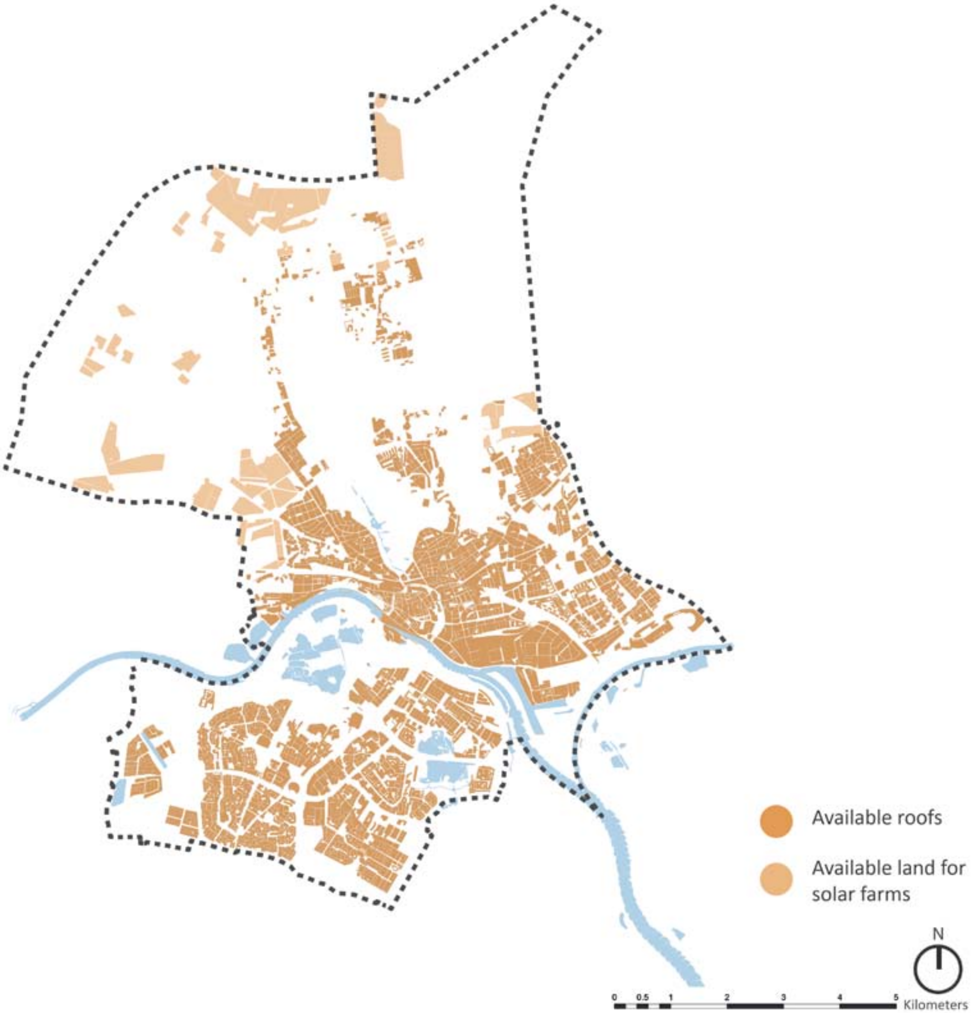

Figure 4.12. Map of the areas with optimal potential for solar power

for receiving this technology increases. Another remark regards the highest potential found in the industrial park Kleefsewaard. Since the neighbourhood has predominantly flat roofs, solar PV cells or collectors can be easily installed covering a highest area than in the traditional tilt roofs.

By summing the 24% area on roofs and all the open fields, 4,021 TJ/ year of electricity can be generated. It means the production of 5.4 TJ/ha, or considering the small scale of roofs, 150Kwh/m2. This amount of electricity can supply 319,160 households, which means more than five times the amount of households in Arnhem. Moreover when compared with the electricity consumption in Arnhem, 1,4 times of the total can be provided by this source. However, once the implementation of solar PV cells is considered the limitations in the city have to be analysed. For instance, the plots in the north may have a variety of destinations such as to nature development. The oldest areas of the city offer certain degree of limitation due to the visual impact the technology may have. More precise evaluation of the importance each limitation has for the technology will be analysed on the **chapters 06, 07 and 08** when the socio-economic scenarios and visions will be discussed.

Regarding heat generation, solar collectors (thermal collectors) can be implemented on the roofs of buildings. The system uses different ways to store the low temperature heat. For instance, a boiler can be installed on the roof to store water or the collectors can be integrated with a complex system, including residual heat and heat and cold storage in the underground as explained on the ***section 4.2*** of this chapter. The potential for this technology was also based on the available area on roof tops to receive the collectors since the system is efficient when working for one single dwelling.

Considering solar collectors are less efficient then PV cells, according with Kema (2009), approximately 230TJ/year can be generated on the feasible roofs. This amount is equivalent to the consumption of approximately 5,800 households and represents about 3% of the total heat consumed in Arnhem. The productivity per area is 2.68TJ/ha, or 75KWh/m2.

As a conclusion, the potential to generate electricity is highest than to generate heat. If the complete area available on roofs (24% of the total roofs in the city), next to all the open fields in the north are considered, more than the total consumption in Arnhem can be supplied by this technology. However, the limitations of the landscape should be considered. With regard to CO2 emissions, solar PV cells and collectors are considered neutral technologies.

Wind potential

In general The Netherlands has a good average of wind speed from about 5.5m/s inland to more than 9.0m/s along the north coast when measured 100m above ground (Bosatlas, 2010). Usually a wind turbine needs at least 3m/s wind speed to start its work and stops working when the wind exceeds 25 m/s (ECN,2011). Hence, the country has a very good potential for this technology.

In the case of Arnhem, the wind speed varies from minimum 5.5m/s 80m above ground to 8.0m/s 120m above ground. The best velocities are on the south-west and extreme north of the city (Figure 4.13). Nevertheless, influential factors such as social acceptance, land use and other general limitations have to be considered in order to wind turbines to be installed. The analysis of the social acceptance reactions (e.g. NIMBY “Not In My Back Yard”) is beyond the aim of this thesis but will be further included as general step advances to the municipality of Arnhem.

As an example of potential sites for the wind turbines installation the studies conducted by KEMA (2009) proposes three wind turbines on the north banks of the river Rhine, on the edges of the industrial park Kleefsewaard, and fifteen in the north of the city. The study uses 3MW wind turbines (Figure 4.15) with 22% efficiency and the range wind speed from 6m/s to 6.5m/s 80m above ground. As a result, 63 TJ of electricity would be generated along the river (03 wind turbines) and 315 TJ in the north (15 wind turbines). Together, both wind parks would deliver about 11% of the electricity used in Arnhem or the equivalent to the consumption of 25,000 households. The productivity is about 1.3 TJ/ha when we consider 16ha need per equipment (Kema, 2009). Weather these possibilities would be implemented will be also discussed during the ***Chapters 07 and 08***. On the other hand the limitations presented by the natural area, between the two national parks in the north, may offer a barrier for the wind park implementation in the north since it depends on policies changes. As a result, the potential for wind turbines installation in Arnhem should be better analysed according with the limitations found in the city.

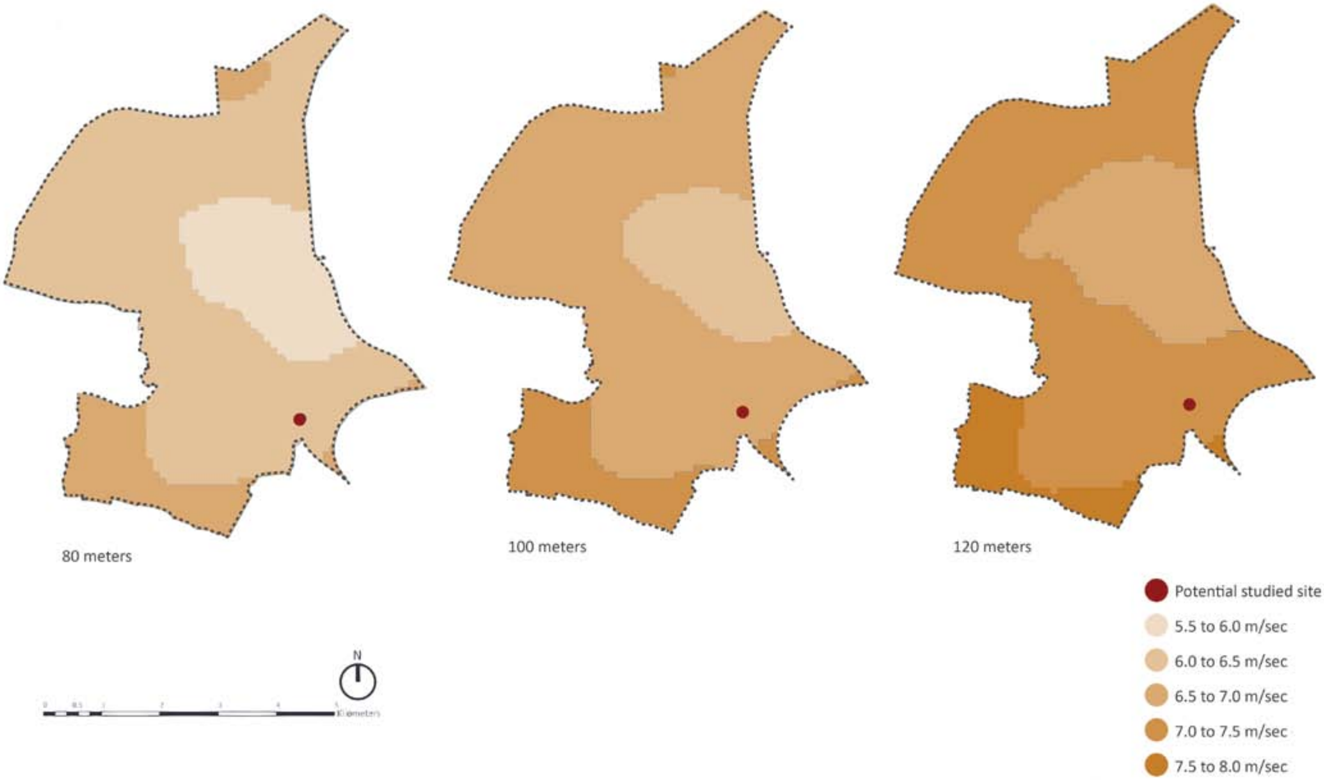

Figure 4.13. Wind potential in The NetherlandsKNMI)

Figure 4.14. Wind farm in Germany (J. Gómez)

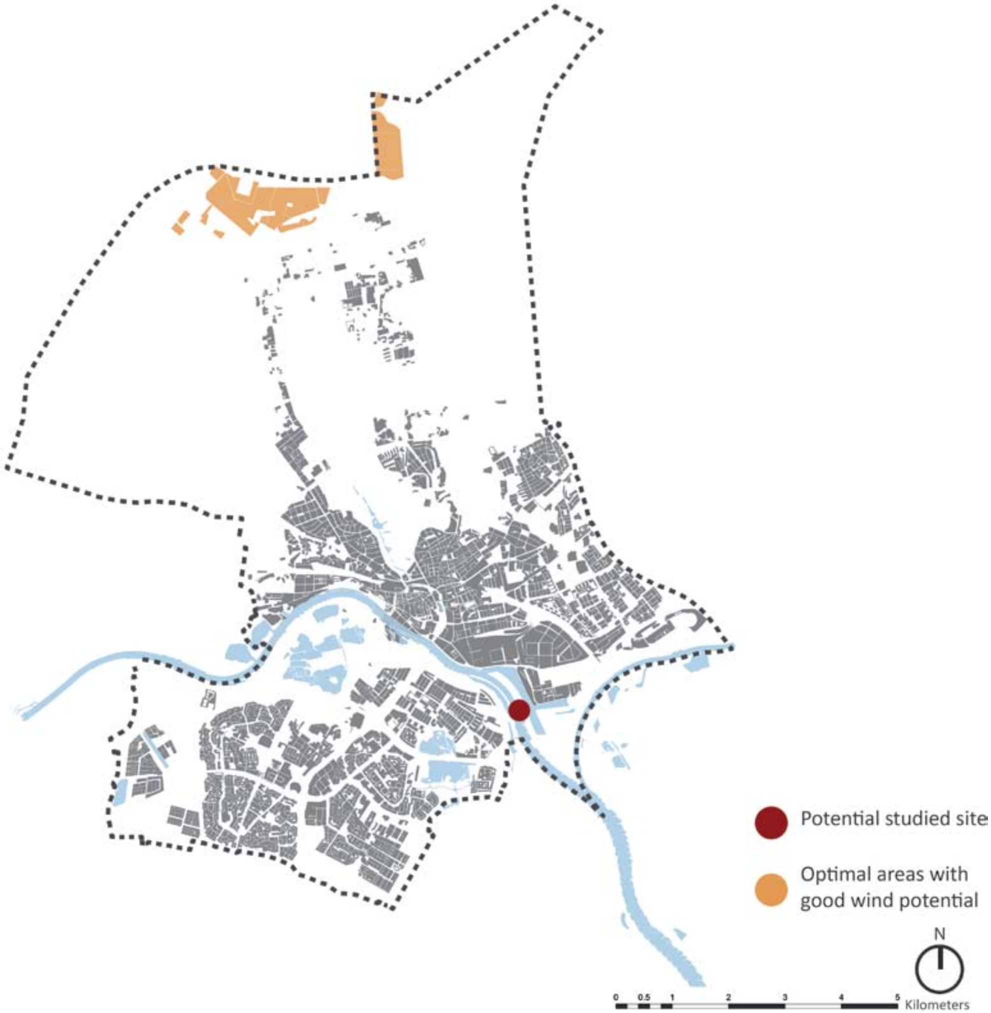

Figure 4.15. Map of areas with optimal potential for wind power at 100 m. (KEMA 2009)

Biomass

Biomass was the first fuel used by humans to generate energy. The burn of wood followed the human evolution through the centuries (Herzog et al., 2001). The current use of biomass as renewable source for energy generation comprises a large range of possibilities. For instance wood provided by forest maintenance, energy crops and organic waste can be used to produce biogas, biofuel and consequently heat and electricity. Even though Arnhem does not count with large amounts of available land for the production of dedicated energy crops, it is possible to find different kind of biomass in the city. We grouped the follow ones: wood chips, municipal green maintenance, energy crops, algae and manure to be analysed now. The ones related with waste will be discussed on a separate item 'Waste' in this chapter.

For the calculations we are going to consider the general caloric value of biomass as 18GJ/ t (0.018TJ/t) of dry material (Elbersen,2011). The exception remains upon the algae production which has a higher value, 24GJ/ton (0.024TJ/ton) (ECN, 2011). Furthermore, we considered an efficiency of cogenerate power plant (CHP) to be 50% heat, 35% electricity and 15% losses during the process.

Regarding CO_2 neutrality an important factor should be considered. In general when crops are produced focusing on energy generation, the combustion or gasification of this biomass is considered CO_2 neutral. This fact happens due to the gas emitted during the conversion process will be sequestrated by the plant on the next cycle of growth. On the other hand, the lag period of each species should be taken into consideration (McKendry, 2002). As a result, on this report we will consider the sources of biomass which have the cycle of harvest and growth of about one year. Therefore, we assume the relation between the amount of CO_2 emitted and sequestrated is neutral on the short term. For detailed implementation, each source of biomass should be analyzed individually and by specialists on this field.

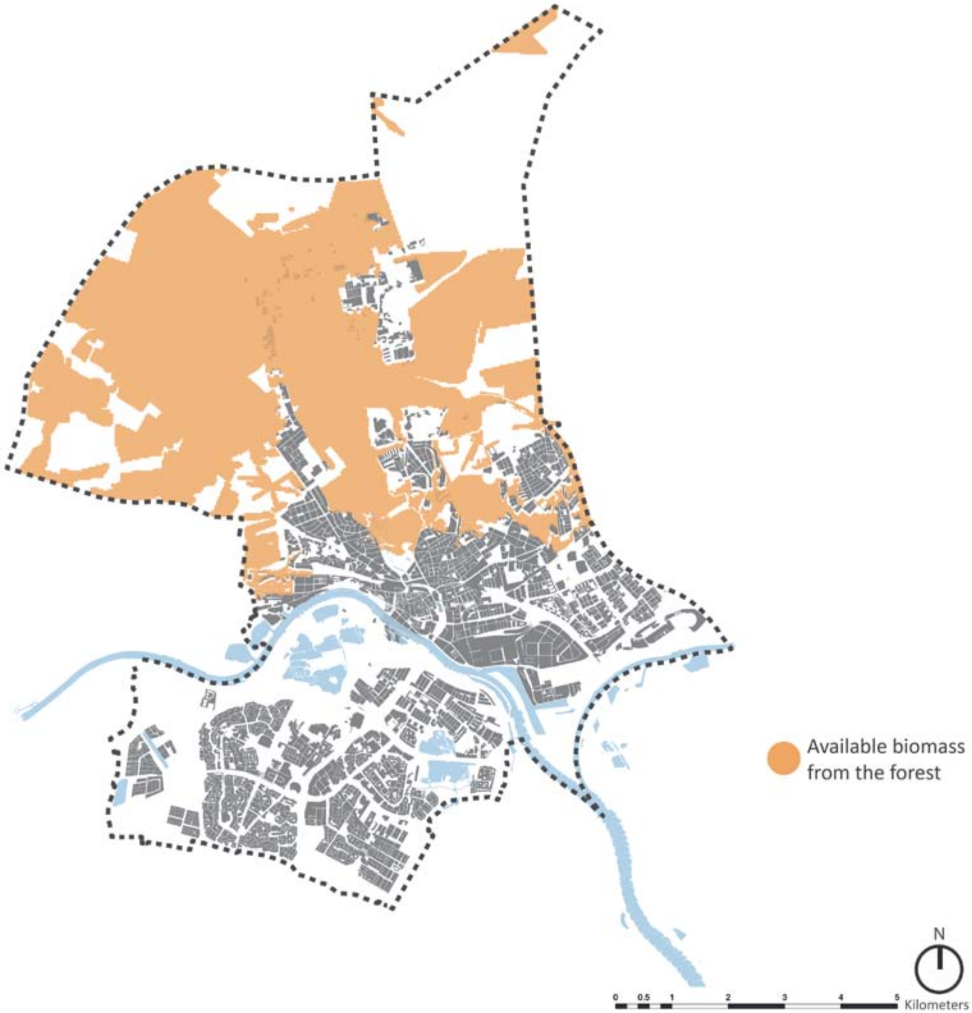

Figure 4.16. Optimal areas for biomass (wood chips) from forest

Wood chips

According with the data from BTG MRA-biomassa studie (in KEMA, 2009) about 2,548 tonnes per year of wood chips can be collected in the forest of Arnhem (Figure 4.16). This amount of biomass can be burned in order to produce electricity and heat. For instance, if we consider the highest efficiency to produce heat (100%) about 45TJ can be generated. When the efficiency of the CHP is applied, the efficiency shifts to approximately 23TJ of heat and 16TJ of electricity. This amount of energy would supply approximately 1,270 households with electricity and 580 with heat. When the TJ/ha is considered, 0.009TJ/ha of heat and 0.006TJ/ha of electricity are produced. As a limitation factor, the extraction of wood chips has to be improved by developing more efficient methods of collection in order to reduce the costs. Moreover, the proximity of the CHP is desired since it improves the efficiency of the process (BTG, 2009).

Considering we are burning wood chips, we are consequently emitting CO2. On the ***Chapter 02***, we introduced the forest of Arnhem as it is being productive. In other words, it means that the amount of wood collected yearly from the forest does not exceed the annual growth (Alterra, 2007). Once we harvest only the amount of wood which grew up during the last year, the forest keeps its CO2 balance on a short term.

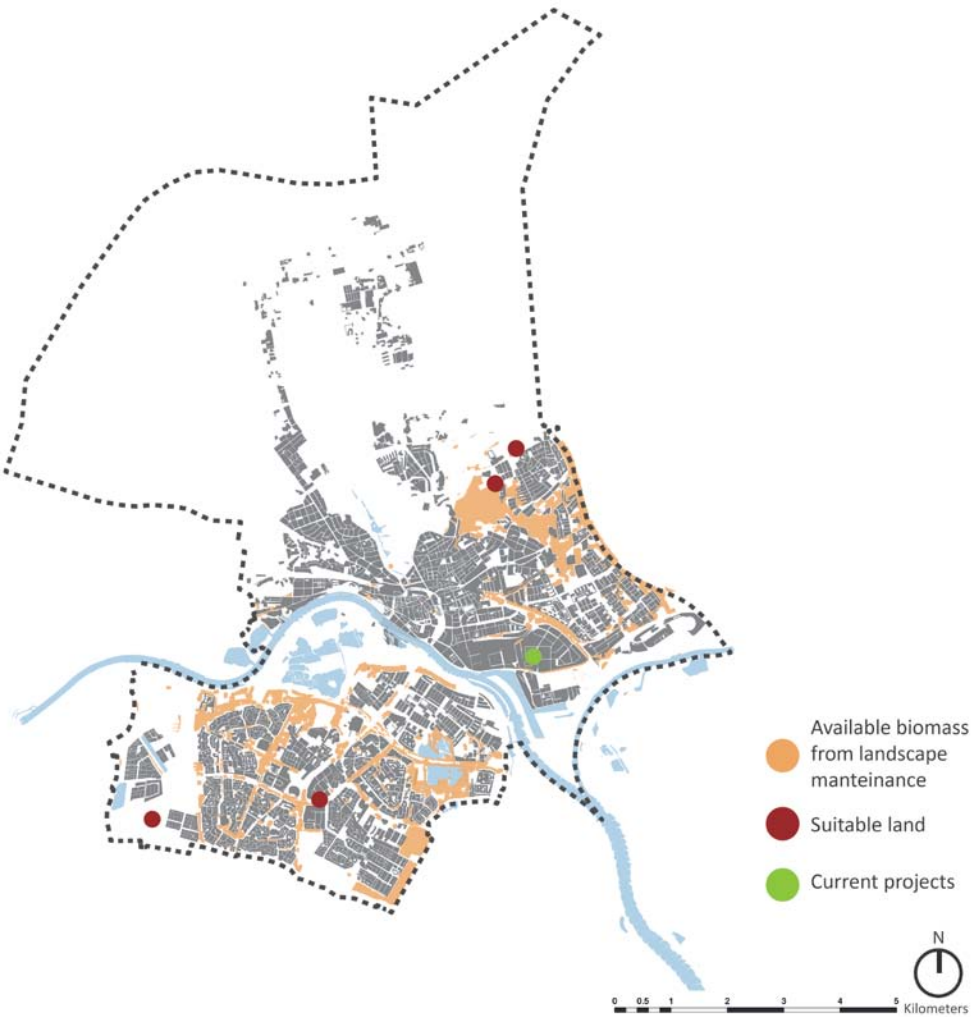

Figure 4.17. Optimal areas with potential for biomass from landscape maintenance

Landscape maintenance

The municipal landscape maintenance sums an average of 5227 tonnes of wet material per year (BTG MRA-biomassa studie in KEMA, 2009) (Figure 4.17). This type of biomass is hard to be converted, since it usually contains rests of soil and other materials that cannot be processed to generate energy. Nevertheless, based on the data from the Energy research Centre of The Netherlands (phyllis in ECN,2011) it is possible to make a rough calculation regarding the potentials of municipal green maintenance. By considering 30% water can be extracted from the wet material and 18 GJ/ton of energy content in the dry material we estimated this source can provide the city with about 28TJ of heat and almost 20TJ of electricity. Based on this information, the energy generated by green maintenance would supply 707 households with heat and approximately 1590 with electricity. The productivity per hectare is 0.026TJ/ha of heat and 0.04TJ/ha of electricity.

Figure 4.18. Optimal areas for biomass from energy crops

Energy crops

Regarding energy crops, the area occupied by the flood plains in Arnhem showed up as a potential site for growing this kind of biomass (Figure 4.18). The flood plains are characterized by natural areas occupied by grass fields and lakes surrounded by a higher vegetation. The configuration of this area was made in order to allow the waters from the Rhine to flow. As a result, the flood plains cannot be occupied for dense high vegetation. Therefore, the choice for the crop should be based on the characteristics of the natural landscape (Biotic layer), the soil qualities (Abiotic layer) and water cycle. For natural safety reasons, invasive species which are not indigenous in The Netherlands, such as miscanthus and switchgrass should be avoided. According with researchers from Biofort NL (Koppejan,2012) reed (*Phragmites australis)* has the highest potential to be introduced on flood plains. Even though studies still have to be done in order to be sure about how efficient this system would be, we decided to pay attention in this niche of the landscape (Stremke and Koh, 2008) as a potential area to contribute for the challenges of energy transition in Arnhem.

The life cycle of the reed on the flood plains would follow the strategy to be harvest just before the spring floods, in the end of the winter season and burned. The restart of its growth would then happen after the floods, during the spring. By assuming an area of 300ha along the banks of the river Rhine, the potential energy production can achieve 16TJ of heat and 11TJ of electricity per year. The amount of energy generated by this source is able to supply 404 households with heat and 873 households with electricity. The productivity would be approximately 0.05TJ/ha of heat and 0.03TJ/ha electricity.

Algae

For a medium-long term implementation (from 10-15 years so forth), new technologies such as algae production are also considered. This technology is one of the most promising feedstock for biofuels (Wijffels and Barbosa,2010). Three main systems are current being studied by the Algae PARC at Wageningen UR, the raceway ponds (Figure 4.19), tubular system and flat panels (Figure 4.20). Each one of them offer pros and cons, thus it is still hard to predict which one of them will be the most feasible in the future (Bosma, 2012.). Hence, we are going to focus on the general contribution the algae production would have in Arnhem rather than focus on the discussion regarding the possibilities of the available technologies.

The general advantage of producing algae, when compared with the traditional sources of biomass, is the high productivity per hectare (Wijffels and Barbosa,2010). While 21t/ha per year of algae can be produced, reed, for instance, would provide 8t/ha per year. It means algae offer a lower competition with arable land for food production. Moreover, the caloric value per ton of dry material is 0.024TJ /t instead of the 0.018TJ/t of the other kind of biomass (Phyllis, 2011). Another characteristic is the ability algae has to convert CO_2 into carbon-rich lipids (easily changed into biofuel). On the other hand, algae production is only profitable when other bio products are extracted and the system requires the availability of concentrated CO_2, heat, light, water and nutrients.

Therefore, better results can be achieved when the technology is associated with CO_2 and residual heat such as, heat district network and industries. The need for large amounts of water makes the sites along water bodies to be more feasible. Besides the need for CO_2, heat and water, algae is able to extract nutrients from the sewage. Detailed studies are being also conducted on this field (Fernandes, 2012). As a result, the association with Waste Water Treatment Plants (WWTP) can be correlated with algae production besides to treat the water to be reused.

Considering these characteristics, the implementation of algae farms in Arnhem would be possible on residual lands in the industrial park Kleefsewaard or in Schuytgraaf (Figure 4.21). Both areas offer the possible connection with the WWTP, residual heat, CO_2 and water from the river. Furthermore, the connection of algae production with the CHP in Duiven (the next municipality) would be another good option. There we found the potential for extending large fields of this biomass, reducing the costs of the system implementation (Norsker et al.,2010).

For calculations regarding algae, two ways will be considered. The first is to be used as dry material on the Cogenerate Heat Power and the second focus on the biofuel production. Considering the caloric value of this biomass, 0.024TJ/t, and a productivity of 21t/ ha per year we applied on the approximately 65ha hectares available on the two sites inside the fringes of the municipality, industrial

Figure 4.19. Raceway pond system by Seambiotic (The Guardian)

Figure 4.20. AlgaePARC at Wageningen UR, (Science Business)

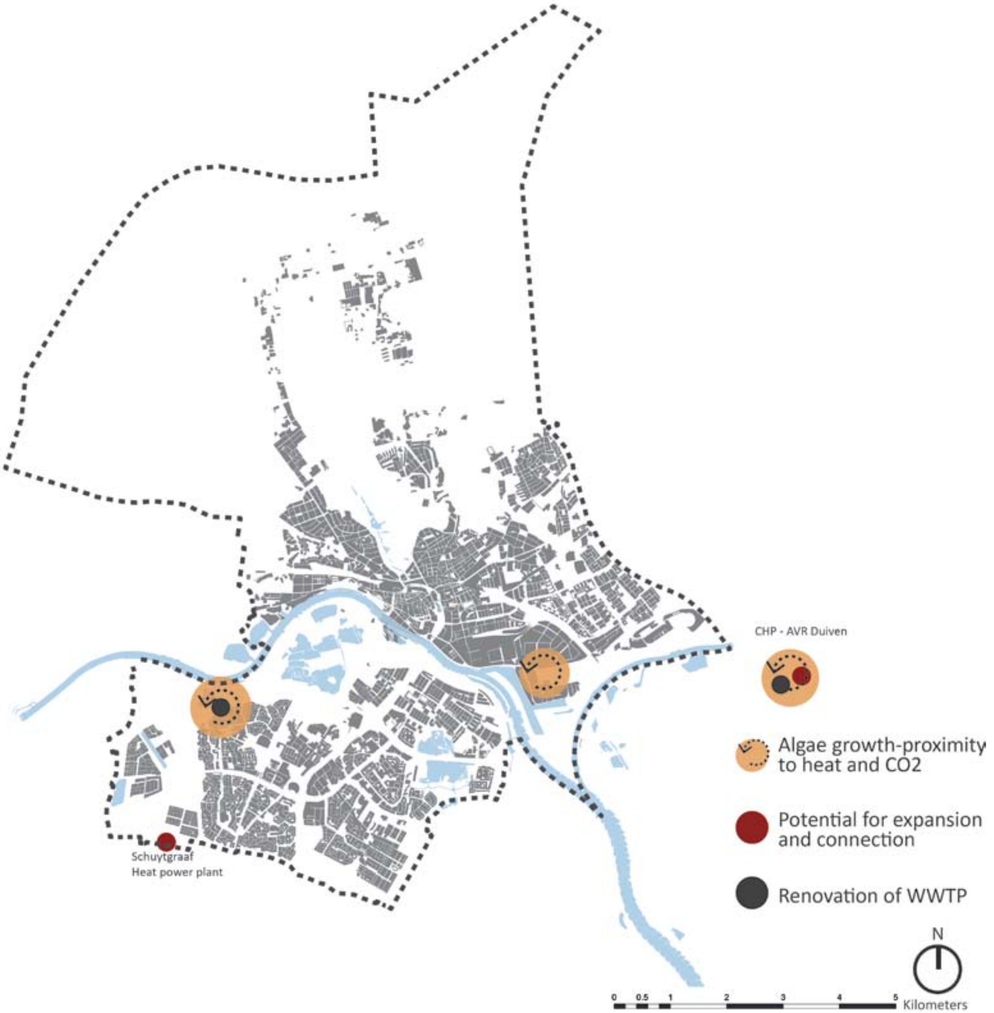

Figure 4.21. Optimal areas for algae growth

area and Schuytgraaf. As a result, 16TJ/year of heat and about 11TJ/year of electricity would be generated. These amounts could supply about 400 households with heat and aproximatelly 870 with electricity. The productivity per hectare would be 0.24TJ/ha of heat and 0.16TJ/ha of electricity per year. Which means much more than the other kind of biomass.

Regarding the biofuel production, 20,000L per hectare was considered (Chisti,Y. 2007). Considering the caloric value of the biofuel is much higher than the biomass, 35.86 MJ/L (Bosma, 2012), the resultant energy generated is about 45TJ/ year. In the case of biofuel the potential amount of energy generated per hectare is 0.7TJ/ha per year.

As a conclusion, algae is a promising technology. If combined with the production of other bio products it can be very profitable. The main advantage of the system is the highest productivity per hectare, besides the low competition with land for food production. On the other hand, researches state the technology has to be developed during the next 10 to 15 years in order to be scaled up. Moreover, they reinforce the need for CO2 concentrated, heat, light, water and nutrients in order to be cost –benefit.

Manure

Regarding the use of manure as source of energy, Arnhem offers inexpressive quantities, (BTG, 2009). This material usually is needed for the fermentation process of biomass to produce biogas. A possible source of manure in Arnhem would be The Burger's zoo. However, due to the low quantities it might be more interesting to use this source locally as a step for the self-sufficiency of the zoo rather than to be used in other systems.

Waste potential

The waste collected in the municipality of Arnhem comes from diverse sources such as, households, construction and demolition and municipal organic waste disposal (GFT). Currently it has three different destinations, recycle (29,456 tonnes), combustion (41,534 tonnes) and storage in landfills (48 tonnes) (Gemeente Arnhem, 2010). Furthermore, other 8,264 tonnes of organic garbage is collected by two municipal waste disposals and have the potential to be fermented as biomass.

Regarding energy generation the waste can be destined to combustion or fermentation. If the entire waste produced would be burned (79,301 tonnes) about 277TJ of electricity and 832 TJ of heating would be delivered (Gemeente Arnhem, 2010). Since the recycle of waste is already a reality and there is the trend to be expanded, the calculations of the waste potential for energy generation consider 41,534 tonnes of mixed household waste to be burned. As a result, about 218TJ of heat and 152TJ of electricity could be generated. When the number of household attended is considered, about 5,500 would be supplied with heat and about 12,060 with electricity. Regarding the CO2 emissions, even though the waste incineration is not a neutral system it emits 0.018t/GJ of energy generated against 0.057t/GJ due to the use of natural gas, 0.074t/GJ by oil and 0.095t/GJ by coal (RenoSam and Rambøll, 2006). Furthermore, the use of Best Available Technique (BAT), the recycle of residues and to have a strict environmental regulation are essential measures in order to reduce the amount of CO2 emitted. Moreover, to clean the flue gas from dust, heavy metals and other pollutants responsible for the global warmth has to be done.

Besides the recycle and combustion of waste, the organic matter, green, fruits and rests from gardens (GFT) from the municipal waste disposals can be fermented in order to generate energy. The amount of GFT collected in the city is 8,264 ton/year of wet material (gemeente, 2010). According with BTG (KEMA, 2009) the potential energy content on this material is 12.95TJ by using fermentation process. As a result, 6.27TJ of heat and 4.39TJ of electricity can be generated. The amount of energy generate by this process is enough to supply approximately 156 households with heat and 348 with electricity. Moreover, organic compost is generated as a sub-product. By summing the energy generated by the waste incineration and GFT fermentation processes and considering the area the city occupies without the green spaces (4834ha), we can estimate roughly the amount of TJ per hectare. In the case of heat, 0.46TJ/ha are possible and 0.32TJ/ha electricity are produced.

Another kind of waste considered is the one resulted by construction/ demolition works (e.g. wood). Nevertheless, it varies a lot and cannot be faced as a constant source of material. According with BTG (in KEMA,2009) there is the possibility of 13,330 tonnes of this kind of waste per year. By burning this amount about 60 TJ of heat and 42TJ of electricity would be produced. Nevertheless, considering the uncertainties regarding the availability of this kind of material its storage to be used in case of extreme necessity (e.g. to cover the intermittency of other systems) or the try for the complete recycle of this material would be preferable.

As a conclusion, the use of waste to generate energy offers diverse possibilities. Some of them are CO2 neutral (GFT and organic waste) while others are still responsible for certain amount of emissions (waste incineration). Due to the trend of recycling, the use of waste for incineration should be reduced along the years. Therefore, this technology would be better proposed as a previous step for other sources of energy.

Examples of incineration plants (Figures 4.22 & 4.23)

Figure 4.22. Incineration plant in Vienna, Austria by Ernst Schauer (The New York Times)

Figure 4.23. Incineration plant in Copenhagen by BIG (Inhabitat)

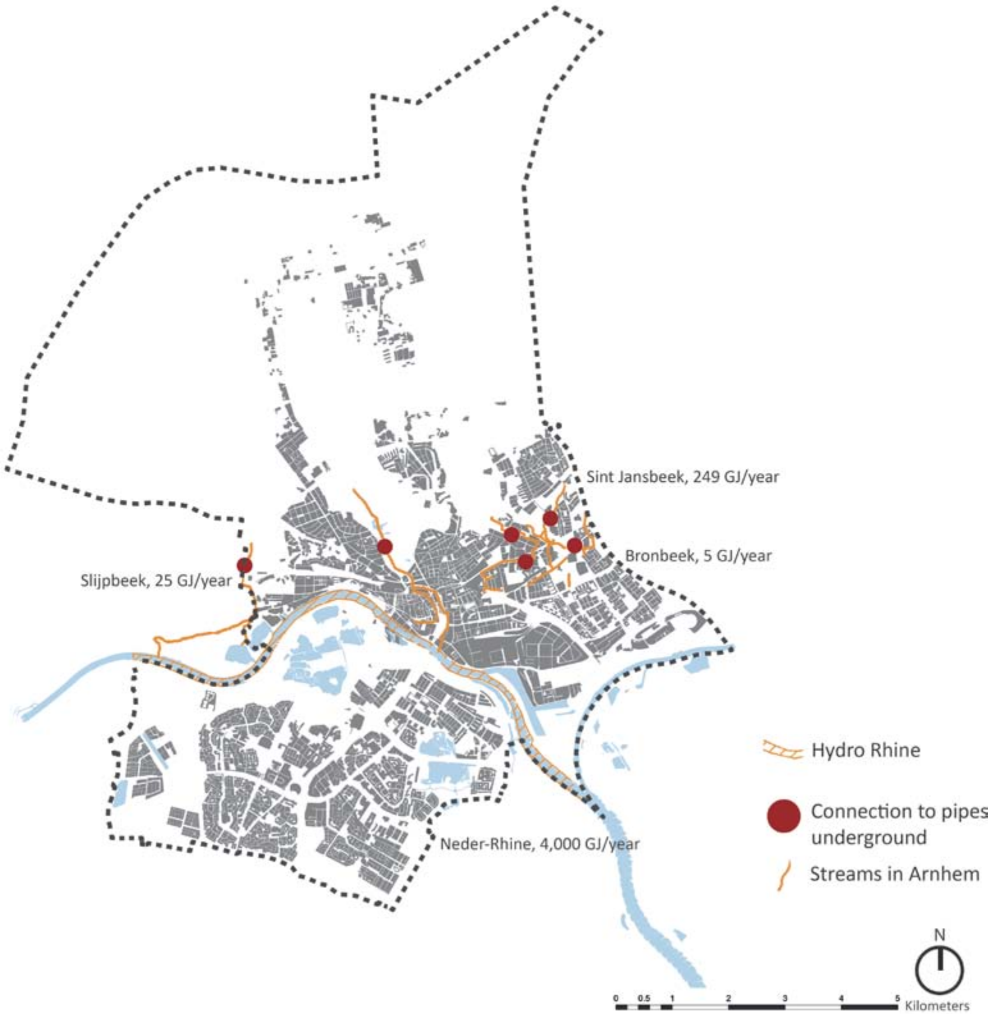

Figure 4.24. Optimal areas with hydro-power potential

Hydrological potential

Hydrological potential usually involves large scale and high cost project, when dams, weirs, large water basins and turbines would be implemented in order to guarantee the efficiency of the system. In the case of Arnhem this large scale implementation would also hinder the shipping on the Rhine. As a result, the hydrological potential is considered on the river by using 35KW small turbines in the free flowing water. In order to generate 4TJ/year, 20% of the flow should pass through the turbine on a constant speed of 3.5m/s (KEMA, 2009). The 4TJ of electricity can supply approximately 315 households.

Regarding the brooks in the city, three of them offer some potential, Slijpbeek (0.025TJ), Bronbeek (0.005TJ) and the Sint Jansbeek (0.249TJ) (Figure 4.24). Considering the small potential, local solutions for the traditional households and water wheels, for instance, are preferred rather than large complex systems. As an example, the water museum (Watermuseum) could use its traditional water wheel in order to produce part of the electricity consumed.

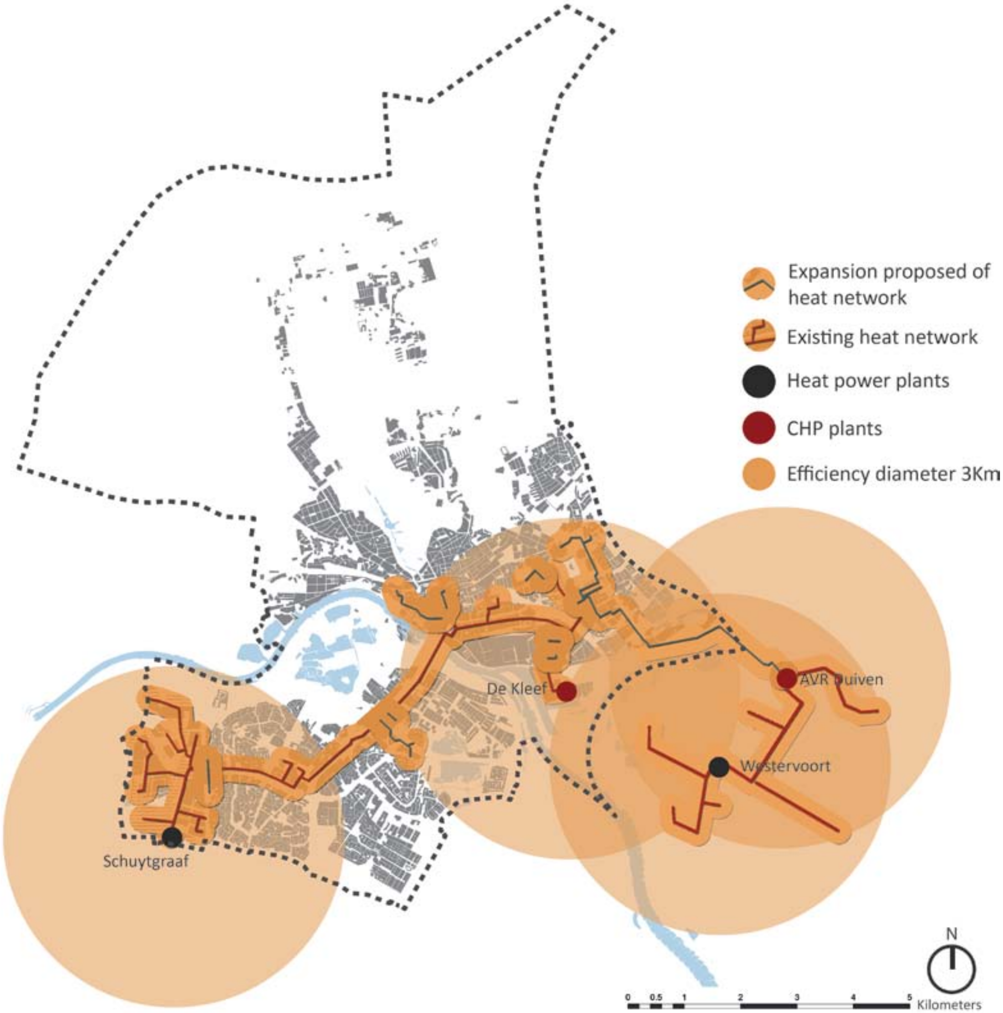

Figure 4.25. Current situation of the district heat network and potential for expansion

Residual heat

The current consumption of heat in Arnhem is 6368TJ/year (based on the gas consumption according with Liander, 2009). The city has the largest heat network in The Netherlands delivering approximately 853TJ/year of heat. The Cogenerate Heat Power (CHP) De Kleef is the main source of heat delivering 579TJ of heat per year, supplying approximately 14,620 households,(NUON De Kleef, 2011). Nevertheless, the plant uses natural gas as raw material. Connected to the CHP De Kleef, the Auxiliary District Heat Plant in Schuytgraaf has the capacity of 56MWth, delivering about 274TJ of heat per year when there is a pick of demand. This system is running by biofuel from rapeseed and gas. Besides the plants inside the borders of Arnhem, there is the potential for connection with the District Heat in Westervoort and the CHP ARV Duiven which could deliver electricity and heat by burning the entire waste from Arnhem (Figure 4.25).

If we consider to change the cogenerate De Kleef to run by biogas (e.g. fermentation of reed), about 64,450 tonnes of material and 8,056 ha (8t/ha) would be necessary to feed the system. The area needed only to supply this system is almost 80% of the area of Arnhem. Considering the total amount of biofuel from rapeseed used in the District

Heating Schuytgraaf, about 6,448ha should be planted with the energy crop, considering 1,200L/ha and 35.28MJ potential per litter of biofuel, (MacKay, 2009).

Therefore, the heat network in Arnhem is responsible for the supply of about 13% of the heat consumed in Arnhem. However, the system is strongly dependent of fossil fuels and importations which reinforce the need for searching for low temperature alternatives to supply the majority of buildings, such as geothermal potential, Heat Cold Storage systems (HCS) and heat and cold exchange between buildings and with the river (***section 4.2***).

Geothermal

Geothermal energy can be extracted from the deep underground (usually under 4,000m), providing high temperature water which can be used for instance on industrial process or to be distributed by Heat District systems. Furthermore, there is the potential for converting the heat into electricity with efficiency about 15%, at 5,500m depth, to 20% at 7,500m depth (IF WEP, 2011).

According with IF technology (KEMA, 2009) currently it is not possible to precisely advice the geothermal potential in Arnhem but it is known that by using a low temperature system (e.g. Organic Rankine System ,ORC), 120◦C is needed for electricity generation. This temperature is available in Arnhem at 3,600m depth (Figure 4.26). Moreover, a vision for the geothermal potential in The Netherlands was launched in 2011 in cooperation between Agentschap NL, IF WEP, Ecofys and TNO. According with the document it is also possible to estimate the geothermal temperature in Arnhem on a depth of 5,500m of about 180◦C to 190 ◦C and conclude the geothermal system would be more efficient when combining heat and power generation. Nevertheless, in order to precise define how much heat and electricity can be generated in the city, by geothermal sources, further research should be done punctually. It is necessary to identify the potential according with underground characteristics in each possible location to be installed. By doing so, the temperature of the water infiltrated, the thickness and permeability of the sandstone found in Arnhem (Abiotic layer) should be analysed.

As a conclusion, a variety of renewable energy sources can be found in Arnhem. Nevertheless, the amount of resources is very limited. Each technology has pros and cons. For instance, even though the productivity per hectare is much better in the case of the wind turbines than by processing biomass the visual impact the first has on the landscape is usually much less accepted for people than the visual disturbance eventually caused by biomass. On the other hand, if biomass does not cause as much visual disturbance as wind turbines, it competes with food production due to the large amount of land needed, while wind turbines can be combined in the same fields than food.

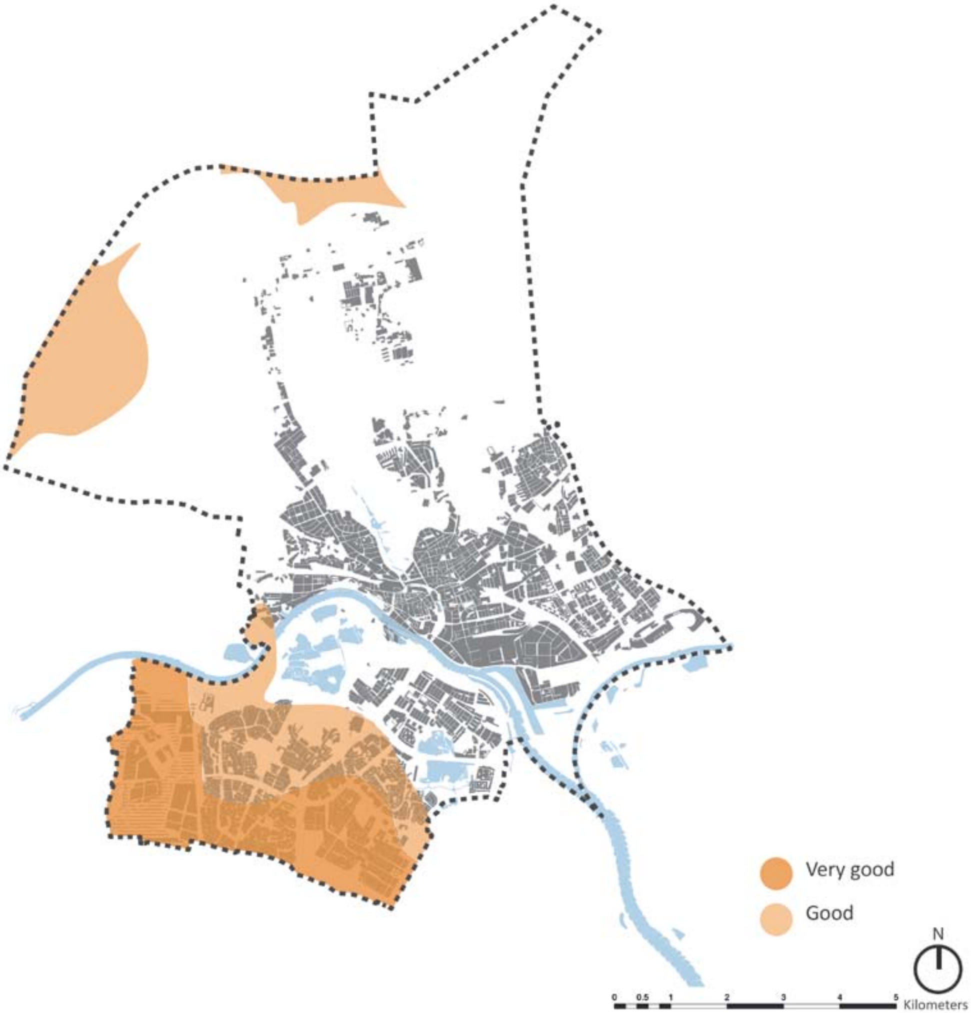

Figure 4.26. Optimal areas with geothermal potential in Arnhem

Such example reinforces the need to consider different aspects of each technology. It is important to keep in mind the efficiency of the systems, how much energy they can provide per hectare they occupy, how they will be related with the landscape and how much energy is delivered according with the amount used to run the system (EROEI). The EROEI, briefly presented on the next ***section, 4.5***. Moreover, renewable sources of energy are characterized by periods of intermittency. The lack of wind, sun or weather conditions for biomass production, for instance, might cause the collapse of an energy system which is not thought to deal with this variable. Hence, it is essential to count with a wide and integrate range of energy sources.

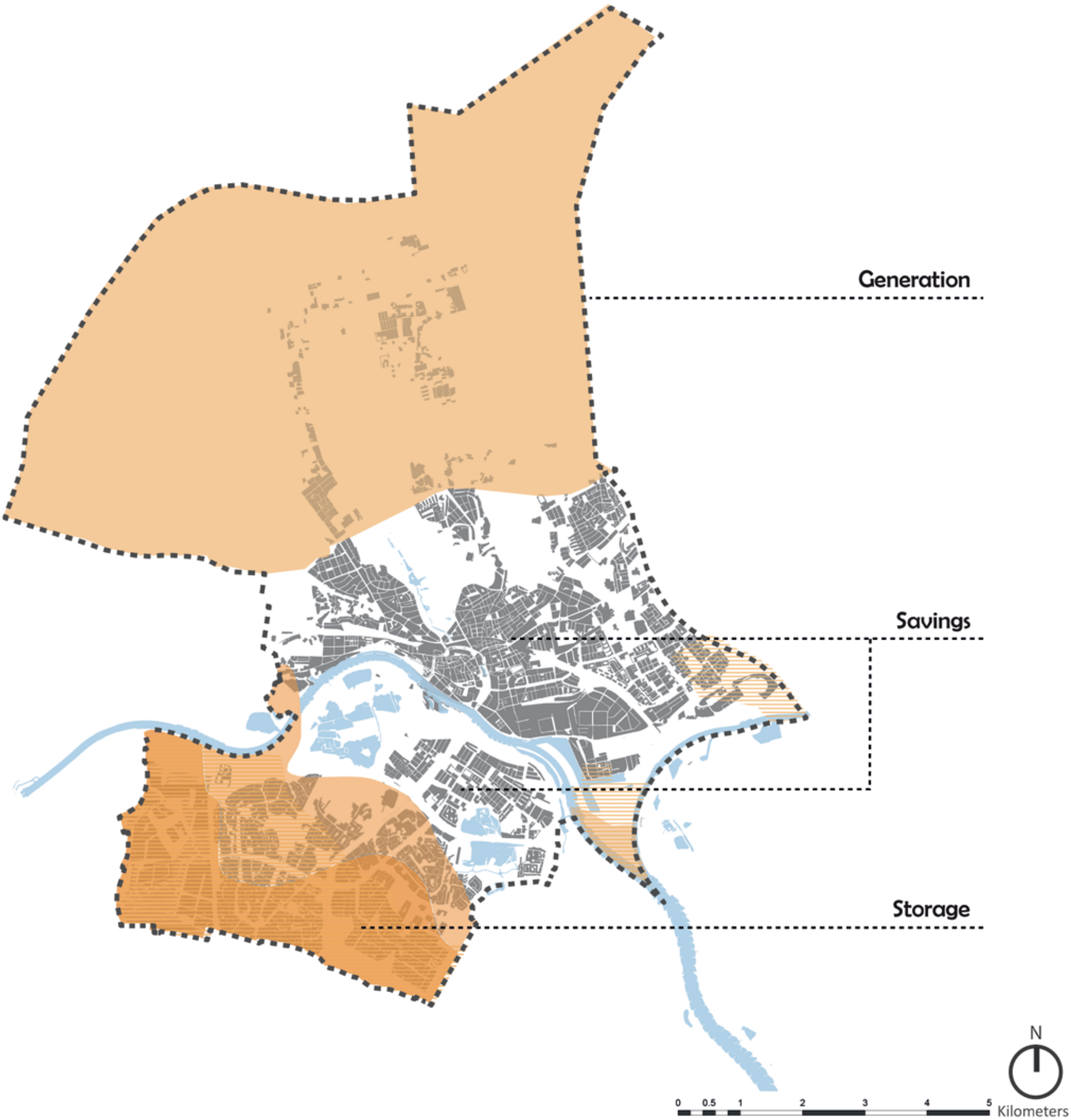

Figure 4.27. Conclusion map with the optimal areas to generate, save and store the energy in Arnhem

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SCHWARZFELLER

Chapter V

Near future and long term developments

The **Chapter 05** comprises the step 02 of the 'Five Step Approach' (Stremke, 2011) and aim to answer the followed sub-questions:

Where the near future developments are located in Arnhem and how much relevance they have for the challenges of energy transition and CO2 neutrality?

Focusing on the energy transition challenge, we selected the developments which can have some impact in the city during the next years. Some of them has a middle-long term implementation and will receive attention during the **chapters 07 and 08**, when the visions based on socio-economic scenarios will be described.

Figure 5.1. Wind turbines factory in Gemany (J. Gómez)

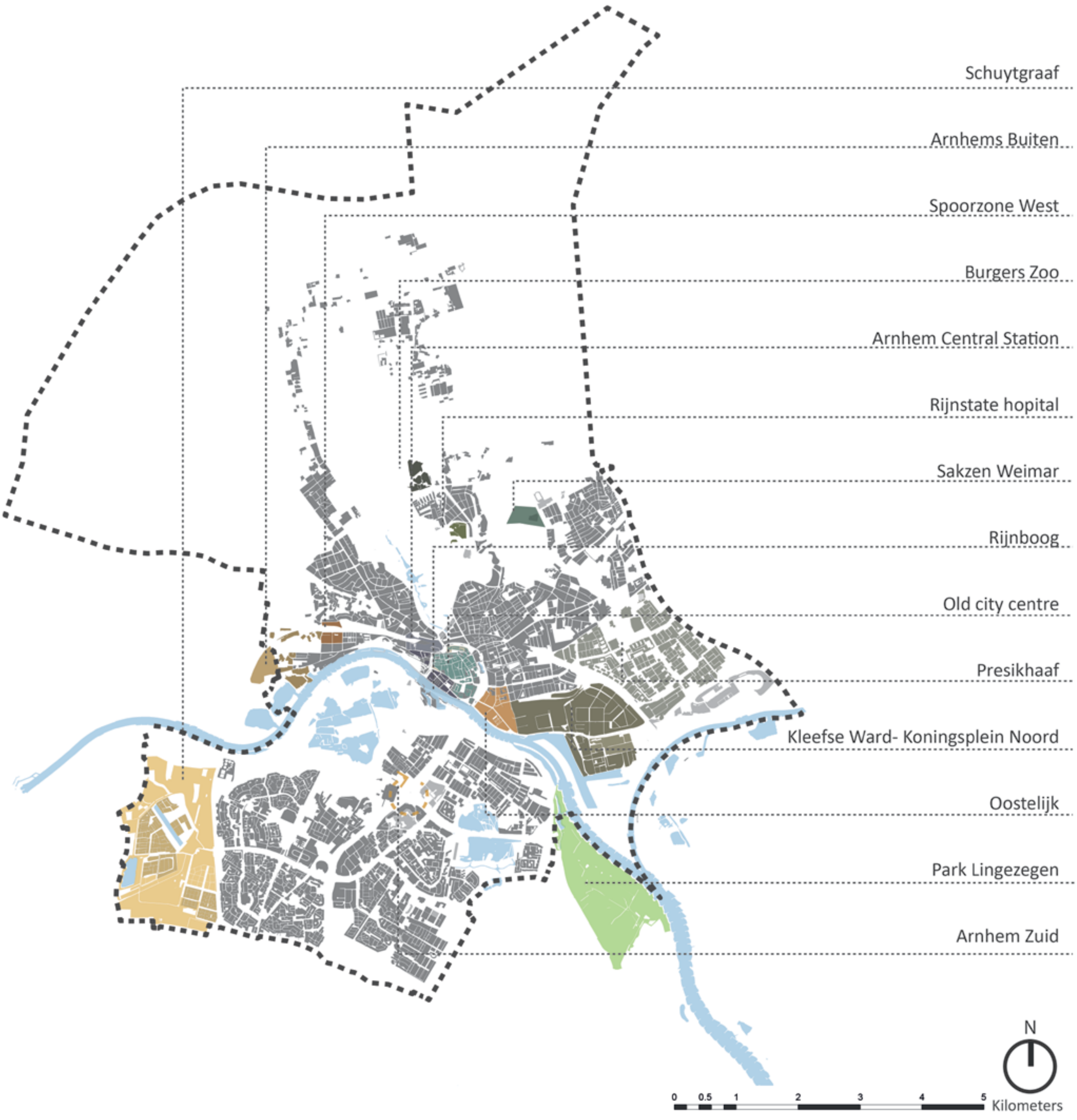

Figure 5.2. Near future developments location map

5.1 Near future and long term developments

The near future developments comprise several projects current proposed for Arnhem. The interventions usually have a short term implementation (about ten years) and differ according with purpose, scale and location. Some of them are already in process of construction while others still do not have a determined date to start. Uncertainties regarding for example financial support as well as the acceptance of citizens might influence whether or not a project will be implemented. Two middle-long term development projects are also proposed. The first is a VINEX area (*Vierde Nota Ruimtelijke Ordening Extra)* in the South –West of the city, the Schuytgraaf, and the other the interregional Park Lingezegen. The knowledge about the most relevant development is important on the context of this thesis since it provides us with some directions regarding how the city will change. Hence, some of the near future developments proposed will be explained. The map on figure 5.2 shows the location of each project.

Figure 5.3. Kleefse Waard aerial view (Milieu informatie Arnhem-Noord)

Kleefse Waard & Koningspleij Noord

Kleefse Waard is the current industrial park of Arnhem. The site is strategically located on the meeting between the rivers Rhine and Ijssel. The area is easily accessible by the highways, a harbour and the railway. On the north side there is the purpose for the expansion of the industrial park called Koningspleij Noord. The project aims to attract companies related with the field of innovation, sustainability, applied energy and environmental technology. The plan is part of a broad development which involves the region Arnhem-Nijmegen (Gemeente Arnhem, 2011).

Moreover, The Koningspleij Noord already counts with the Industrial Park Kleefse Waard (IPKW). The industry (a branch of NUON) generates and provides electricity, heat, gas and a range of other supplies, to the companies located in the area. (Figure 5.3). Additionally, the implementation of three electric charging spots for cars is desired. Still focusing on transportation, the IPKW has projects such as the implementation of cars, vans and buses running by bio fuels.

Nieuwstraat/Rijnboog

This project is part of the master plan for Arnhem. The main concept is to develop a connection between the central train station and the river Rhine, besides to link north and south banks of the river by a pedestrian bridge. By doing so, the project aims to improve the whole area by making it more vibrant and dynamic especially the southern part of the city centre. The last area comprises the blocks of modernist buildings dated from the end of the WWII (mainly 50's of the 20^{th} century) which forms a visual barrier from the city centre to the river next to present low quality of construction.

The Nieuwstraat/Rijnboog comprises and area over 70,000m2 of new developments and is being designed in collaboration between public and private parties (Urban progress, n.a.). The focus remains on making room for different cultural attractions in order to strengthen the economy in the city centre while provide people with a more liveable urban space. In order to attend the cultural propose two biggest interventions area planned, the knowledge cluster (Kenniscluster), which is already being build, and the art cluster (Kunstencluster) (Figures, 5.4, 5.5 & 5.6).

Regarding the link between north and south banks of the river Rhine, a pedestrian/ cyclist bridge is proposed. It would runs from the Niewstraat to the back of the south dike in direction to the central part of the south. Another focus of the project is to bring back to the surface the former brooks of the city, specially the St. Jansbeck broek and reinforce the green network on the urban landscapes. Moreover, technologies such as SEWEEX, which is able to exchange low temperature heat and cold from the sewage pipes are being studied to be applied in the area.

Centre

Complementary to the Nieuwstraat/Rijnboog many other punctual projects are being done in the old city centre. The target is to renovate the district by improving the quality of the buildings and consequently the quality of people's life. These interventions also want to strength the identity of the area (Figure 5.7). Furthermore, the central train station has being completely modified and should be ready by 2013. Regarding energy a special attention is paid by the preservation of the Bakerstraat, one of the main 5commercial streets in the city centre. The main project consists in the renovation of houses and shops buildings to make them energy efficient.

Figure 5.4. "Kerkplein"visualization in Arnhem (Buro Poelmans Reesink)

Figure 5.5."Kunstencluster" in Arnhem (Rijnboog arnhem)

Figure 5.6. Arnhem Centraal, train station (UNStrudio)

Figure 5.7. Bartokkwartier (Synchroon)

Stadsblokken Meinerswijk

Staddsblokken Meinerswijk comprises about 450ha of flood plains, located on the opposite side of the old centre of Arnhem in the south. The area is characterized by is dynamism duo to the changes on water level from the river. Moreover, it has a historical and cultural value, since meinerswijk is one of the oldest inhabited areas in Arnhem. Thus, the projects for this area focus on preserving these values while leave space for nature development and guarantee room for the river (Figure 5.8).

Oostelijk Centrum Gebied

This area will have one of the biggest transformations in the municipality. The former industrial park of Arnhem is already abandoned for several years without receiving any big intervention. Furthermore, a Gas factory (Gas fabriek terrein) used to be installed on the area and after 100 years of functioning left behind a large plot of heavily contaminated soil. The rehabilitation of the site is currently in process. The works started in 2010 and the municipality expect by 2015 the area will be suitable for receiving the new houses (Gemeente Arnhem, n.a.)

The project aimed to build 800 houses including, dwellings, apartments, studios and so forth). Nevertheless, few space for facilities is considered making this area practically a residential neighbourhood.

Considering the location between the Industrial park and the old city centre, there is the possibility to connect the area with the heat network. Another measure regarding energy is the possibility to introduce a ferry running by biofuels to link the two sides of the river.

South of the river

Regarding the south districts of Arnhem, the idea is to promote a second city centre. The area would provide people who live in the south with facilities currently found only in the old city centre (north bank of the river) (Figure 5.9). As a result, the mobility of citizens from south to north and vice versa would decries. Formed by large buildings such as the Gelredome stadium, the Kronenburg shopping centre and the Rijnhal centre of events the project is currently one of the largest urban developments in the Netherlands aimed on improving the public space and to reinforce the economic development of an urban area.

Regarding energy, there is the proposal to connect the area to the district heating system besides to make interventions on the district of Malburgen. The focus in this area is to renovate the old buildings in order to adapt them for energy saving and in some cases energy generation.

Figure 5.8. Stadsblokken Meinerswijk (Gemeente Arnhem)

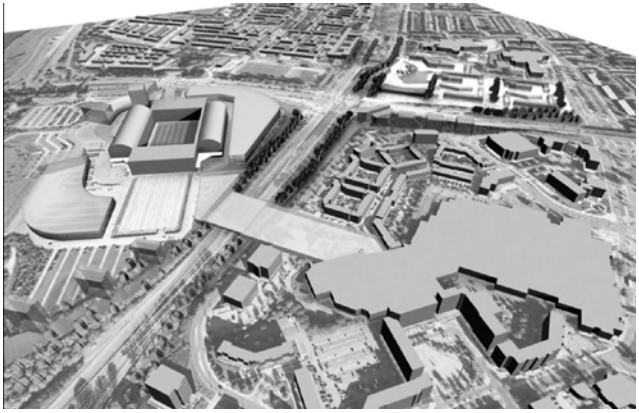

Figure 5.9. Arnhem Centrum-zuid (de Gelderlander 2009)

Presikhaaf

Presikhaaf is a densely occupied district composed by five neighbourhoods with large groups of modernist residential buildings constructed from 1948 to 1970. Since 2004 the area has been receiving interventions. The projects varies from renovation of the old buildings until the demolition and construction of new dwellings (Figure 5.10). As a result the district counts with most of the current projects being implemented in the city.

In Presikhaaf, another project deserves attention. It is on this area that the pilot project regarding public transportation running by renewable energy sources is being tested. The project is developed in cooperation between the HAN University of applied sciences and companies located in the area.

Arnhems Buiten

Arnhems Buiten occupies the former area of Kema laboratories and Arnhem Business Park. The site is located on the western limits between Arnhem and Renkum, the next municipality, and counts with moraines and flood plains landscapes. The project aims to build a mixed used neighbourhood, comprising 300 dwellings and 47,000m2 of offices integrated by a park. The current buildings of Kema and Tennet spread through the area will change its headquarters in order to avoid the mobility in the park. Regarding energy, the new constructions should be energy efficient. Kema also studies the possibility of residual heat cascading from the Rosandepolder. Charging stations for electrical vehicles will be implemented in order to facilitate and to incentive the rise of transportation running by renewable sources.

North-West of the river

The north-west area of Arnhem is the target of some punctual projects such as, the Spoorzone-west, the Burger Zoo, Saksen Weimar and the Hospital "Rijnstate Ziekenhuis" (Figure 5.11). Even though there are punctual interventions, each of the projects deserve attention since they are closely related with the challenges of energy transition or will impact the transport connections in the city and province of Gelderland.

Regarding the Spoorzone-west, the neighbourhoods of Heijenoord- Lombok are considered by a regional vision. These areas are located on the surroundings of the west tracks of the railway in Arnhem. The objective of the project includes the reduction of noise due to the traffic of trains while improve and expand the railway connections inside the province of Gelderland and with the next provinces in The Netherlands.

The Burger´s Zoo has the current challenge to become energy neutral and to make available public transportation by renewable sources. Thus, there is punctual studies focus on the evaluation of the possible solutions for renewable energy sources. For instance, a geothermal study is being conducted and the potential use of manure for energy

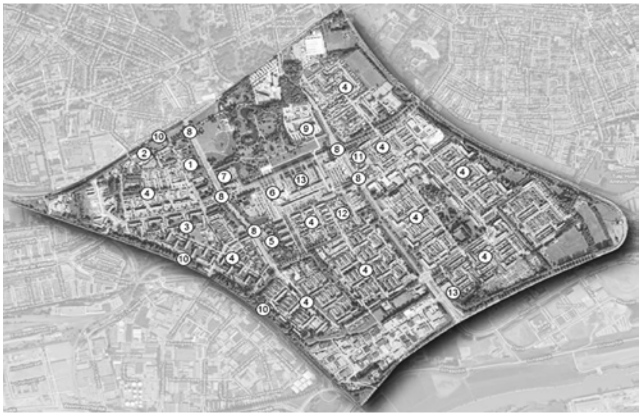

Figure 5.10. Presikhaaf master plan (Presikhaafnet)

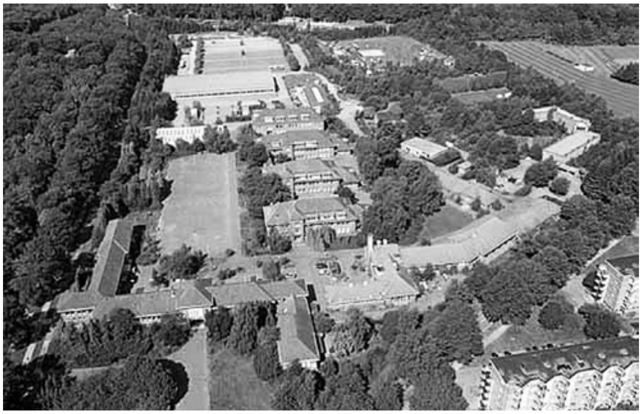

Figure 5.11 Saksen Weimar (Gemeente Arnhem)

supply is analysed.

The called Saksen Weimar project, regards an area in the slopes of Veluwe's forest where 450 new houses are planned to be built, moreover they will be well equipped with new technologies such as insulation for energy saving.

The last project which deserves attention regards the Hospital "Rijnstate Ziekenhuis". The hospital is the target of several studies regarding the feasibility to apply different technologies for energy generation and saving. For instance, heat and cold storage and the connection with the current district heating system. Furthermore, the feasibility of using heat recovery from the air conditioner system and heat cascading are considered. In the area an electrical charging station for vehicles is also proposed.

Schuytgraaf

The new neighbourhood located South-west fringes of Arnhem (VINEX) is the largest housing development in the city, comprising about 6,500 unities to be built from 2010 to 2050 (Figure 5.12). The idea is to integrate the area with the landscape and to be energy neutral. Currently the Auxiliary District Heat Plant constructed to supply Schuytgraaf is already working by burning bio fuels, oil and gas and connected with the heat network of Arnhem.

Figure 5.12. Schuytgraaf master plan (Ontdek Schuytgraaf)

Park Lingezegen

The regional park Lingezegen is planned to link the metropolitan area composed by Arnhem and Nijmegen through 1,500ha of green- blue network. The vision also considered the mixed use of the space, where, agriculture, nature and recreation would share the space. Furthermore, bike paths, hiking tracks and special attention for flood areas along the rivers Rhine and Ijssel are comprised.

5.2 Conclusion

As a conclusion, most of the projects focus its attention to the areas along the river Rhine and south areas where the urban settlements are concentrated. The neighbourhoods in the centre north receive most of the interventions since this is the oldest area in the city and it is currently facing an urban redevelopment process. In the south the main measure comprise the emphasis on a new urban centre. Moreover, the urban fringes are the focus of middle- long term development projects, such as Schuytgraaf and the Park Lingenzengen. Therefore we can access the sub-question:

Where the near future developments are located in Arnhem and how much relevance they have for the challenges of energy transition and CO2 neutrality?

In general all the projects presented will impact the way Arnhem works regarding energy consumption and CO2 emissions. A special attention should be paid for the large scale developments in the old city centre (Nieuwstraat/ Rijnboog), the expansion of the industrial park (Koningsplij Noord) and the VINEX expansion (Schuytgraaf). The three areas can develop important tasks with regard to energy. However, the complete implementation of these projects will be affected for socio-economic changes during the next years. As a result, we will review these projects during the **Chapters 07** and **08** framed by the two scenarios addressed by the present thesis.

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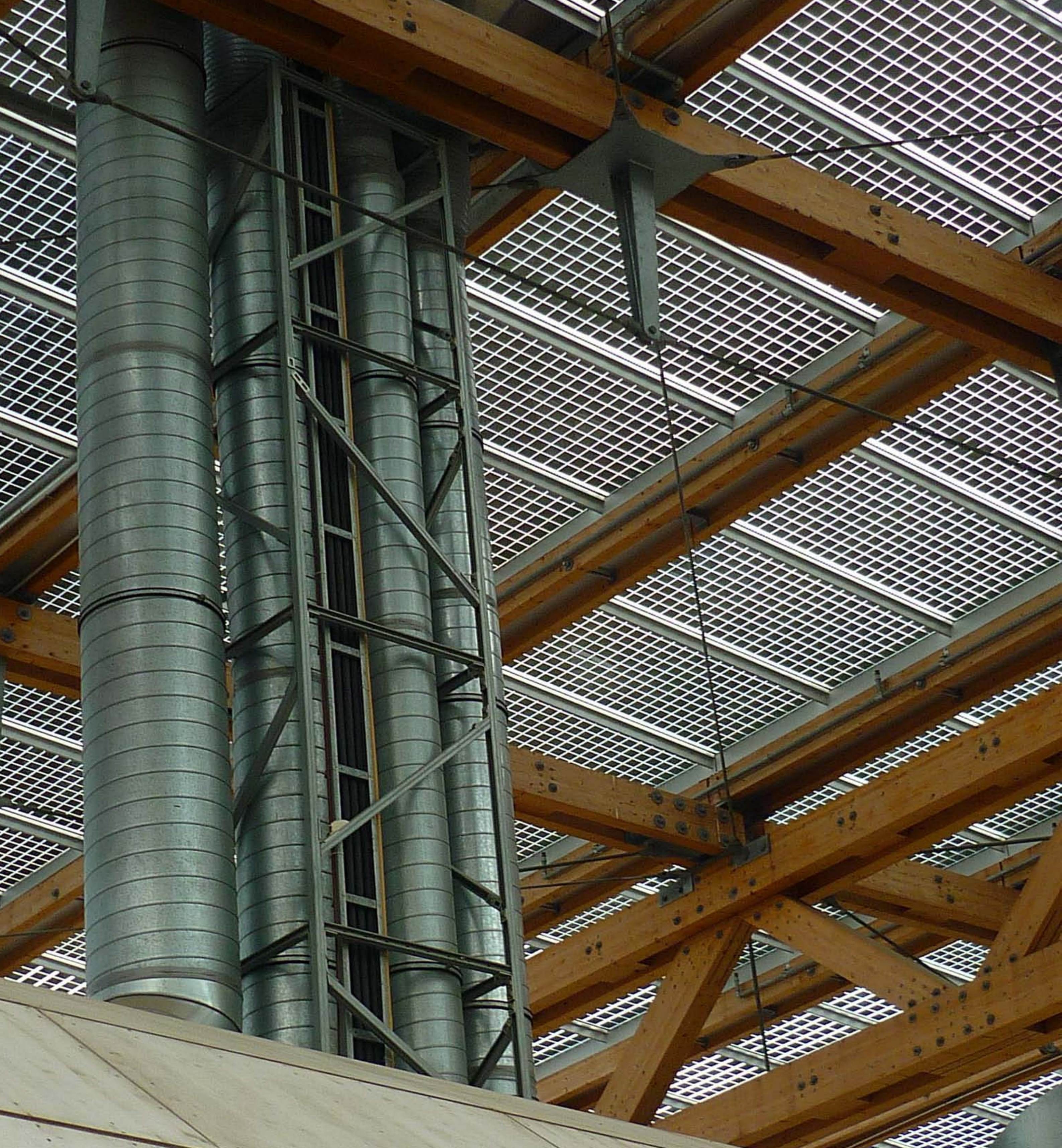

Chapter VI

Scenarios

The Chapter 06 regards the step 03 of our methodology. The target is to answer the question:

Based on socio-economic scenarios, what kind of possible long-term developments are expected in the city?

First of all, it is necessary to understand why we chose to work with socio-economic scenarios. A scenario represents strategic planning method that involves thinking and analysis, to make robust long-term plans (Stremke, 2010). Scenarios offer a perspective of the possible future. Comprising the elements independent of man's control, for example, climate change, economic growth and population fluctuation, a scenario provides the 'visualization' of the consequences of these possible futures and allows us to take measures in order to redirect the turn of certain events and minimize/maximize the effects of certain influential factors. Thus, by a design process based scenarios we, landscape architects, are able to propose a shift from possible future to a desirable future to happen. In order to define the scenarios addressed on this thesis, two main sources of information were used. The first regards the socio economics scenarios proposed by the WLO (WLO, 2009) and the second the scenarios proposed by the KWh/m2 Studio (2011), **section 6.1** . The summary of these sources resulted on the two story lines to be used on this thesis, **section 6.2 and 6.3.**

As a result of the strategic planning method provided by the scenarios, we will design two distinct visions, ***Chapters 07*** and ***08***, to be further compared, ***Chapter 09***. Therefore, by pointing out the differences and similarities between the two cases we will be able to define which are the most feasible and robust long-term intervention to be implemented in the city by assuming all the possible scenarios can happen.

Figure 6.1. (previous page) Akademie Mont Cenis in Herne, Germany (J. Gómez)

6.1 Analysis WLO and KWh/m2

Two sources of information were used in order to define the socio-economic aspects of the two scenarios addressed by this thesis. The first comprises the scenarios Less is Better and Business as Usual (BAU). They were introduced by the KWh/m2 studio based on the European Union documents focus on mitigating of climate changes (EUPOPP, 2008). From these scenarios we were able to have an overview of the possible changes regarding energy. For instance, while the Less is Better will face a decrease of 30% of energy consumption by 2050, BaU will increase in 15% during the same period of time. In both cases, the partial shift of the fleet of light vehicles from running by fossil fuels to electric engines is considered.

In order to add complementary information, which will also influence our decisions when designing sustainable landscapes to Arnhem, we used the WLO (2006) document as our second base of data (Figure 6.2). According with the importance Arnhem has in the context of The Netherlands, and could have internationally, besides the closest relation with the scenarios provided by the KWh/m2 Studio, we decided to work with the Regional Communities scenarios and Strong Europe. The main characteristics of these final scenarios we are going to work with are shown on the (Figure 6.3).

In order to simplify the study and considering we are part of a larger group of students working on the KWh/m2 Studio, we will use the names of the scenarios respected the ones provided by them. Therefore, *Less is Better* (Regional Communities at WLO) and *Business as Usual* (Strong Europe at WLO). The **sections 6.2.** and **6.3.,** will introduce the story lines referred to each scenario.

Figure 6.2. Diagram of "KWH/m2" and "WLO" scenarios

	Less		BAU	
Energy	↓	30%	↑	15%
Housing	—	Less	↑	1.5%
Industry & Buisiness	↓	3%	↑	20%
Transportation	—	Less	↑	30%
Congestion hours	↓	30%	—	Less
Agriculture	↓	10%	↓	15%
Nature & recreation	↑	20%	↑	20%

Figure 6.3. Comparative table of trends of change for 2050 on “Less” and “BAU” scenarios

6.2. Less is Better storyline

During the past forty years Arnhem reinforced its sovereignty in the province of Gelderland as well as strengthened its public responsibilities. The main reason for this fact to happen was the shift of the trade relation to be internally oriented. Therefore, the Dutch government allocated power in decision to municipalities and provinces. The relation between the municipal government and small social representations made with the initiative 'Made in Arnhem' gained importance, since it develops the essential link between the public and private representations.

The *population* slightly decreased if compared with 2010 and followed the national trend of aging. This fact had effects in almost all the sectors. Regarding the built area, a negative impact was noted since some neighbourhoods became less inhabited leading to a certain decay. On the other hand, this situation was controlled due to the income per capita rose along the years and has being contributing to improve the quality of life in the Arnhem. The decrease of number of inhabitants also caused the municipal government to decide stopping some *urban developments* which should take place in the middle long term, especially after 2020. Another consequence was the decrease of labour force and the shift from work positions on *industry* to *service* positions.

Due to the aging of the population, with regard to *transportation*, less private vehicles can be found in Arnhem when compared with 2010. Investments of the local government to improve the infra-structure for more efficient mobility contributed with this scenario. Another measure regarding transportation was the partial shift of the light fleet to electrical vehicles.

Regarding energy, the consumption of energy decreased 30% by 2050 when compared to 2010. The shift from fossil fuels to renewable *energy* sources has being one of the biggest challenges of Arnhem. The task the government developed by offering financial benefits The depletion of the natural gas reserves decreased about 75% if compared with 2010 and the need for an efficient heat system became essential for the city. Large investment in energy saving and storage next to the use of the limited renewable sources found inside the borders of Arnhem, were essential in order to adapt the city to be less dependent of energy imports. These actions were also essential for decreasing of *CO2 emissions* of 80% by 2050 when compared with 2010.

As well as in other areas of the Netherlands *agriculture* was under pressure in Arnhem. Since this sector occupied a small area of the city and did not represent an important contribution for the economy, the government decided to bring new uses for the plots such as *nature development and recreation*.

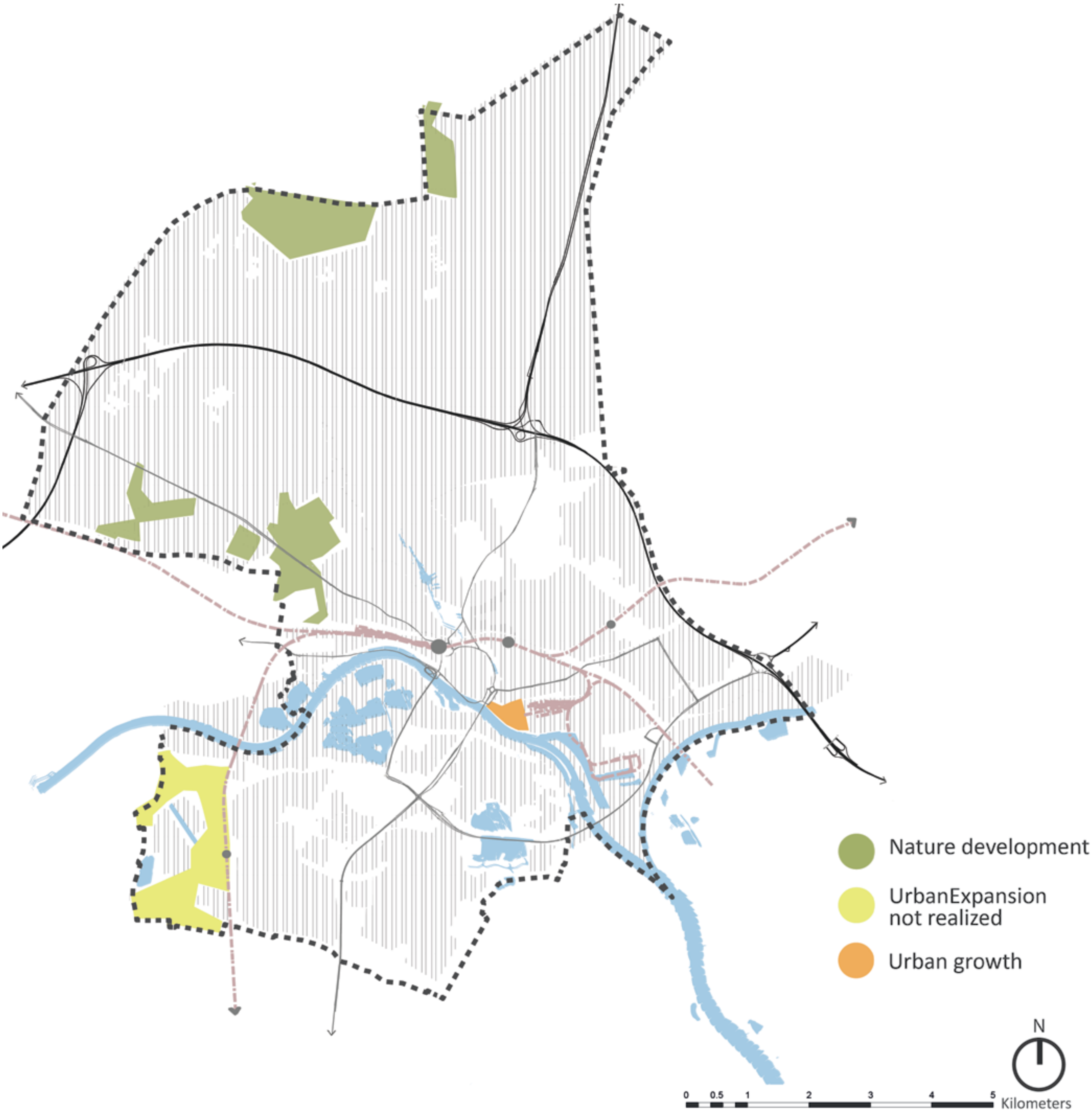

Figure 6.4. Less is better scenario basemap

6.3 Business As Usual (BAU) storyline

In 2050 climate change causes the raise of sea level in about 40cm and the central government invested large amounts of money on water defences. Arnhem had prepared itself for the increased amount of water from the rivers Rhine and Ijssel by measures during the first decade of the century but the project is currently being reviewed.

During the first decades of the XXI century, the Dutch government centred its power on decision. On the other hand, in order to strengthen its competitiveness in the European business market, agreements with innovative companies were made and subsidies were spread through the country. By doing so, the potential Arnhem had regarding renewable energy technologies next to the energy crises faced during the last decades attracted the attention of the government and the city became a pole for high innovative technology in this field. As a consequence now, in 2050 the identity of the city is strongly based on this characteristic. Also the collaboration between municipalities and provinces was very important for the development and growth of Arnhem.

The *population increased* about 18% if compared with 2010 and the dwellings and offices developments planned by 2050 are already completed in 2040. The Schuytgraaf is completely implemented. The redevelopment in the Rijnboog and the Oost-Centrum had its density increased in order to absorb the raise of demand for living, working spaces and leisure. The city centre can look to the Rhine more freely since part of the buildings from the 1950´s were demolished during the 2010´s in order to receive new developments and to provide a better connection between the old city centre and the river Rhine. Moreover the central train station is surrounded by high commercial buildings, since Arnhem has been attracting workers from all the regions and the Kleefse Waard & Koningspleij Noord is completely occupied.

In relation with the transportation, another 02 train stops were implemented: Arnhem East (next to Kleefse Warrd industry park) and Arnhem West (next to Arnhems Buiten). High investment in diverse sustainable and efficient ways of public transportation took place during the last forty years and now in 2050 Arnhem is very well connected inside the city but also with the provinces and countries. Furthermore, the light traffic fleet of electric and hydrogen powered cars has being increased and each year new innovative technologies are tested in the city.

The *transport of goods* also increased 40% and the river Rhine has more constant boats passing by. Moreover, nowadays a new harbour in the centre allow visitors to come easily to the city. As a result, a very dynamic area was created along the Rhine. The new bridge across the river is made for pedestrians and light transport use, linking south and north areas more efficiently.

Regarding *nature development*, it took place basically in the flood plains and in some former agricultural land in the north part of the Municipality. The green areas in the city remained almost the same which could be found in 2012.

Even though the government invested on subsidies to *decrease the energy consumption and generate energy from renewable sources* the amount of energy demanded increased by 15% as a result of the rise of population. Moreover, the number of tropical days per year had a slight increase and the heat island effect caused a small increase in the energy consumption for cooling.

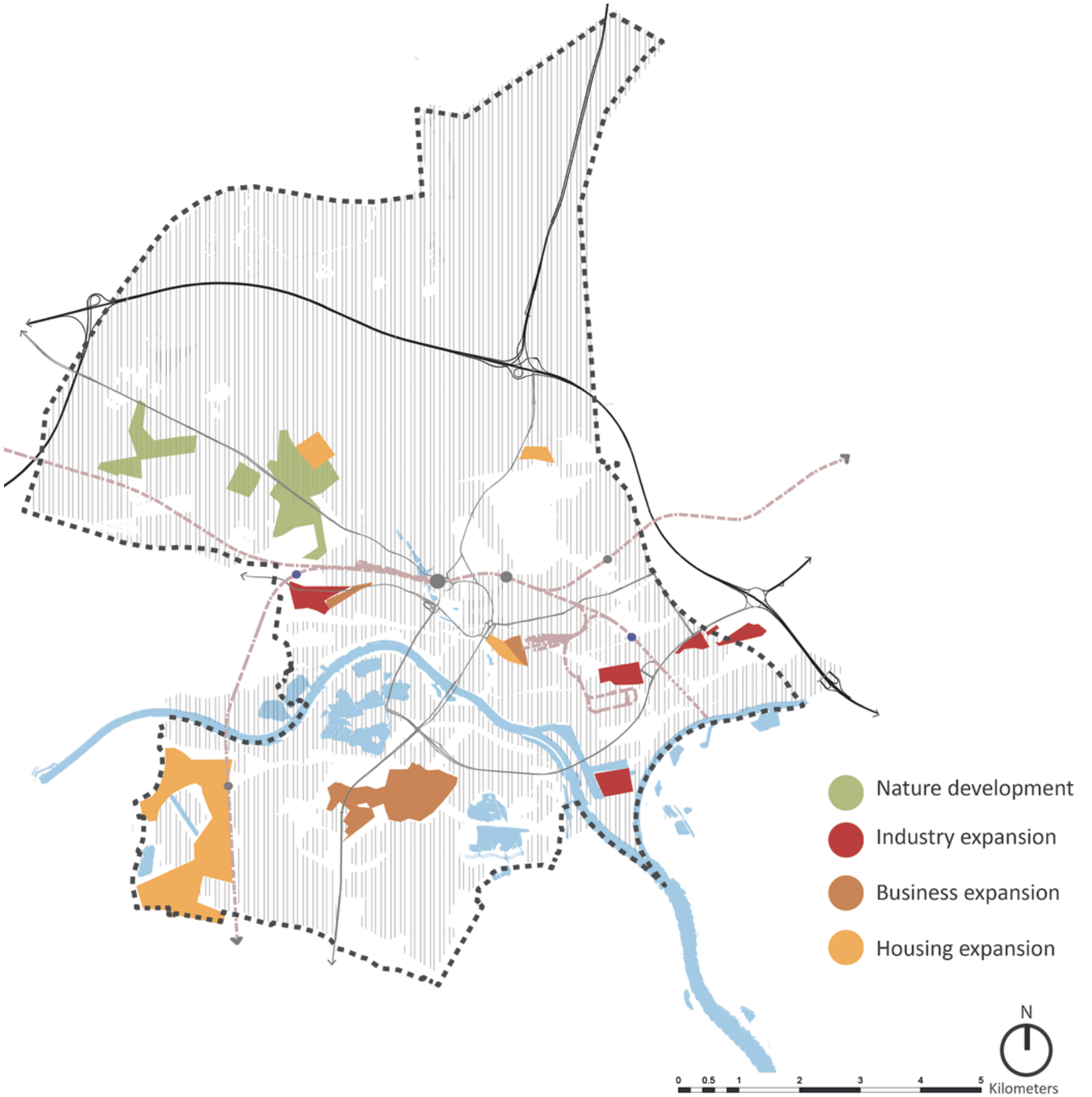

Figure 6.5. Business As Usual scenario basemap

As a conclusion, during the **chapter 6** we introduced the socio-economic scenarios which are going to guide our decisions when designing sustainable landscapes to Arnhem. The two story lines provided the overview of what kind of long term developments are expected in the city. By doing so, we answered the sub-question:

Based on socio-economic scenarios, what kind of possible long-term developments are expected in the city?

The next two ***Chapters***, ***07*** and ***08***, will focus on the steps 04 and 05 of the 'Five Step Approach'. The target is to answer the two sub-questions:

How can we change possible futures into desired futures by designing an energy sustainable landscape?

Which desired intervention should be implemented?

The two authors of this research, Taícia Marques and Jaime Gómez, will split at this point starting an individual phase. Chapter 07 will be conducted by Taícia Marques, focusing on the Less is Better scenario. Chapter 08 will be developed by Jaime Gómez and focus on the BAU scenario. Each one of them will propose one vision (desired future) and an intervention based on the scenarios. On ***Chapter 09***, the results of the two visions will be compared. Remarks and advices will be made for the municipality, researchers and Landscape Architects.

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Figure 7.1 Jardim Suspenso da Babilonia (Flickr: F. Morozini)

I grew up without shoes, on the streets. No, I was not a homeless, but a child who have learned the value of public spaces on life since her early years, who had a naive spontaneous way of living.
The neighborhood was calm and peaceful. The side walk was an extension of each house and the streets our playground. It was the place where creativity could be expressed and developed, the place where the world could gain form due to chalk draws on the floor. Place to meet people, to inform and be informed, to transform and preserve, to experience.

Taícia Marques

Chapter VII

Desired future
Less is Better vision

Based on the socio-economic scenario Less is Better, a desired future to Arnhem will be proposed. The concept will be generally introduced and further related with the three layers of the landscape, abiotic, biotic and anthropogenic based on the challenge of energy transition and CO2 neutrality.

"Above all, do not lose your desire to walk. Every day I walk myself into a state of well-being and walk away from every illness. I have walked myself into my best thoughts, and I know of no thought so burdensome that one cannot walk away from it."
(Soren Aabye Kierkegaard- danish philosopher- 1813-1855 in Ghel, 2011)

Jane Jacobs, Kevin Lynch and Jan Ghel agree when they defend the idea that city should be made for people use rather than cars. According with them the daily experience should be emphasized for planners who must step out of their profession for a while in order to understand how people use the space they live and work. From the energy perspective the emphasis on walking and cycling makes still more sense. The shift from car to ways of transportation which do not use fuels may be responsible for a considerable decrease on the energy consumption next to avoid CO2 emissions. Therefore, a 'city for people' supports the idea of a sustainable energy landscape.

In order to understand the changes the landscape in Arnhem will face during the next 40 years from the energy perspective and based on the socio-economic scenario 'Less is Better' a vision was proposed. The vision comprises the desired future to the city. The interventions will be explained according with the three layers: abiotic, biotic and anthropogenic. Moreover, the energy strategy will be explained according with savings, storage and generation. The interventions together with the energy strategy will be further positioned on a time line of implementation which comprises approximately forty years (2012-2050).

7.1 Concept + Design principles

Based on the data from CBS (2008), the average distances of commuter journeys are related with the means of transport (Figure 7.2). In The Netherlands, people walk predominantly distances equal or shorte r than 1Km. Bikes lead until 5Km distances and then lose space for private vehicles and public transportation. Hence, the location of facilities to short distances from dwellings should be emphasized in order to reduce the use of vehicles running by fossil fuels in the city. Moreover, this measure will enhance the liveability in the city being integrated with the green- blue network and energy systems. As a result, a multifunctional landscape will be created.

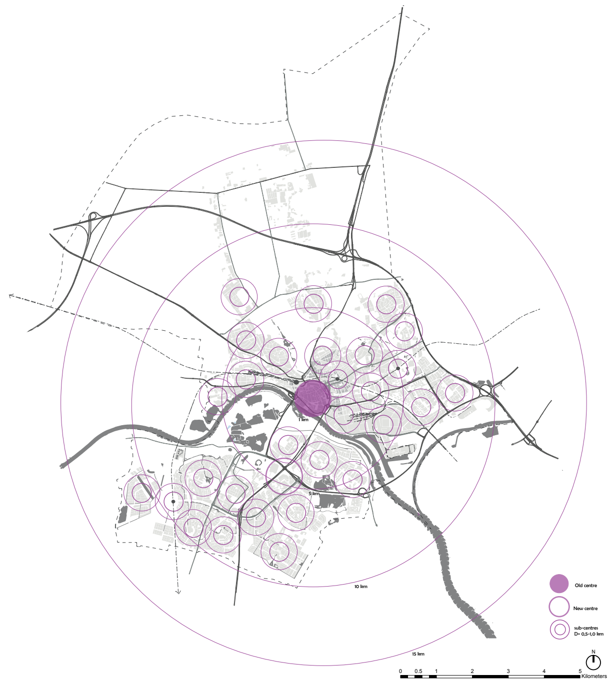


Figure 7.2 Sub-centres per district.

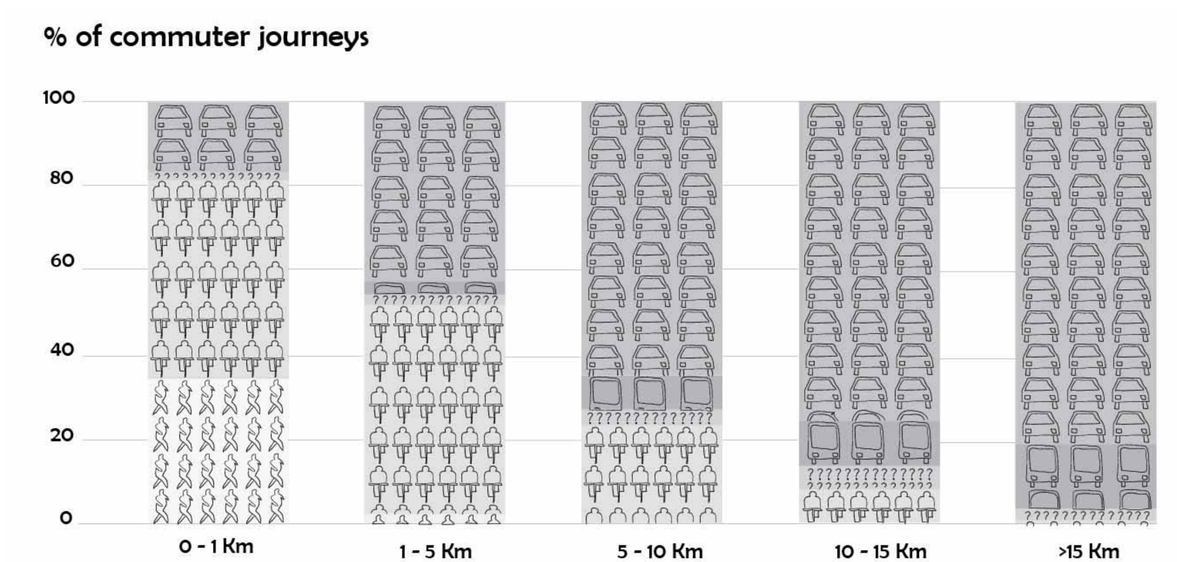


Figure 7.3. Commuter journeys_relation between means of transportation and distance (CBS,2008)

Abiotic

The abiotic layer gain importance on the vision since heat and cold storage systems will be implemented. Moreover, the control of the water table level should receive attention. By expanding the forested area in the north, the speed the water infiltrates will slow down. As a consequence, it will prevent the fast discharge of water in the shallow aquifers located in the south.

Furthermore, the careful use of the southern aquifers should be done in order to avoid drink water contamination. On the surface level, rain water storage connected with the green network and the current drainage system will be essential for the water management.

Biotic

A green-blue network will permeate the urban fabric of Arnhem while linking large natural/ recreational areas (e.g. Veluwe and flood plains). The characteristic green fingers in the north will be introduced in the south. Respecting the characteristics of the polder landscape besides the limitations found on the abiotic layer, the network will count much more with the presence of water than in the north. In the north, the blue will be composed by the recovered former brooks, Slijpbeek, Bronsbeek and Sint Jansbeek.

The integration between urban landscape and green-blue network has three main purposes. First of all it will enrich the aesthetical experience of the landscape (Koh, 2008). In other words, people will be provided with a diverse landscape able to stimulate vision, smell, hear and touch. The second function is based on the mitigation of Urban Heat Island effect (UHI). Especially in the old city centre and the industrial park, the recovered of the old brooks to the surface next to the implementation of green buffers might improve the thermal comfort and the consequent reduction of air conditioning use during warm days. This feature will contribute to energy savings on building scale. As a third purpose, the green-blue structures will be closely related with the energy network. For instance, the resulted green maintenance from these areas will be used to energy generation. Moreover, in certain places the network will be composed basically by crops to be used as biomass, for instance, reed (Phragmites australis), willow coppice (Salix sp.) and miscanthus (Miscanthus giganteus). Technologies such as solar panels and wind turbines will coexist in the landscape. Therefore, blue, green, urban and energy networks will be intrinsically related in a multifunctional sustainable landscape.

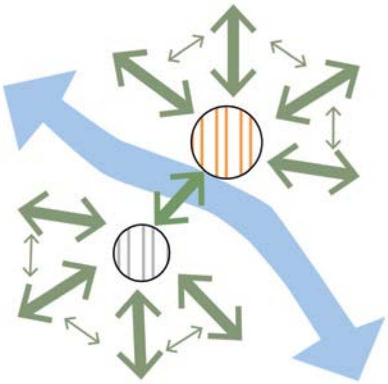


Figure 7.4. Connections green-blue network

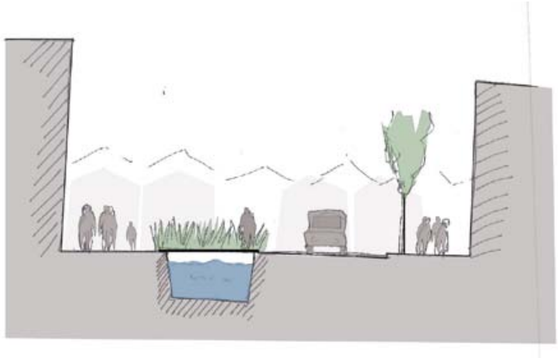


Figure 7.5.Green-Blue network permeating the urban fabric

Anthropogenic

Once the number of inhabitants will slightly decrease by 2050, new large urban developments will not take place. For instance the district of Schuytgraaf will be not fully implemented. Another example is the industrial park, which will not expand. As a result, empty plots and large areas will be available for different land uses.

The lack of Investments in new developments will lead to the rearrangement of facilities in sub-centres. This measure will be an important step in order to guarantee citizens can satisfy daily needs by walking or cycling distances. Each district will have mixed use areas established according with the features of the neighbourhoods and the needs people have. Even though a certain degree of functional clustering should happen, houses, commerce and all kind of facilities might be mixed. The restructuration of these areas will enhance the potential for building exchange of energy while allow the use of the space by different groups of people during long periods in the day. Furthermore, the new central area in the south will be partialy implemented, providing the city with two main city centers (Old and South).

Regarding liveability, general measures can be applied. For example, Jan Gehl (2011), proposed key measures to encourage the life in the city, "(...) compact, direct and logical routes; modest space dimensions; and a clear hierarchy where decisions have been made about which spaces are the most important" (Gehl, 2011, p. 67).

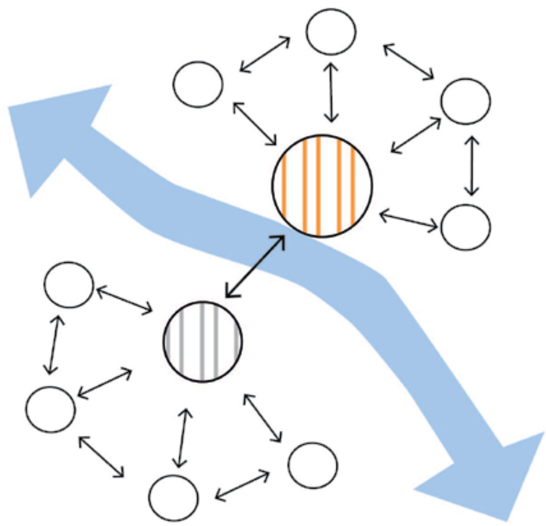


Figure 7.6. Connections sub-centers and main centers

Figure 7.7. Benches and green areas for relaxing moments

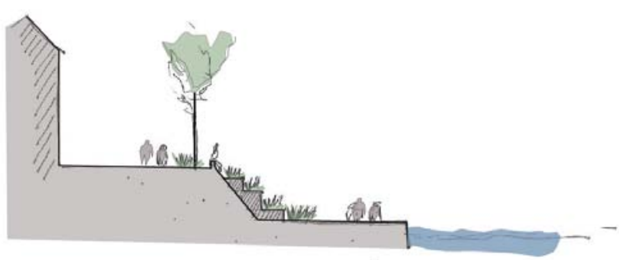


Figure 7.8. Green connection of the old center with the Rhine to be linked with the green areas in the south

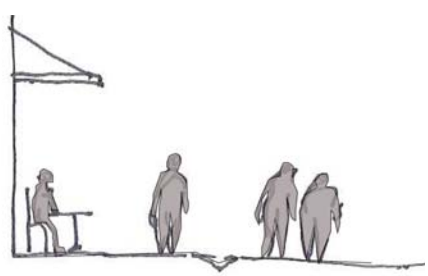


Figure 7.9. Liveable street with caffes

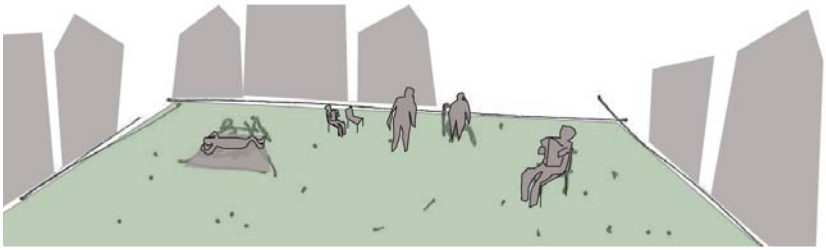


Figure 7.10. Open green areas for different activities

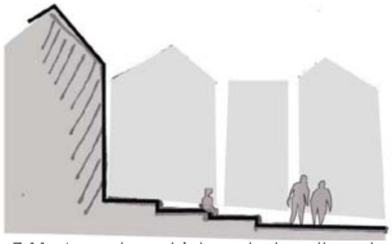


Figure 7.11. Areas to rest integrated on the urban landscape

On the context of a sustainable energy landscape to Arnhem, the key measures proposed by Gehl (2011) will be complemented by strategies in order to make people aware about energy generation and consumption. The green-blue network will count with energy crops integrated with wind turbines, algae production and solar panels. The challenges on the urban dense areas are higher and should count with punctual measures along the urban fabric. For instance, the effective participation of people on the generation of energy will happen by the installation of kinetic floors in the Old centre and sub-centres of Arnhem. The energy resulted by the motion of people during the day will be harvest by green- light poles. Hence, this system will make users aware about how much energy is generated according with the intensity use of the public spaces. Another consequence, is the governmental authorities will be aware of the dynamic use of the public areas in Arnhem. For instance, if almost no energy is generated, and excluding seasonal features, it might mean people are not using the area as much as they were supposed to. The awareness of this information will lead to the study of what is happening in the area and how the situation can be improved and readapted according with people's need.

Transport

When a desired future to Arnhem is proposed, to reduce distances, improve collective transportation as well as to provide the infra-structure to people to walk and cycle safely are essential. As the development of sub-centres will take place sidewalks and bike paths will be wider while roads will trend to narrow down. The major bike ways will be integrated with the regional network (Fietsroutenetwerk Stadsregio Arnhem Nijmegen).
The shift of about 50% of the fleet of light transport to electric vehicles will reduce in 42% the consumption of fuels for transportation. Considering the elderly people will represent the majority of citizens, the special fleet aimed to attend this

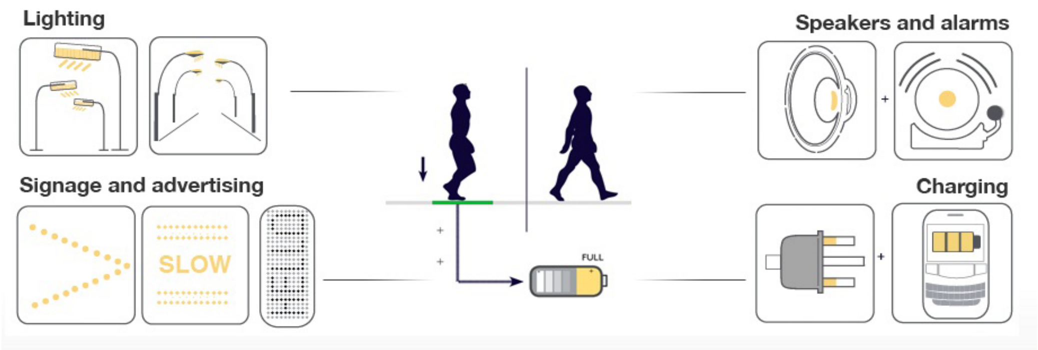


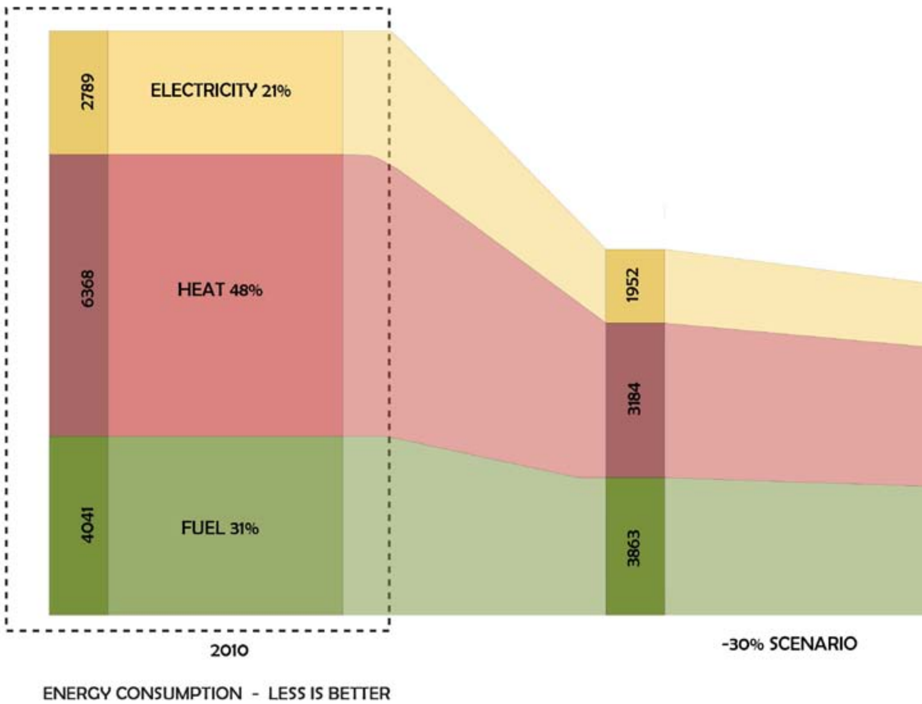
Figure 7.12. Kinectic Floors (Pavegen)

7.2 Energy vision

The general measures for Arnhem will be closely related with the energy strategy. According to the Less is Better scenario, the consumption of energy in Arnhem would reduce 30% by 2050 when compared to 2010. However, the effort to strengthen Arnhem's sovereignty, will lead the government to invest in a large range of measures in order to save energy as much as possible. The three groups, buildings, industries and transportation will receive attention on the three energy carriers, heat, electricity and fuel. As a result, 42% rather than 30% of the energy consumed will be saved by 2050 (Figure 7.13). Moreover, the extension of the heat network besides the emphasis to generate energy inside the borders of Arnhem will be stressed. Approximately 13% of the energy need in the city will be generated by renewable sources inside the limits of the municipality. With regard to CO2 reduction, the contribution will reach approximately 50%. In order to reach the 80% a step advice should be followed by the municipality.

Energy saving

With regard to heat, the near future developments, proposed during the first decade of the 21st century, aimed on the refurbishment of entire neighbourhoods (e.g. Presinkhaaf), will be fully implemented. These projects will be followed by a sequence of new proposals, to be implemented especially until 2020, in all the districts of Arnhem. As a result the consumption of heat for buildings will drop 50% by 2050 when compared to 2010. With regard to electricity, the savings will fluctuate along the forty years. An initial



decrease due to the refurbishment measures in buildings will be followed by a slight increase during the next decades. It will happen as a consequence of the need for more power to pump heat and the partial shift of the light fleet to electrical vehicles. By 2050 30% of electricity will be saved compared to 2010. Moreover, large buildings such as the hospital, large companies, the Zoo and University campus will have a self-sufficient system.

The industrial sector is also the target of ambitious refurbishment and focus on the reuse of wastes and the improvement of material efficiency. Additionally, this sector will be the target of carbon taxes to be applied by the government from 2030 (KWh/m2, 2011). As a result, the private sector will be more concerned and invest on the developments of more efficient and self-sufficient systems. Therefore, in general, the industrial sector was responsible also for 50% reduction on the three energy carriers.

Transportation was responsible for the largest amount of fuel savings. The partial shift of the light vehicles contributed with other 42% reduction. In total, approximately 45% of the fuel consumption in Arnhem was reduced by 2050.

Energy storage and exchange

Storage and exchange system receive lots of investments during the last 40 years. The areas in the south, which counts with the better potential for HCS in the aquifers use almost 100% of its capacity. The system is connected to the return pipes of the heat network, storing the low temperature water in the aquifer WVP2. Furthermore, closed systems were installed in large buildings in the central area in the south and industrial park. The Low temperature heat systems also received attention along the Rhine.

Energy generation

In order to achieve the maximum potential for energy generation by renewable sources inside the borders of Arnhem, many technologies were used. Two wind and several solar farms were proposed. Solar panels and solar collectors are also spread through the roofs in Arnhem. Moreover, two new systems were designed in the north, one Cogenerate Power Plant and a Heat Plant.

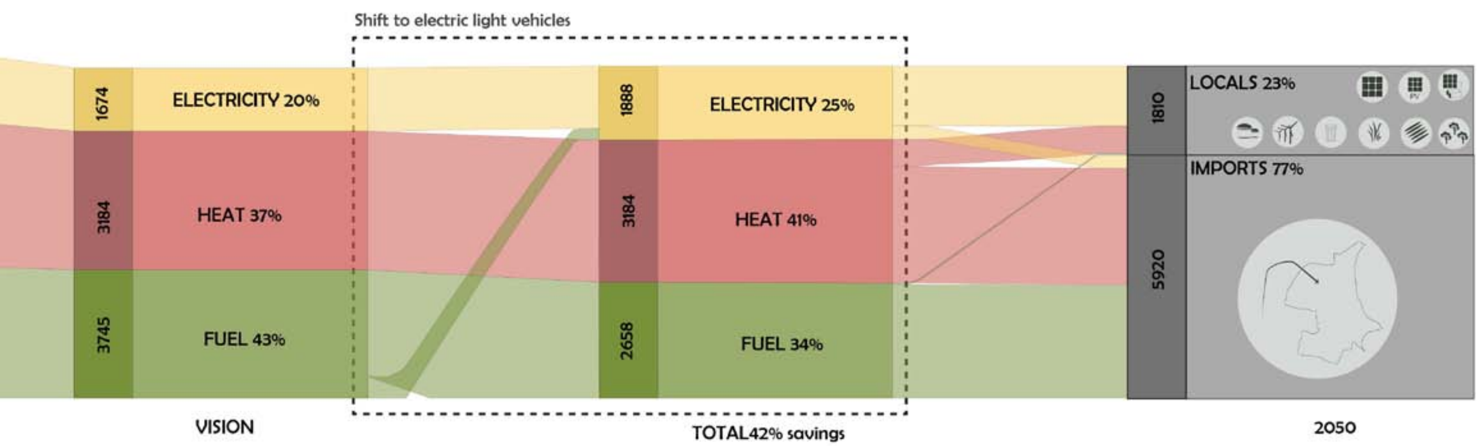


Figure 7.13. Sankey Diagram- Energy development 2012-2050

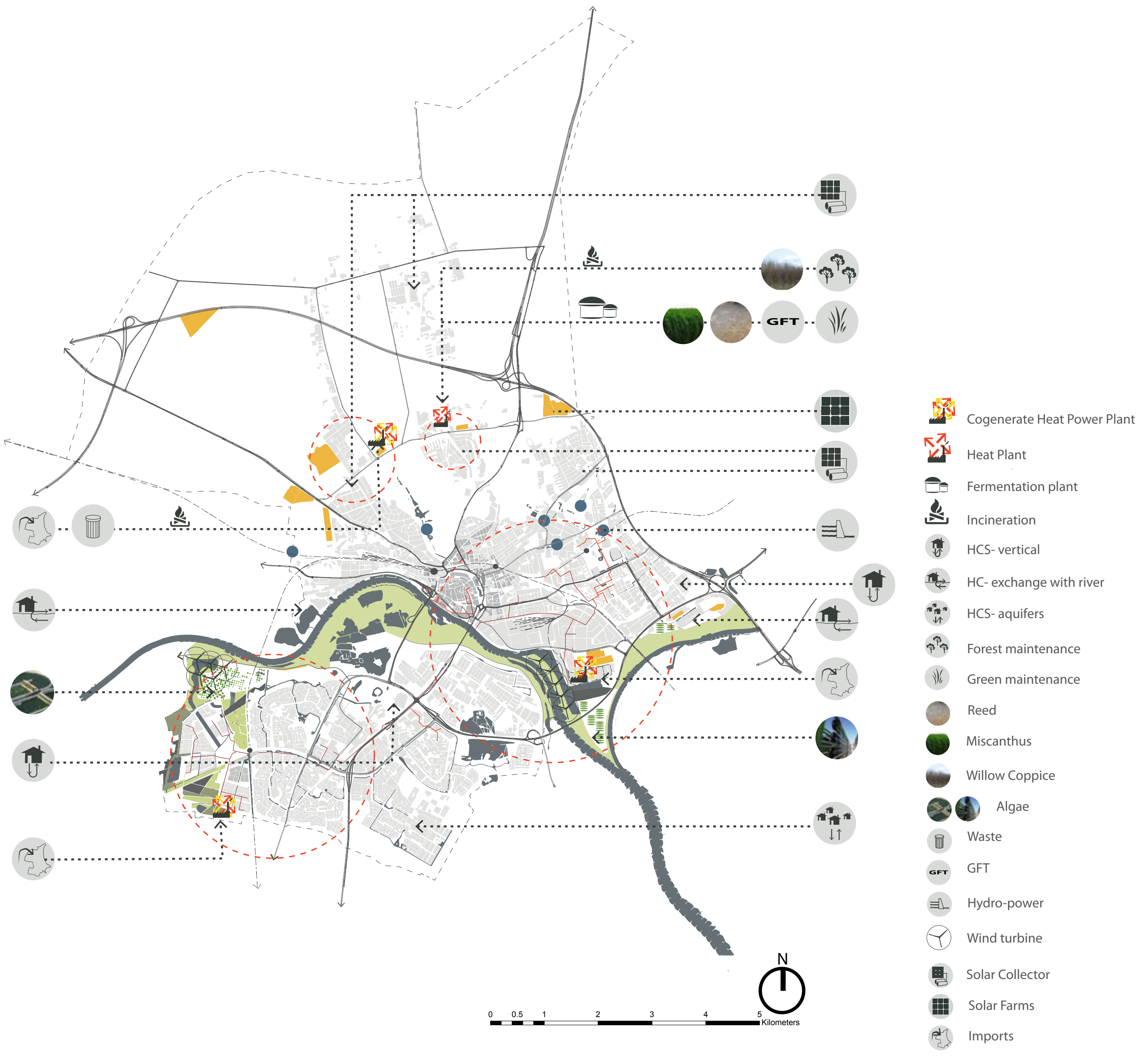


Figure 7.14. Less is Better- Energy Vision

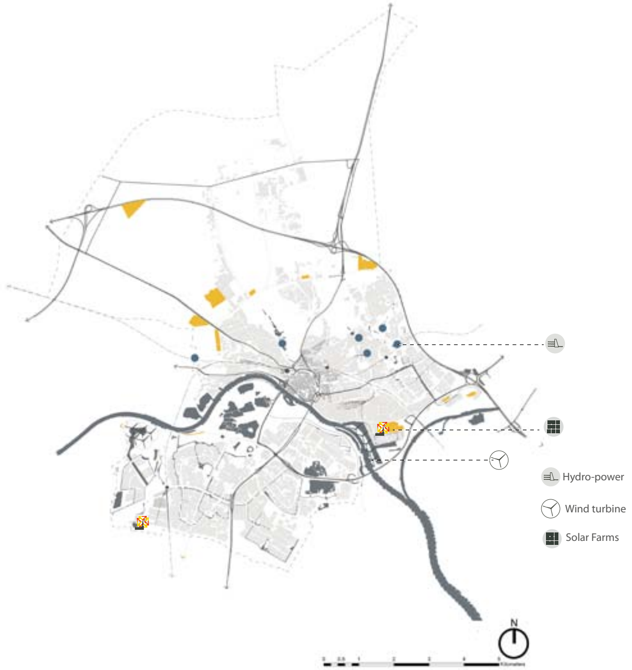


Figure 7.15.- Electricity

Figure 7.16. Heat

Solar

Most of the solar farms are spread through empty plots in the north. Two solar farms will be disposed along the high ways A12/ A50. Other four will be installed on the surroundings of the N224, bellow the electricity pylons. Other empty plots will remain for nature expansion and recreational uses.

The stagnation of the industrial sector will lead to the permanent empty plots in the industrial park. The empty land will then be used partially to settle solar farms. Moreover, the south face of the dike will be used to install this technology. Together all the solar farms will provide about 633TJ of electricity. When this number is translated to the amount of households attended we conclude about 50,200 dwellings can be supplied by this source of energy.

The total area occupied by those solar farms is 107ha. The efficiency of the system is 15%.

Besides the solar farms, PV cells will be installed in 16.8% of the roofs (42ha). This measure will provide the city with 231TJ of electricity. Other 7.2% of the roofs will receive solar collectors able to generate approximately 95TJ of heat, the equivalent need of almost 2,400 households. The last technology will be implemented mainly in the northern districts since these areas are not connected with the District heat network. Therefore, by using solar PV cells and solar collectors 958TJ or 34% of the electricity consumed in 2010 next to 95TJ of heat will be generated.

Wind

The location of the wind farms considered the best wind speed can be found in Arnhem, together with the available land and safe distances from households. The questions regarding NIMBY reactions were not analysed by this research. Nevertheless, authors, for instance Polatidis and Haralambopoulos (2007) in Bergmann et al. 2007, affirm the participation of people can lead to social acceptance of the wind turbines. Therefore, to involve people on the process and profit of wind turbines may be extremely important.

The first wind farm will be implemented along the dike between the industrial park Kleefse Waard and the river Rhine. There, five turbines of 3MW (e.g. ENERCON model E82- hub height 85m , 2011) will compose a row along the Kleefse Waard. Considering the urban developments in Schuytgraaf will not be fully implemented, besides to have the best wind speed at 80m above ground, other five 3MW turbines will be placed. One of them will be accessible to people, working as an 'overlook' from inside the hub to Arnhem. Together, both wind farms will provide 240TJ of electricity per year. This amount can supply about 19,000 households (27% of the dwellings in Arnhem) and represents approximately 8% of the electricity consumed in the city.

Hydrology

The recovering of the former brooks in Arnhem will receive water wheels able to generate a percentage of the electricity used locally, for instance on the Watermuseum. Together they will deliver 0.279TJ of electricity (Slijpbeek, 0.025TJ, Bronbeek, 0.005TJ and the Sint Jansbeek 0.249TJ). The total generate would supply approximately 22 households. Even though the potential is very low, the value of the water wheels will remain on the historical and cultural value of the technology.


Biomass

The use of biomass for energy generation comprises a large range of possibilities, forest, green maintenance and energy crops. Even though the sources are many, the amount provided by each is small. As a result, the most feasible system would combine the use of all the sources of biomass and the GFT (waste) in order to supply energy for the city. Considering the configuration of Arnhem, the 'green fingers' in the north separate some of the districts turning it difficult to be accessed by a district heat network. Consequently, the district of Alteveer/ Cranevelt will receive a Heat Plant.

The system will count with a fermentation plant, which will convert the green maintenance, part of the energy crops and GFT into biogas, and an incinerator plant responsible for the burn of wood chips and willow coppice. The biogas will feed the incineration plant. Considering a high efficiency of the system of 90%, 155TJ of heat will be delivered. Moreover, solar collectors will be implemented in the roofs and the hospital will shift into a self-sufficient system. Hence, the district will be 100% supplied with heat.

Waste

The district of Burgemeesterwijk/Hoogkamp will be supplied partially with electricity and heat by the waste incinerator plant. Even though recycling will increase during the next decades, 30% of the garbage produced in Arnhem was considered as potential to be burned on a CHP. 32TJ of electricity and 138 TJ of heat will be delivered. Other 10.8TJ of heat will be provided by solar collectors. There is a need for imports and/ or the advance of researches for other potential renewable sources (e.g. geothermal) in order to be 100% CO_2 neutral while provide the district with full demand of heat.

Algae

Two algae fields will be implemented in Arnhem, one in the industrial park and another in Schuytgraaf. In total, 83ha of empty plots in both areas will be occupied by this technology. Approximately 60TJ of energy can be generated by 1,660,000L of biodiesel. The areas were chosen according with the potential to connect with residual heat, CO2, water and waste water from industries or residences. Even though the biomass will be harvested in both places, it will be processed in the industrial park, since the place already counts with industries and the potential for producing a range of bio-products during the conversion process.

Schuytgraaf

The Auxiliary heat district in Schuytgraaf will be converted into a CHP. By doing so, the system will run by imported biofuel and deliver 274TJ of heat besides approximately 195TJ of electricity. The residual heat and the CO2 resulted of the burn of biofuel will feed the algae park in the district.

De Kleef

The CHP will shift to run by biofuels rather than fossil fuels. As well as Schuytgraaf, the fuel should be imported. The system will provide 651TJ of electricity and 579TJ of heat to the industrial park and cascading to the next neighbourhoods. The algae park on this area will be connected with the residual heat and CO2 from the CHP.
Both systems, Schuytgraaf and De Kleef will stay linked as in 2010, and the HCS systems will be connected on the return pipes of the heat network.

Energy systems

Considering the sources described above, four main systems are proposed. In order to identify the location of each they received the names of the districts where they will be implemented. 1. Burgemeesterwijk/ Hoogkamp; 2. Alteveer/ Cranevelt; 3. Industrial Park; 4. Schuytgraaf. The wind turbines and solar PV cells are not related with one particular system, but direct connected to the grid. Therefore, they are not included on the following diagrams.

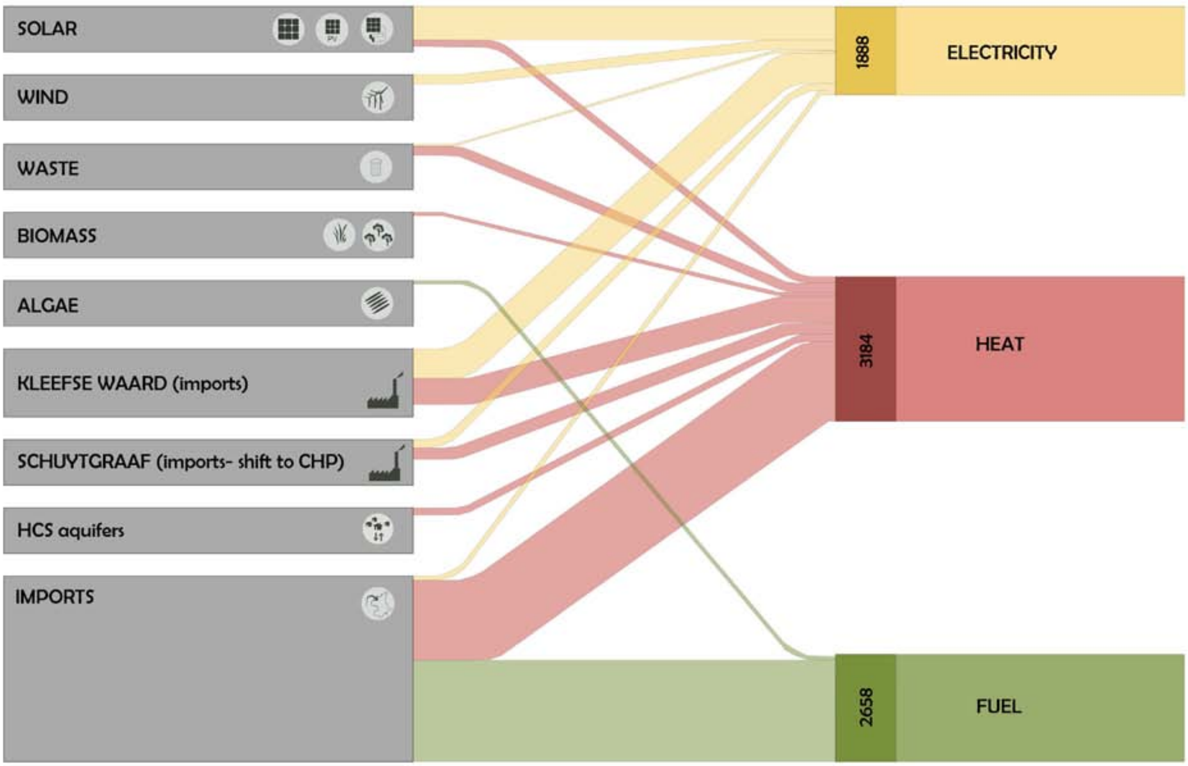
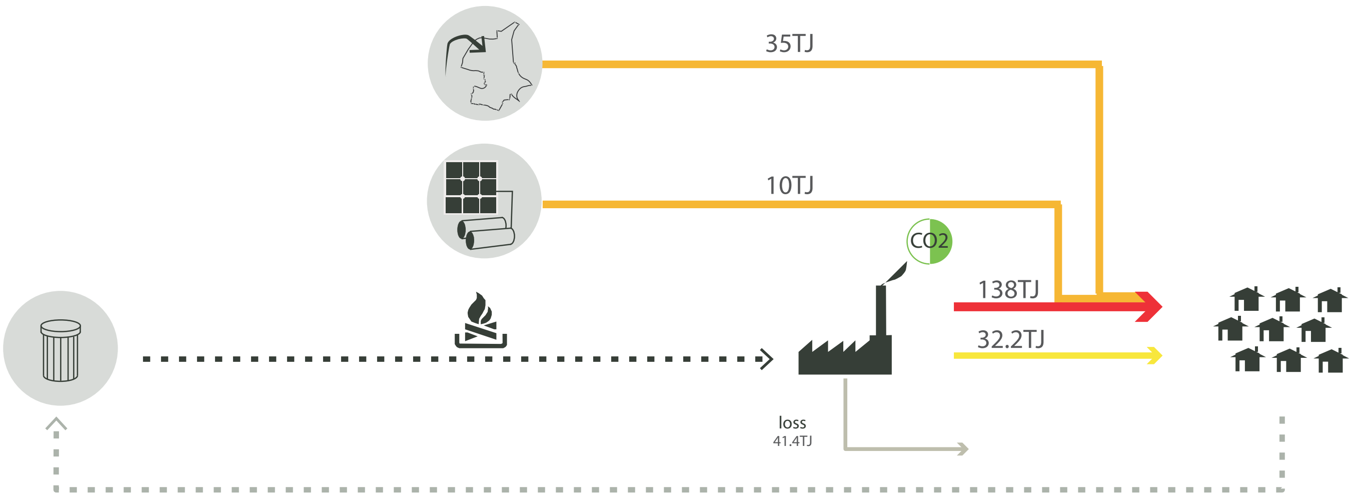


Figure 7.17. Renewable sources and energy carriers



Diagramxxx- System Burgemeesterwijk/Hoogkamp

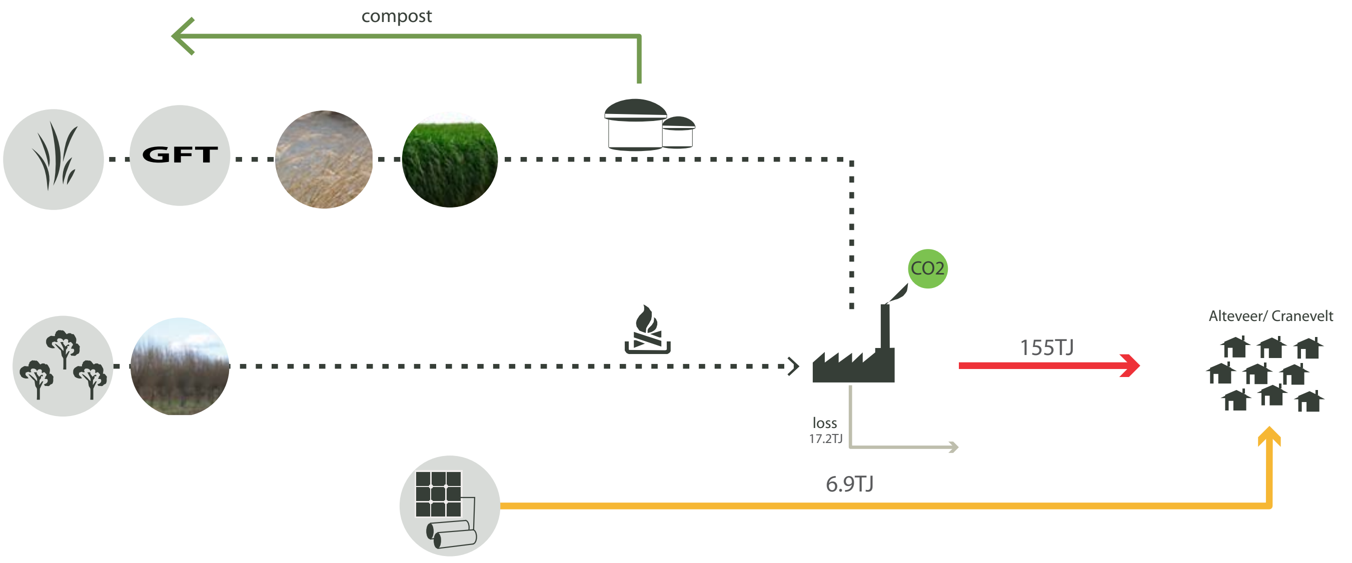


Figure 7.18. System Alteveer/ Cranevelt

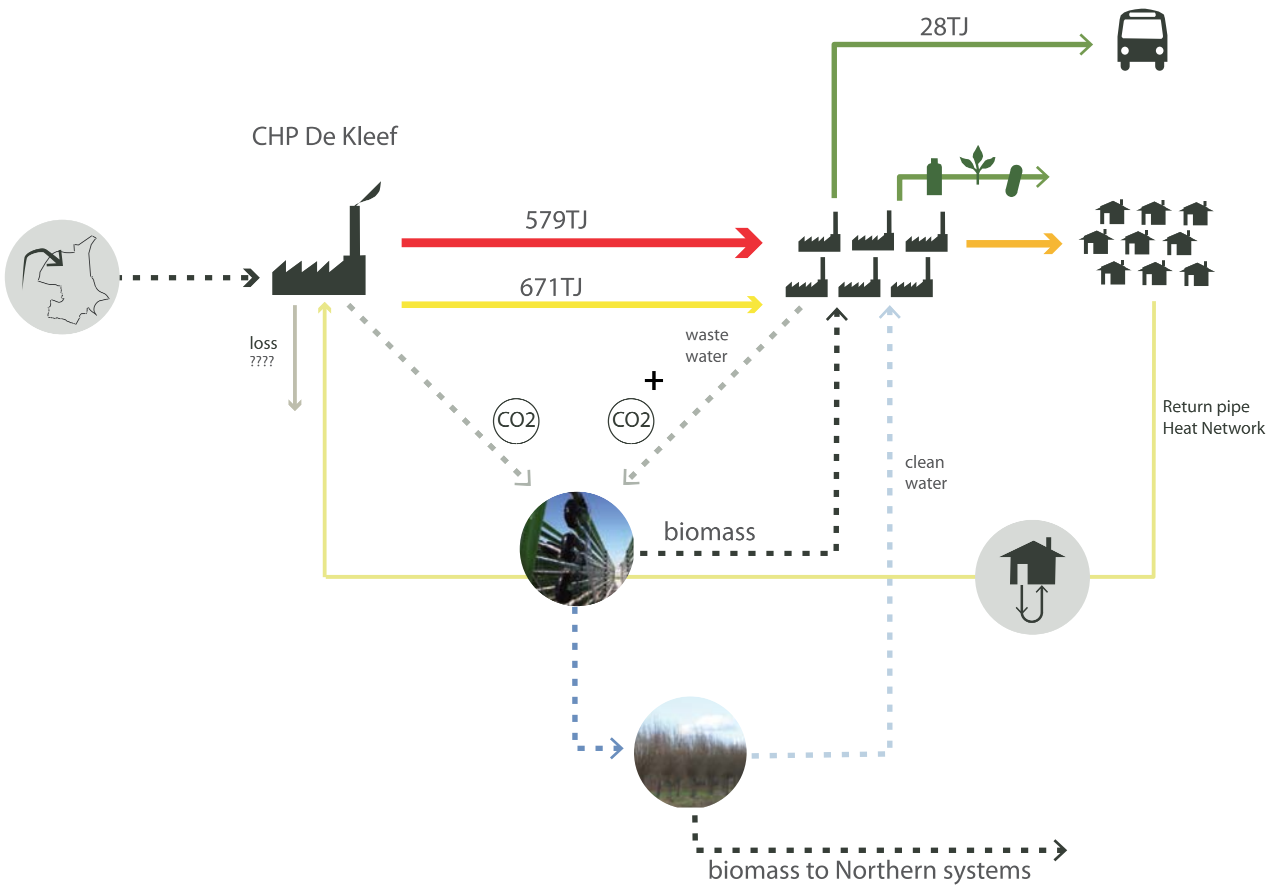


Figure 7.19. System Industrial Park

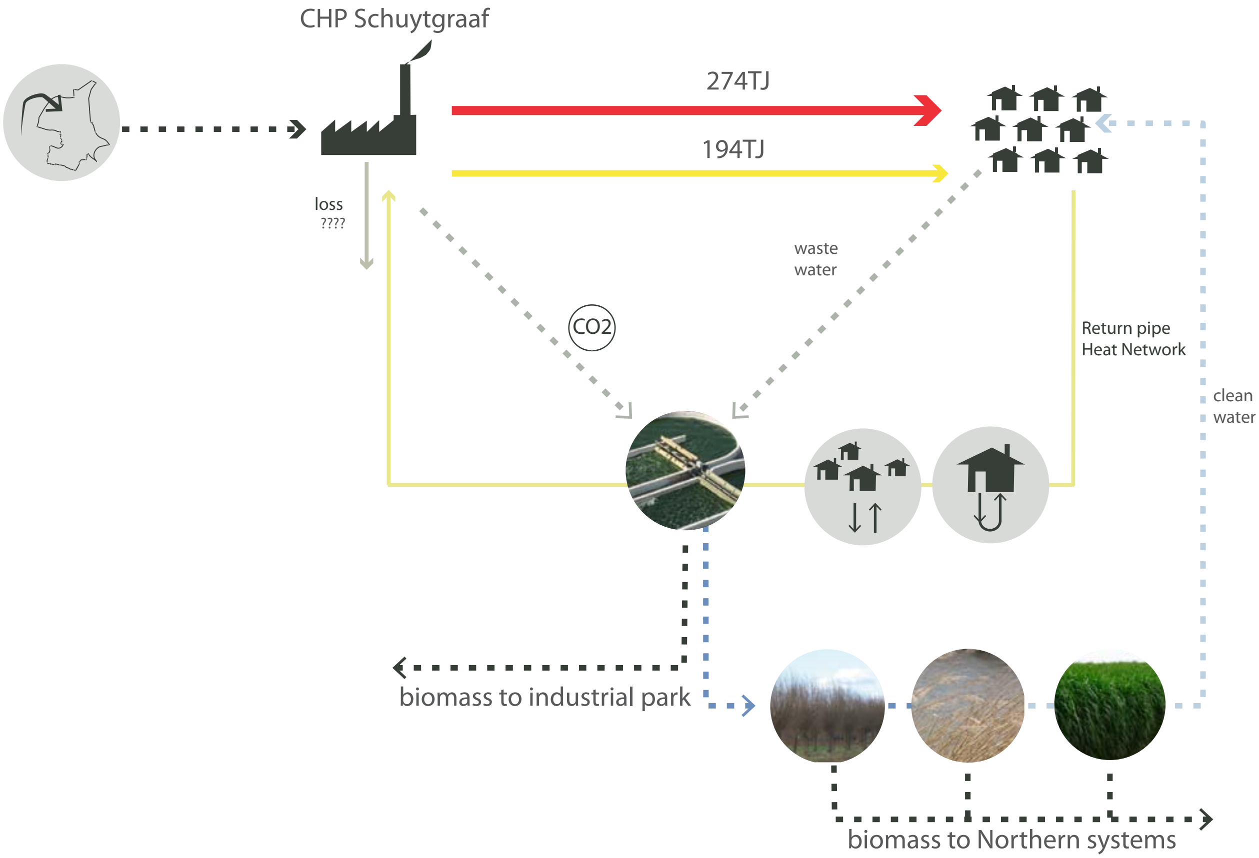
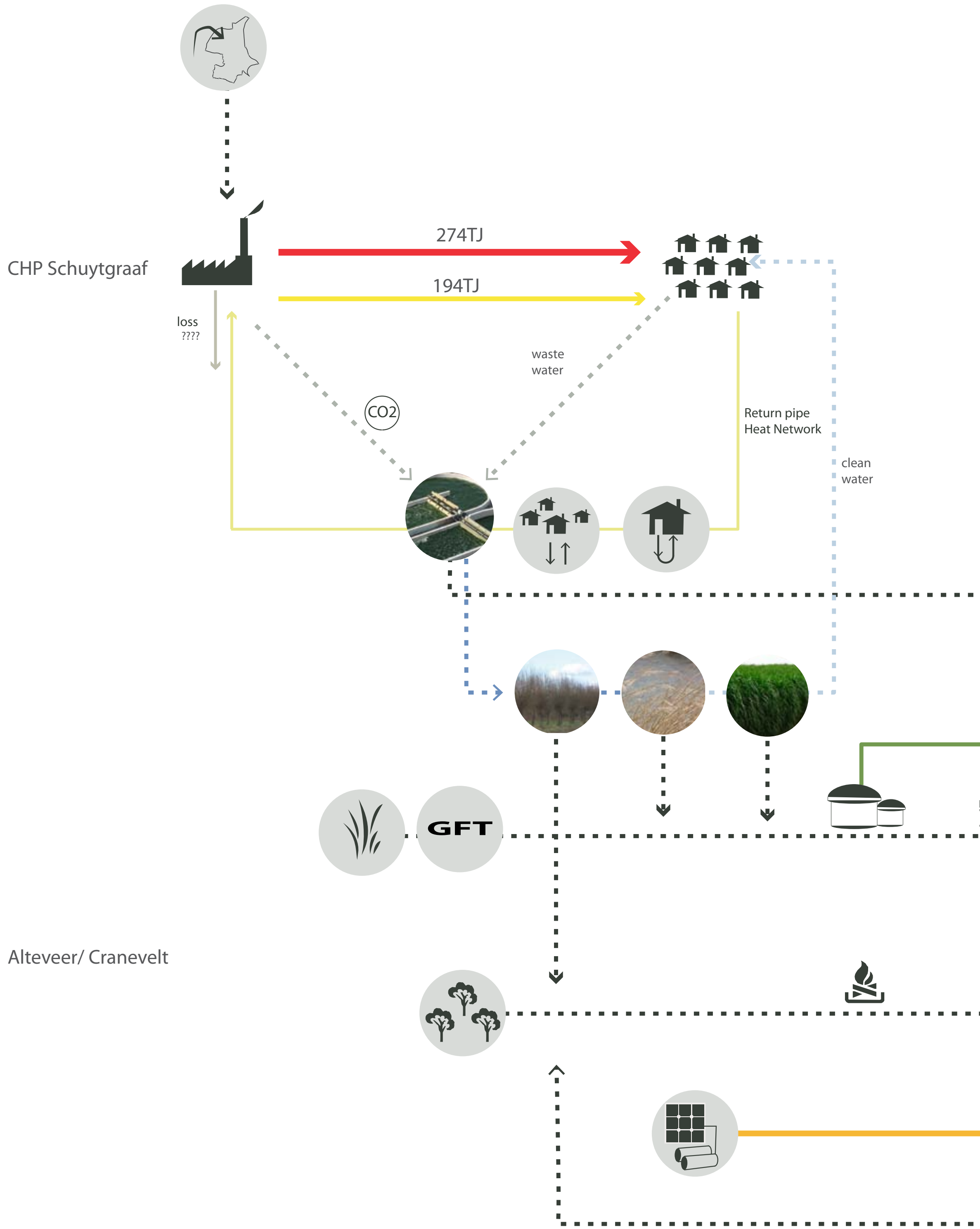


Figure 7.20. System Schuytgraaf


CHP Schuytgraaf
274TJ
194TJ
loss
????
waste
water
CO_2
Return pipe
Heat Network
clean
water
GFT
Alteveer/ Cranevelt

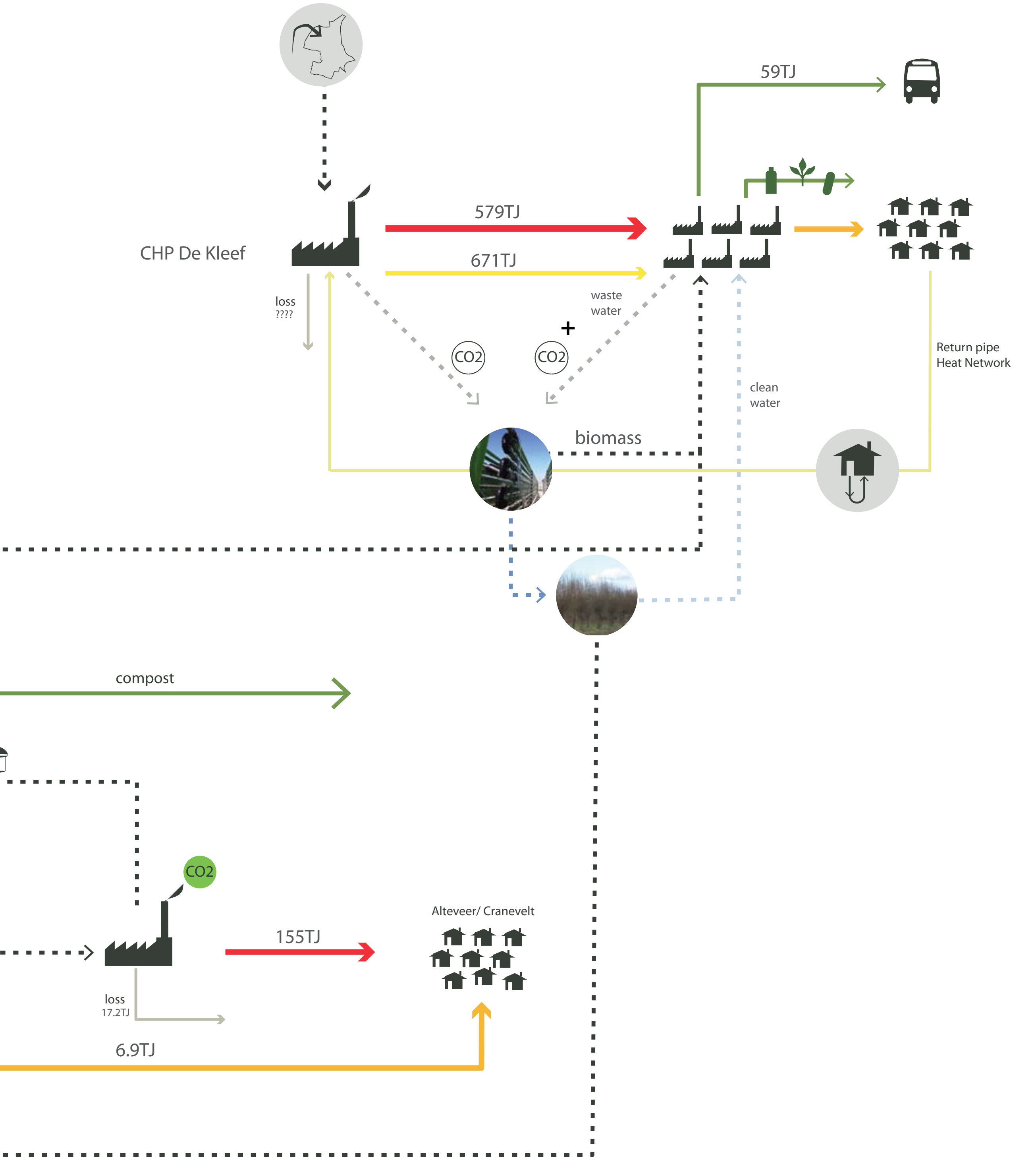


Figure 7.21. Correlation of systems

7.3 Phasing of Implementation

First Decade (2012-2020)

Following the Trias Energetica proposed by Lysen (1996) the first decade (2012-2020) will be marked by intense investments in saving. The heat network will be reviewed, expanded and adapted followed by intense investments on buildings refurbishment. The development of small sub-centres will also receive attention. With regard to the blue-green network, the natural areas in the north will start its extension as well as the recovering of the former brooks.
Even though energy generation will not be the target of the government during this decade, participatory measures involving private parties and social organizations will be done. The objective is to involve the interests of the three groups, (government, private and citizens) on the discussion regarding specially wind turbines and solar farms placement

Second decade (2020-2030)

During the second decade the main steps to energy saving next to the adaptation of the existing infra-structure for energy transition will be ready. Nevertheless, this decade will be extremely important with regard to energy generation. Fermentation and the Heat Plant in Alteveer/ Cranevelt and the waste incinerator in Burgemeesterwijk/ Hoogkamp will be built. The planting of reed in the flood plains besides the biomass production in Schuytgraaf and Industrial Park will be made. Moreover the auxiliary heat plant in Schuytgraaf will be converted into cogenerate heat power plant and the CHP De Kleef will run by imported biofuels.

The government will subsidise the PV cells installation on roof tops and the first wind farm will be placed in the industrial park. Heat and cold storage in the aquifers will be implemented. Other technologies, such as heat and cold exchange with the river and geothermal potential will still receive attention of researchers and developers.

Regarding transportation, the electric fleet will start being implemented as well as thwe charging places for batteries will be integrated in the small centres spread in each district of the city.

The green –blue network will count in the north with all the brooks recovered, where water wheels will be installed. In the south, the expansion of the green network and biomass will be related with the water table management.

Third decade (2030-2040)

The implementation of the second wind park, in Schuytgraaf will be take place. The development of algae as a fast growing crop for biofuel and bio products during the first two decades will lead to the implementation of this technology from 2030. The two algae parks will be placed. The first is along the industrial park, counting with the tubular technology. The second will be built in Schuytgraaf and use the open ponds technology, being integrated with the biomass production in the area.

Furthermore, the built of solar farms will start in the north, in the industrial area and along the dikes in the south. Nature will keep being developed mainly in the empty plots in the north.

Fourth decade (2040-2050)

The last decade will be characterized by the implementation of the last solar farms. Moreover, the first wind farm, in the industrial park, will be replaced by more efficient mechanisms. On this decade Arnhem will achieve the maximum potential to generate energy inside its borders as well as to save energy as much as possible. The electric fleet will be very well expanded.

Figure 7.22. 2012-2020

Figure 7.23. 2020-2030

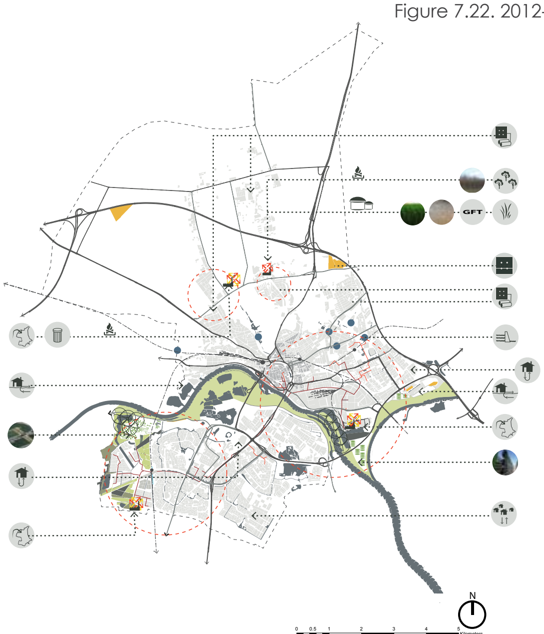


Figure 7.24. 2030-2040

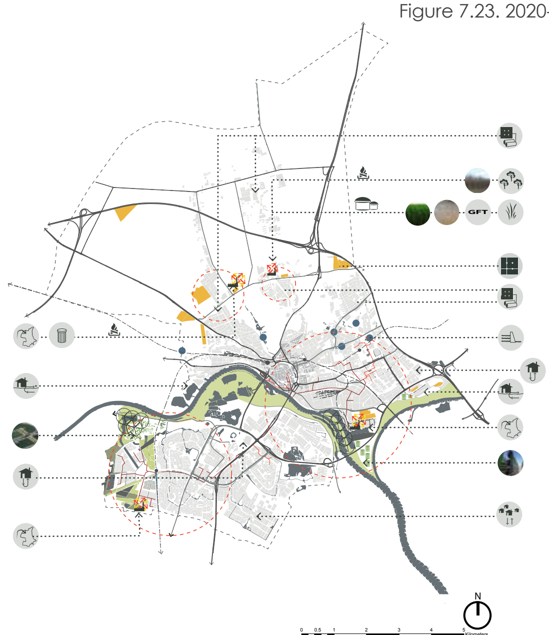


Figure 7.25. 2040-2050

Figure 7.26. 2012-2020

Figure 7.27. 2020-2030

Figure 7.28. 2030-2040

Figure 7.29. 2040-2050

Complete Vision phasing of implementation -2012-2050

	2010	2020	2030	2040–2050
ENERGY	INSULATION BUILDINGS SAVING CAMPAINS EXTENSION HEAT NETWORK RECHARGE PLACES FOR BATERIES	FERMENTATION PLANT CROPS FOR ENERGY SOLAR PANELS ROOFS WASTE INCINERATOR PLANT 1ST WIND PARK- INDUSTRIAL PARK START ELECTRIC FLEET IMPROVING WWTP WATER WHEELS	ALGAE PLANT CROPS FOR ENERGY EXTENSION 1ST PHASE SOLAR FARMS 2ND WIND PARK- SCHUYTGRAAF BOILERS AND STORAGE	CHANGE 1ST WIND PARK 2ND PHASE SOLAR FARMS
OTHERS	SUB-CENTRE SOUTH GREEN NETWORK EXTENSION BLUE NETWORK EXTENSION FORMER BROOKS ON THE SURFACE NATURE EXTENSION	SUB-CENTRES GREEN NETWORK EXTENSION BLUE NETWORK EXTENSION NATURE EXTENSION	GREEN NETWORK EXTENSION NATURE EXTENSION	GREEN NETWORK EXTENSION NATURE EXTENSION

Figure 7.30. Time Line_Vision phasing of implementation 2012-2050

7.4 Contribution to CO2 neutrality

Regarding CO2 reduction by using renewable sources of energy, it will be possible to achieve approximately 50% of neutrality without count with imports. The main contribution is found on the electricity carrier, 63%, due to the implementation of large solar farms in the city besides the two wind parks. Even though the amount of biofuels produced inside the city is small, the shift from fossil fuels vehicles to electrical vehicles was responsible for 42% of reduction on this energy carrier. Heat contributed with lowest amount, approximately 17%.

Even though according with the scenario, the sovereignty of the city will happen. In order to reach the target of 80% CO2 reduction, the cooperation with other municipalities, provinces and national government would be necessary. The cooperation with other areas would lead for instance to the shift of the two CHP, Schuytgraaf and De Kleef, inside the city, to run by biofuels. As a result, about 80% CO2 neutrality would be possible.

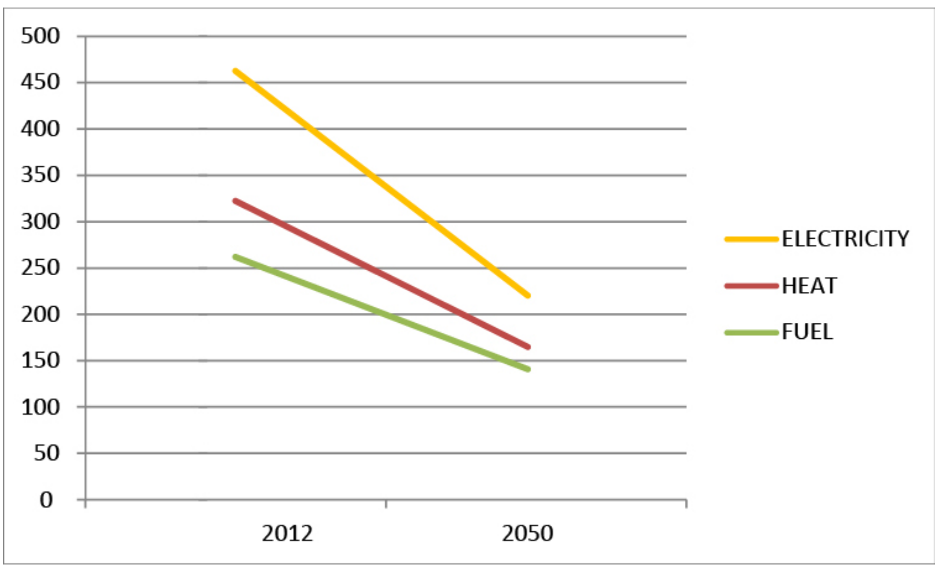


Figure 7.31. CO2 reduction

7.5 Conclusion of energy vision

It was clear the essential contribution saving measures would have for the reduction of energy consumption and consequently CO2 emissions in Arnhem. These measures usually are not so visible on the biotic and anthropogenic layers of the landscape, which is much more influenced by the implementation of technologies to generate energy. Other important actions, such as the improvement and extension of the heat network should be done as soon as possible. Therefore, the first decade (2012-2020) will be marked by the hurry to prepare the landscape to accommodate the most feasible technologies to generate energy, once saving measures as well as the improvement of the existent system will be already done. The visual impact on the landscape will be noticed mainly from 2020, when the first technologies will be implemented.

As well as the green-blue network, the energy network composed by diverse kinds of renewable sources will permeate Arnhem. The concept was based on the use, as much as possible, of the potential found inside the borders of the municipality. Some limitations of the landscape, such as the old centre, natural areas on the Veluwe were considered.

After the discussion made for the Vision, one of the energy systems proposed, will be focus of a site specific design. The implementation process will start mainly from 2020.

Figure 7.32. Aerial View with location (Google.maps)

7.6. Landscape Analysis

The area is located on the extreme south west of Arnhem. On the edges with Driel and Elst. Being a new urban development on former agriculture land, Schuytgraaf is a transition zone, which carries characteristics from urban areas as well as from rural areas. Researchers, such as Whitehand (1967) and Pryor (1968), defined site with these features as urban fringe. Spacial problems can be perceived, such as the lack of direct connection with the next neighbourhoods as well as the weak links with the surroundings rural areas. mapxxx due to the elevated train line across the city.

Abiotic

Schuytgraaf is located on a polder. The predominant soil is heavy clay, interacted by layers of sand. This features make with the run-off water infiltrates well through the superficial sand layers, but stagnates once it reaches a subsequent layer of clay, which is not so permeable. As a consequence, a shallow water table is founded in the area, approximately 1 meter under the ground. The increase level of water on the river has a direct affect on the level of the ground water in the district as well as the amount of water infiltrated in the north moraines. Currently a system of canals is responsible for the drainage of water and a small wind turbine are responsible for the discharge of the exceed in the river Rhine.

Biotic

Few areas of vegetation can be found. It is composed basically by a small wood (approximately 6ha) and some trees along the former dike of the arable fields. On the east borders the shallow water forms a natural basin.

Anthropogenic

The anthropogenic features present some of the barriers of the landscape. Faced on the north side by the dikes of the river Rhine and on the west by the mounds of the railway, Schuytgraaf is a district apart of Arnhem, on its urban fringes. Even though it counts with the Arnhem-Zuid station and stops of the troller-bus it is not possible to reach facilities by walkable distances. Therefore the implementation of at least one sub-centre will be essential for the area. With regard to energy, the District is fully supplied with heat by the CHP Schuytgraaf.

As a conclusion, Schuytgraaf has characteristics of urban fringe. As a transition zone it is pressured by the urban expansions and the possible conservation of rural areas. The challenge is to integrate both characteristics while designing a sustainable energy landscape. Hence, green, blue and energy networks should be integrated while re-define the connections between urban and rural landscapes.

Figure 7.33. Schuytgraaf _ Current situation (Gemmente Arnhem, 2011)

7.7 Design Proposal

The design of the landscape in Schuytgraaf is based on all the objective data collected during the thesis. Moreover, subjective information such as, visit to the place, sketches, photographs and observation were additional methods used. The inspiration for the design was based on site specific features.

The improvement of connections with the next districts and with the recreational areas on the flood plains received attention. The barrier composed by the elevated rail way track will be broken near the WWTP and expanded in the central part, where the sub- centre will be developed.

Figure 7.34. Schuytgraaf _ Urban fringe

On the side of the WWTP the new opening provides people with a wide passage from Schuytgraaf in direction to the recreational areas on the flood plains along the dike. The amount of soil removed will be used on the landscape in order to create different levels of mounds, which forms a playful labyrinth on the flat polder landscape (Figure 7.35) Taking part of the elevation of the mounds, algae ponds will be placed, being perceived as gigantic mirrors of water, reflecting the sky. The algae production will be feed by the WWTP after the decontamination process. Sequentially, the water from the algae will be driven to willow and reed beds.

Nevertheless, considering the underground composition of the soil and water table dynamics, small water basins will be shallow excavated along the energy crop fields next to a large pond which will be constructed in order to store water, offering a recreational option for people. Moreover, the run-off water will be collected by the system and stored to infiltrate slowly while provide the biomass with nutrients. The clean water infiltrate in this area will influence positively the further drinking water extraction. The system will integrate green, blue and energy networks.

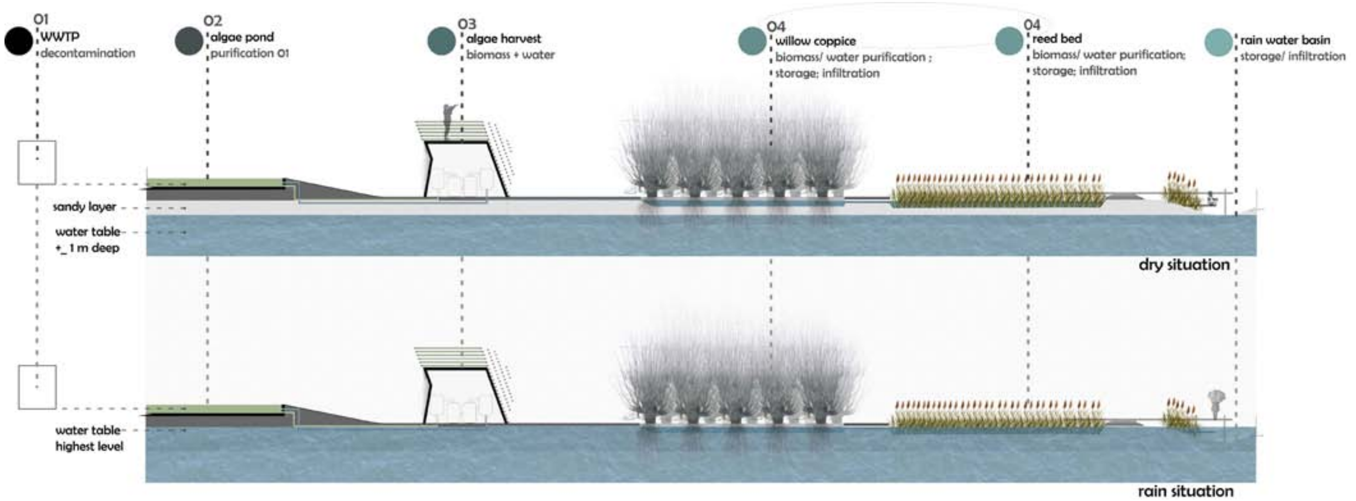


Figure 7.35. Water treatment and biomass production; with accessible harvest of algae

Figure 7.36.Design Inspiration- Roberto Burle Marx (The New York Times)

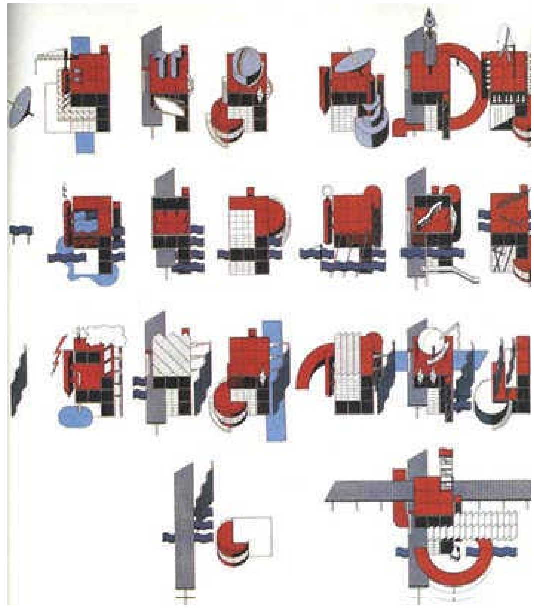


Figure 7.37. Design Inspiration harvest points- Folie- Parc de la Villette- Bernard Tschumi (kmtspace)

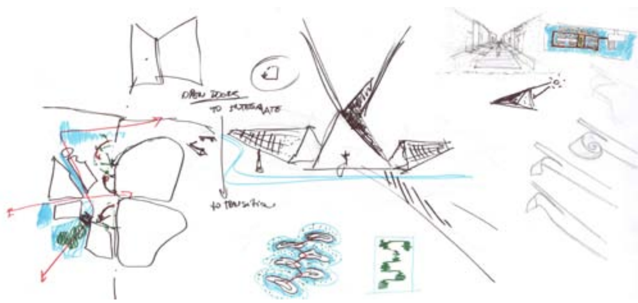


Figure 7.38. Sketch- studies to 'break the walls'

Figure 7.39. Sketch- spacial organization

Figure 7.40. Sketch- spacial organization algaes elevated ponds

In order to make people still more aware about the energy landscape, the harvest points of algae and to store the biomass will be accessible to people. By doing so, the dynamism of the landscape in order to generate energy will be experienced by the users.

As part of this multifunctional landscape, five wind turbines will be placed in Schuytgraaf. Two of them will be 'floating' on the large water basin. The placement of this technology will follow the grid composed by the harvest areas of biomass, since the turbines are harvesting the wind in order to generate electricity. As well as the harvest areas, one of the turbines will be accessible for people.
The implementation of the project begin between 2012-2020, when the sub-centers will bedeveloped. During 2020-2030 the area under the rail way will receive atention as well as the implementation of biomas and water basins. From 2030 the wind turbines and algae farm will be implemented.

Figure 7.41. Blue network

Figure 7.42. Green network

Figure 7.43. Energy network (above ground)

Figure 7.44. Harvest areas

Figure 7.45. Bike network

Figure 7.46. Heat Network

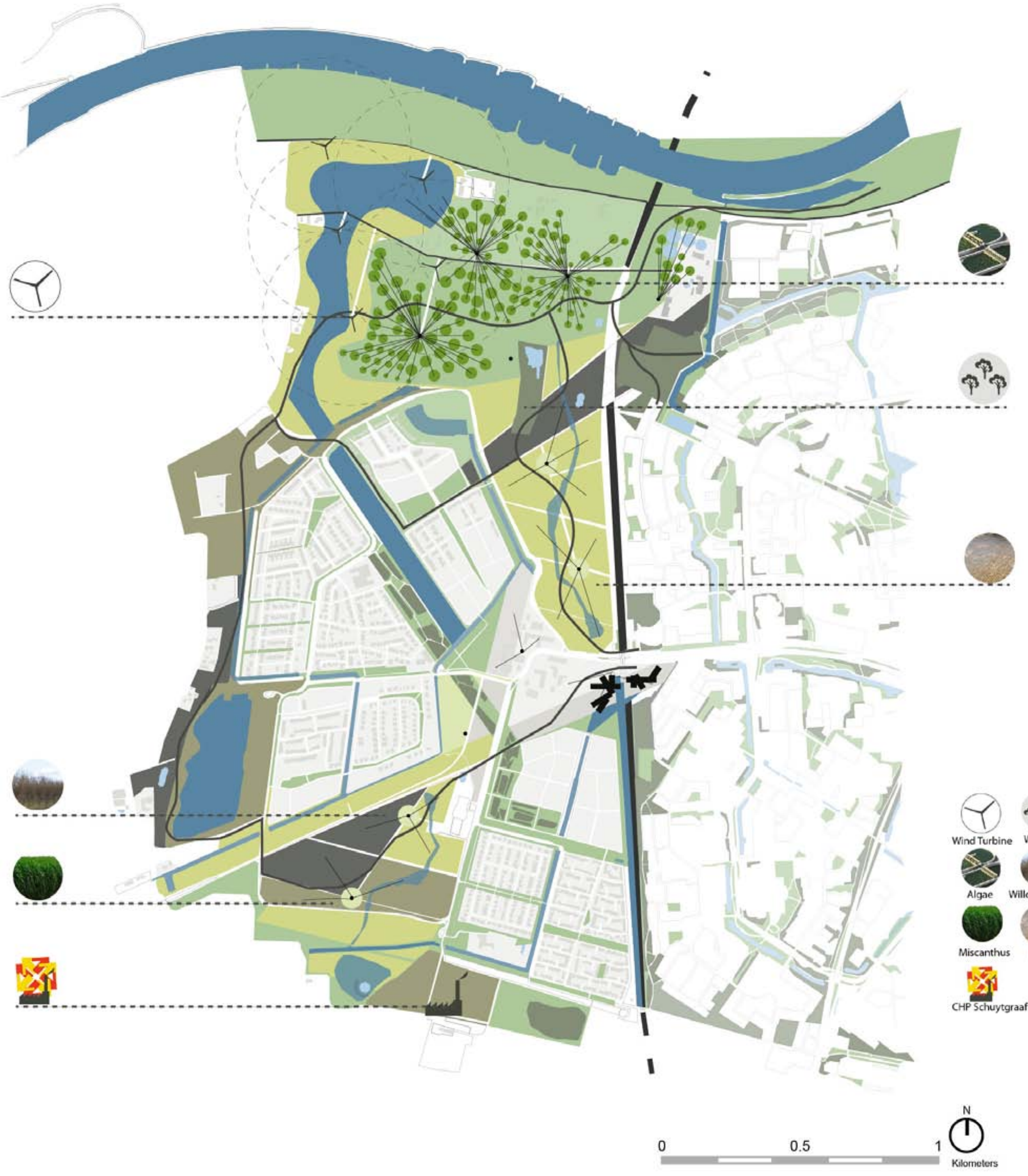


Figure 7.47. Master Plan Schuytgraaf

Figure 7.48. Aerial view Algae park Schuytgraaf

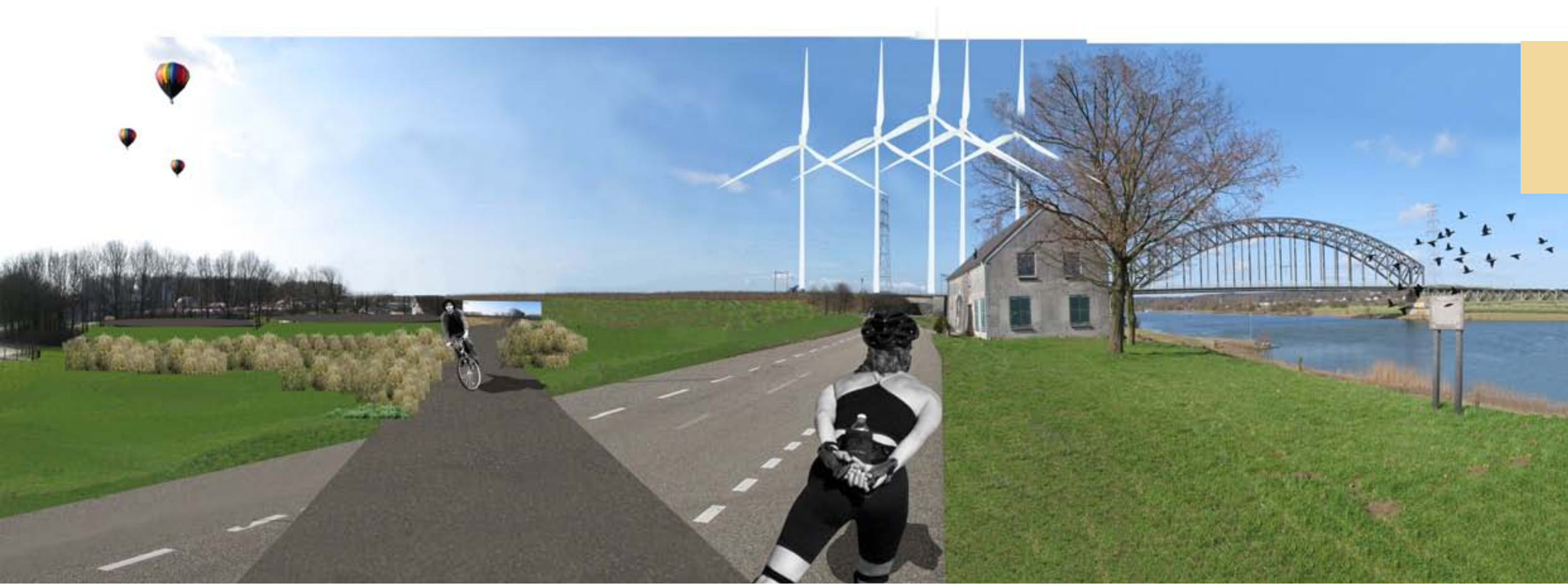


Figure 7.49. Access Schuytgraad by the flood plain

Figure 7.50. Reed and willow beds_ water storage area

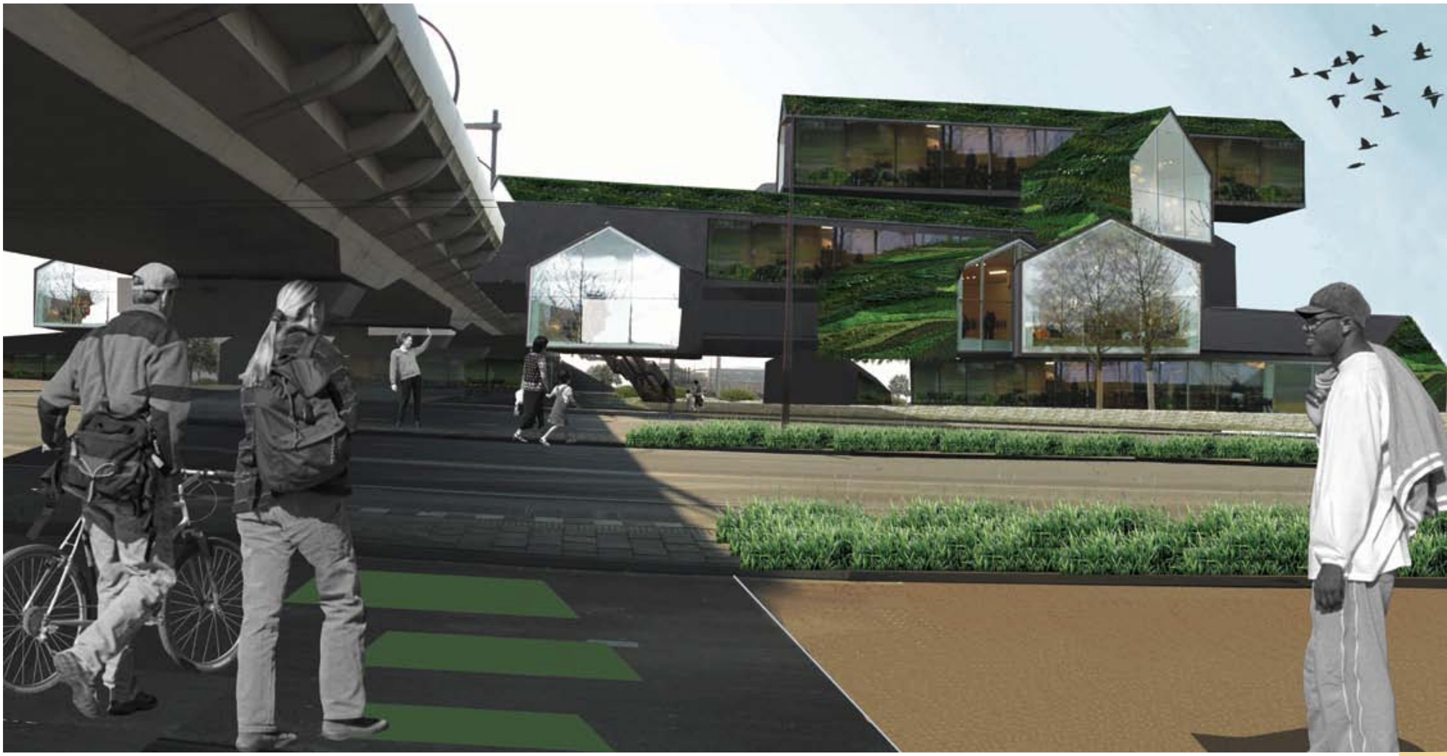


Figure 7.51. Sub_centre Schuytgraaf- Kinectic floors

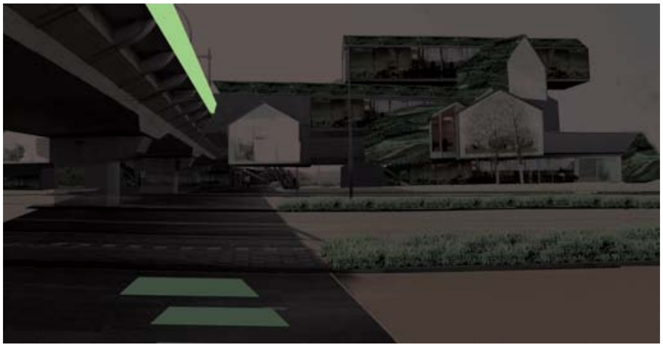


Figure 7.52. Sub_centre Schuytgraaf- Kinectic floors- night situation

7.8 Conclusion of design proposal

The Design of a sustainable energy landscape to Arnhem proved to be a challenge which involves not only the choice of technology, but the knowledge of a large range of characteristics of the landscape. The intervention, as well as the vision, was framed by a socio-economic scenario. As a consequence, both are influenced by future uncertainties. On the other hand, the exercise to propose a desired future and to zoom on a particular area of the landscape open space for future discussions while bring possibilities which can be adapted for different possible futures.

Most of the technologies implemented are already proved. This fact makes the design more consistent to be implemented. The exception remains upon the algae production. This technology is still being studied, on the other hand, since there are lots of investments on the research of this source it rose as a potential to be explored during the design proposal. Moreover, considering the flexibility of the system, to be correlated with waste water treatment plant, residual heat and CO2 to bring space for this possibility was very interesting.

Regarding the target the city proposed, 80% CO2 reduction by 2050, based on energy transition, the system in Schuytgraaf will contribute with almost 3%. Even though the percentage is very small, it is still attractive, since Arnhem does not have plenty open fields for the installation of energy technologies. Moreover, the features to be a urban fringe makes the challenge still more interesting, since a multifunctional landscape had to be proposed.

Therefore, the implementation design was based on a well structure research. The work with scenarios provided the base for a discussion of possible and desired futures. Even though the proposal was made based on one particular scenario, it does not constitute a master piece or a closed master plan for Arnhem. Rather, the idea of designing a particular area of intervention, is to show how the landscape has being challenged, not only for the energy transition perspective, while help to guide decision makers.

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FRANZISKA
JANA
MAREIKE
MICHELLE
VANESSA

Chapter VIII

Desired future
"Business As Usual" vision

Figure 8.1. Wind turbine "art" in Dardesheim, Germany (J. Gómez)

8.1 Concept + Design principles

One of the aims of this research and proposal was that people would be aware and would be able to understand the importance of an energy transition. Therefore, they would be in direct contact with the technologies, become part of their daily life. Awareness and collaboration were important. Moreover, changes in policies happened.

Abiotic

The abiotic layer was important to be understood. In BAU vision, an increase in the water flow from the rivers Rhine and Ijssel was expected and the weather conditions to be more extreme. The ground water level was affected and an extra effort took place especially in the south part where the polders are located and where the area to harvest the fresh water were located. This ensure security against flooding and supply of fresh water.
Regarding the soil layer, Arnhem had a wide variety due to the special conditions of the moraines and the rivers. This offer possibilities to find and grow different kinds of plants (e.g. reed or rapeseed). Due to the elevation of the city, different aquifers can be found in the underground, some of them offered the possibilities for heat and cold exchange and storage. It was possible to grow different kinds of plants due to the characteristics offered by the kind of soil composition and groundwater level
Another characteristic related to the topography was the favourable slope in the city of Arnhem facing the south. This provide the best conditions when installing PV panels.

Biotic

The green and blue structure in the city did not expand in size but the quality of them were improved. As the BAU scenario predicts, recreation and sports took place. Diverse implementations happened in the city to improve the quality of the green and blue structure including as well the recreational function to them (Figure 8.2).
It was predicted that temperature will raise. Therefore, green walls and green roofs were implemented, spreaded in the city as a new element in the urban landscape. They worked as an thermal insulation element especially for cooling during warm days, besides helping in the mitigation of the Urban Heat Island effect (UHI), reducing air and noise pollution and capturing small particles from the environment.
With the purpose of making a multifunctional landscape, diverse technologies for energy generation were implemented in the green areas.
Concerning the blue structure, it remained as in 2010. The only change occurred in the harbour area, it was expanded to give more space for commercial and private boats. It was considered the potential for heat and cold exchange with the river, especially for those buildings in the industrial area.

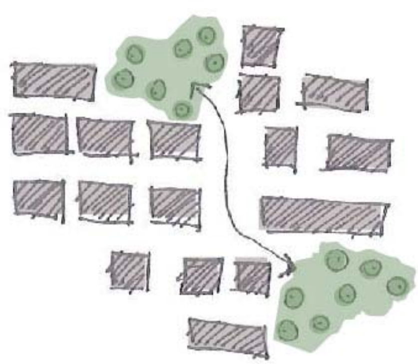


Figure 8.2. Good quality in specific green areas on the urban context

Anthropogenic

It was important to understand the urban fabric, the land use and the transportation infrastructure.
In the BAU vision there was an increase in the industry and business sector of around 19%. Some specific areas were analysed and proposed to settle this growth, with the following criteria: proximity of services, good accessibility and the necessary potential according to the BAU vision. Most of this growth was located in Arnhemse Broek. In the same way, a slight growth in the demand of housing took place. A shift to a more dense and mixed land use was proposed (Figure 8.4) in order to reduce the distances that people make to get to their jobs, shops and other amenities, as well as improving the quality of the city making it more lively. The concept of having 2 main city centres succeed and a good connection between them took place (Figure 8.3). Schuytgraaf neighbourhood was the neighbourhood with the biggest growth in the housing sector. Since one of the main principles is to improve the quality of life of the inhabitants, one of the ideas was to promote the connection with the river. Actions to connect the old city centre with the river took place in the decade of 2010 and they continue in further decades. (Figure 8.5)

An important attention received the transportation sector. An efficient and sustainable public transportation was implemented (Figure 8.6). Arnhem holds the biggest trolleybus infrastructure in the Netherlands in 2010.
There was an increase in the transportation of goods through the river and by train, that was why the relevance of the location of Arnhem between the two rivers as well as its proximity to the border.
A diverse transportation system was created, different means of transportation: electric cars, electric bicycles (Figure 8.7) and the expansion of the trolley-bus system. An especial effort was done trying to electrify as much as possible the means of transportation. The connection by efficient and sustainable means of transportation between both city centres took place, reinforced by the bridge implemented for low traffic vehicles.

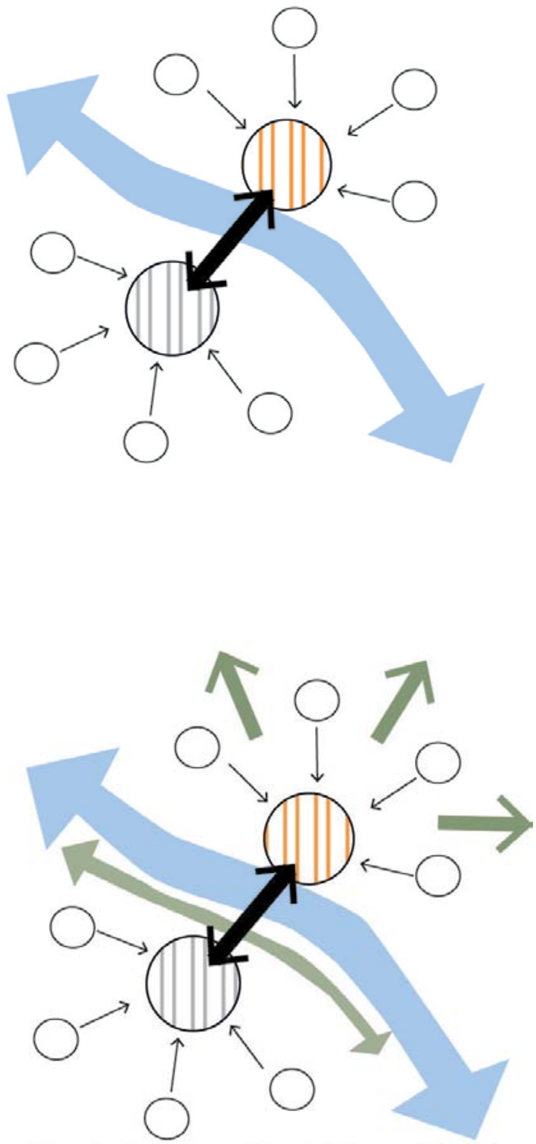


Figure 8.3. Strong city centres concept

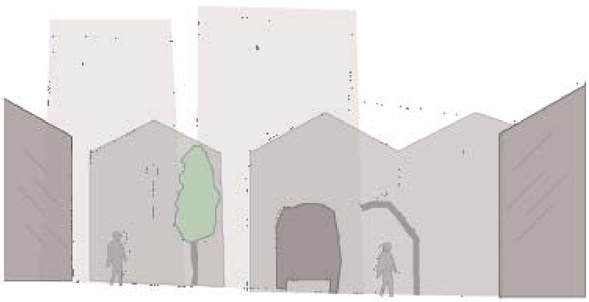


Figure 8.4. More dense urban fabric

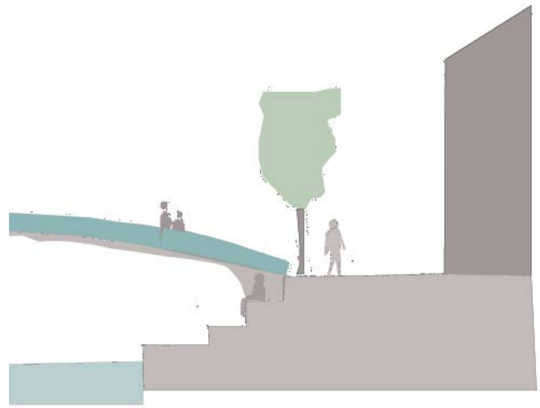


Figure 8.5. Connection between the river and the old city centre

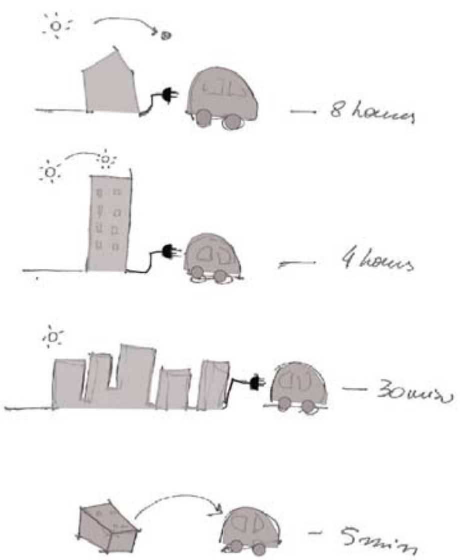


Figure 8.6. Shift to electric vehicles

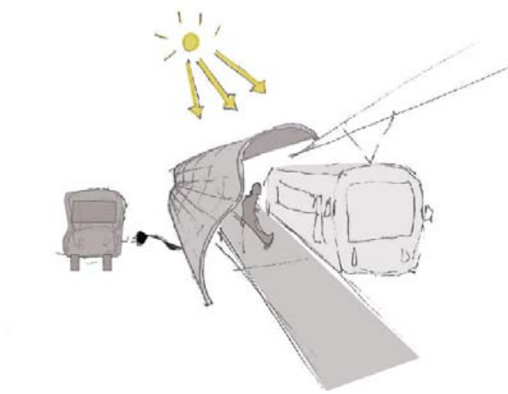


Figure 8.7. Diverse wats of sustainable transportation

8.2 Energy vision

The aim of this vision was to reduce the dependency of energy imports and to generate the energy as much as possible from sustainable sources. According to the BAU vision, these sources should come from the Municipality of Arnhem and from the neighbouring municipalities, as part of a regional strategy for the robustness of the energy system. The preservation of the quality of the landscape in Arnhem has always been considered even though new functions were incorporated.

A reduction of 29% instead of an increase of 15% as predicted by BAU scenario. Different actions and interventions took place in order to reduce the energy consumption (Figure 8.8).

Looking for a stronger and robust energy infrastructure, the implementation of diverse technologies and the use of different sustainable energy sources. All this to obtain a decentralized energy system.

Energy saving

The way of living and/or the habits of people were hard to change in the BAU scenario but it was expected to have a slight change.

Different actions took place; all the near future developments were developed under certain guidelines to be efficient in terms of energy and those developments built before 2010 received special attention to make them more efficient in terms of energy consumption. It was from 2010 to 2030 where the biggest efforts for saving energy took place.

In terms of electricity, the new developments considered the reduction in energy consumption as one of the main and most important facts and a reduction in the energy consumption per capita is expected as well. Despite those actions, there was an increase of 5% due to the shift to electricity of 50% of the light traffic fleet in the city.

In terms of heat, a reduction of 34% took place. There were severe campaigns for improving insulation in buildings especially for the old ones. This was next to changes in policies and subsidies from the government.

The connection with the CHP AVR-Duiven represented the expansion of the heat network and this gave the chance to have a more robust infrastructure in terms of heat supply. The connection to the district heat network represented a saving in terms of energy due to the efficiency to produce heat by this system.

In terms of fuel, a reduction of 44% was achieved. Diverse actions took place such as promoting the use of low energy consumption means of transportation, (e.g. bicycle or electric bicycles), incentive the switch to electricity as much as possible all means of transportation, (ECOFYS, 2010) It was proposed a shift of 50% of the light traffic fleet vehicles to electricity, this reduced the amount of CO2 emissions, but that will be explained in chapter 8.4. It was important to incentive the use of sustainable public transportation instead of private transportation using fossil fuels. Arnhem was one of the cities in the Netherlands with the highest number of commuters (source CBS?). Therefore, the expansion of the trolleybus system in the north and the south, and the opening of 2 new train stops, one in Arnhemse Broek and another one in Klingelbeek. The industry in Arnhem was not heavy industry, therefore, no demand of extremely high temperature. It was expected a reduction on the fuel consumption due to the efficiency of the technologies used in the industry sector and by the switch to electricity of part of it.

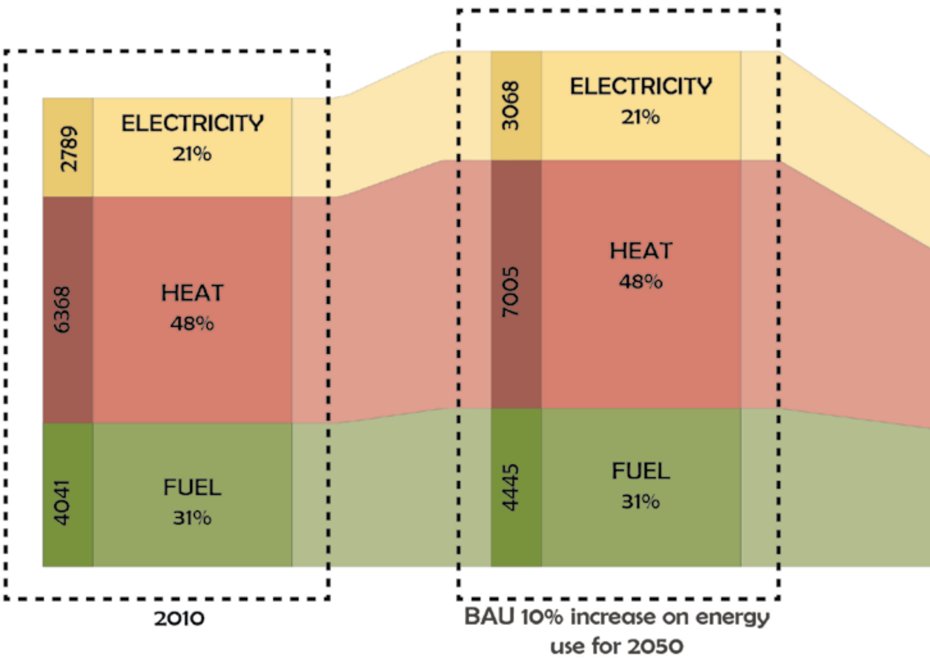
Regarding heat and cold exchange, it happened mainly in the industrial area, for cooling during the warm days that were predicted to happen more often under the BAU scenario.

Energy storage and exchange

A heat and cold exchange with the river took place with the buildings next to the Rhine river, especially those located in the surrounding of the new harbour in Kleefse Waard.
As part of the energy storage as a possible solution for intermittency, 2 possibilities are mentioned, the first one is the use of salt molten tanks in the north part of the municipality next to the solar farms, and the second one is the potential to store energy from the electric vehicles network. It is not analysed and design a proposal in this area, that is not the focus of this vision. The aim is just to mention the chances of potential it has.

Energy generation

In order to achieve the maximum potential for energy generation by renewable sources, different technologies were considered. Four wind parks and several solar farms were implemented. Solar panels and solar collectors were installed at the available roofs of some buildings in Arnhem.
As part of the strategy of the BAU scenario, collaboration with the neighbouring municipalities took place. BAU vision was trying to implement the best technologies in the best locations under the previous analysis of the different layers and the natural and cultural limitations that compose the Municipality of Arnhem. However, the proposal was considering extreme measures under the understanding of the energy demand and the scarcity of other fuels (e.g. oil and gas).
One of the aims of the BAU vision was to create a robust energy system based on renewable sources. This sources



were obtained from the multifunctional landscape designed for Arnhem.

Joining all the previous information from the different steps implemented for this energy transition, a Sankey diagram can be found below. Starting in 2010, followed by the influence of the BAU Scenario and then by the BAU vision, the three differnet energy Carriers (Electricity, Heat and Fuel) were considered. As a conclusion of this diagram, the amount of energy that can be produced for each energy carrier from renewable sources (31%) can be identified.

At the regional scale, different implementattions at the 3 different levels based on the Trias Energetica concept (Lysen, 1996) took place. As a result, an energy vision map was developed (Figure 8.9).
As part of the complete analysis and understanding of the energy possibilities in Arnhem, a subdivision based on the enrgy carrier was made. Three different plans were developed:
1. Electricity Plan (Figure 8.10)
2. Heat plan (Figure 8.11)
3. Transportation plan (Figure 8.12)

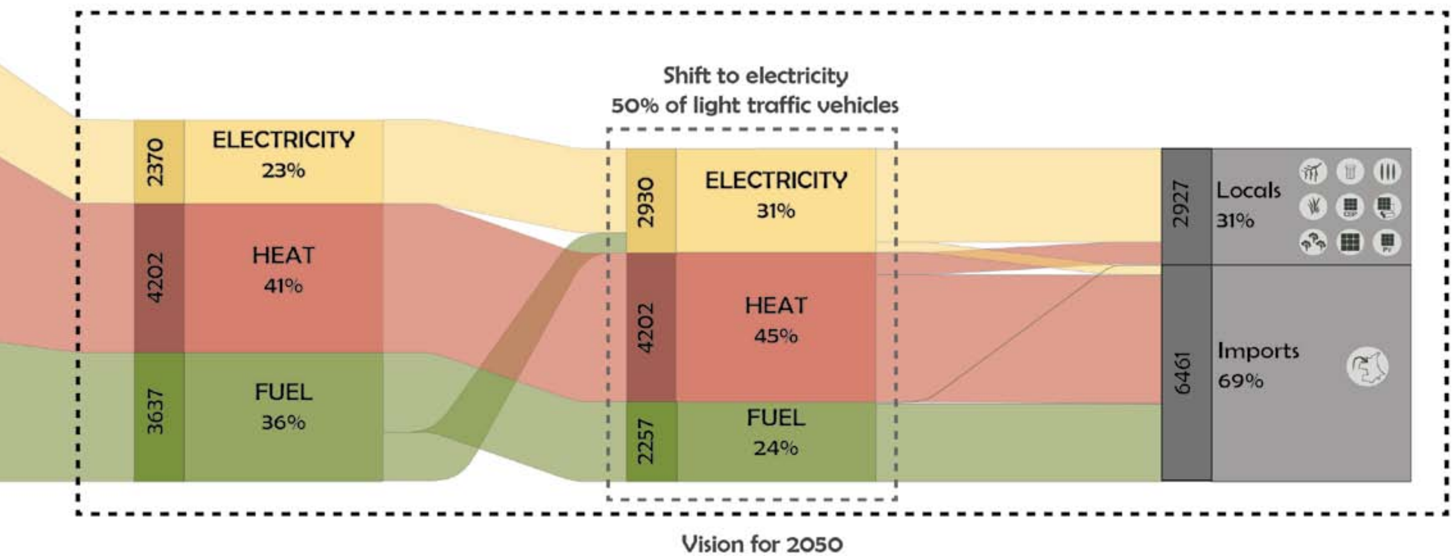


Figure 8.8. Sankey diagram, Flux of energy by energy carrier from 2010 to 2050 on BAU vision

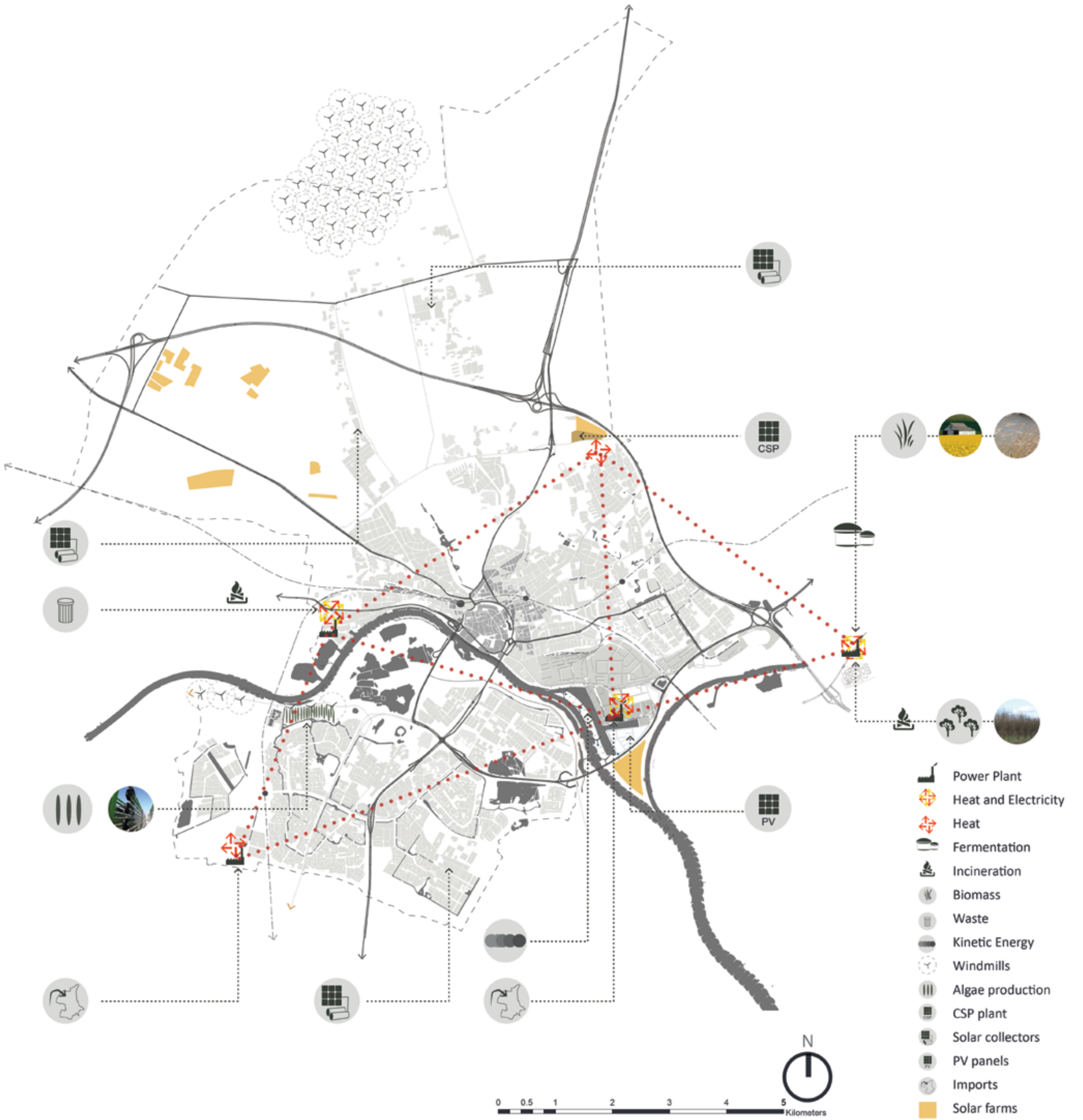


Figure 8.9. Energy vision in BAU vision

Figure 8.10. Electricity strategy plan

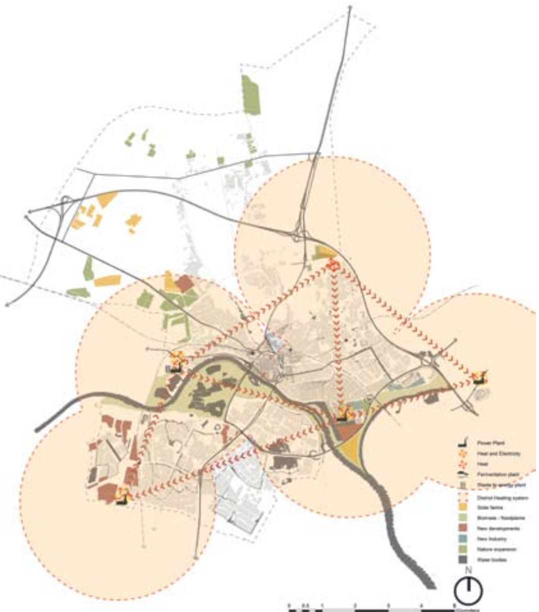


Figure 8.11. Heat strategy plan

Figure 8.12. Transportation / Fuels strategy plan

Solar

Regarding the solar potential, different systems were implemented to produce electricity and heat. In terms of electricity production, solar farms were implemented in some available empty plots in the north of the Municipality. Since agriculture was not one of the main characteristics in Arnhem, some of the agricultural plots were used to settle solar farms . It was taking into consideration the preservation of some empty plots in the nature area located in the north next to the border with the Municipality of Ede. They are protected by Natura 2000 and on this vision this areas were assigned for nature development. In the area next to the Industrial park Kleefse Waard, just at the other side of the road N-325, a solar farm was implemented, considering the multifunctionality of the land, PV panels with elevated structures were proposed to allow the use of the land for other purposes such as grazing or growth of crops with low sunlight demand. The available roofs of the buildings were considered to receive PV system in some neighbourhoods (67 ha). Roofs of historic buildings such as the ones located in the neighbourhoods Centrum, Heijenoord-Lombok and Klingelbeek were not used due to the cultural limitation. In terms of electricity, 1,175.32 TJ/year were produced by solar system. This represents 40% of the total amount of electricity needed in Arnhem in 2050.

In terms of heat, one solar farm was implemented in the neighbourhood of Schaarsbergen, at the south part of the A-12. As mentioned before, the available roofs of some neighbourhoods (33 ha) were used to install solar collectors and provide heat in those places where the heat network cannot reach or is insufficient. In this term, a total amount of 125.29 TJ/year.

In total, solar potential generated 1300.61 TJ/year.

Wind

The location of the wind farms was based on the highest potential due to the analysis of wind speed and the location in terms of distances to residential areas and the availability of the land.

The acceptance of this technology by the people is not part of this thesis, only the design and implementation of it due to the demand of energy by clean and sustainable sources. It was considered that changes in policies has to take place and they took some time. Therefore, the technologies were considered to be implemented in the decades of 2030 and 2040.

Trying to disturb as less as possible the visual impact on the landscape, the windmills selected to be used are (medium size) windmills vestas V112 of 3 MW and 85 m. to the hub. Those were the optimal due to the efficiency and because of the height of them.

The first wind farm was located at the north of the Waste water treatment plant (WWTP) and the Schuytgraaf neighbourhood, parallel to the dyke consisting of 6 windmills. One of them was considered as the update of the one existing in 2010 to pump out the water from the polder area. The second one was located in the dyke protecting the harbour of the industrial area, forming a line of 5 windmills.

There were 2 big wind farms in the north part of Arnhem, in the former military airport. They were next to each other but one was on the municipality of Arnhem, with 20 wind turbines and the other one was located in the Municipality of Ede, with 26. The reason of this location was related to the availability of the land. The military airport is not in use any longer and furthermore it has the required distance to the housing area. The topography of the place allows the windmills to be more efficient without the need of having tall wind turbines.

All together the electricity produced by wind potential sums 1,194 TJ/year that represents 41% of the total amount of electricity consumed in Arnhem in 2050.

Biomass

The potential that Arnhem has in terms of Biomass is important due to the surface of green in the municipality. It was considered the greenest city in the Netherlands. Almost half of the municipality was covered by forest. The area of the floodplains along the Rhine river was important, such as the green structure inside the urban context.
This offers a very diverse kind of biomass. For this analysis there is a division between them (1)Forest, (2)Green maintenance and (3) Energy crops.

As described previously, the available amount of wood is limited to keep the ecosystem and the CO2 emissions in balance. It is considered the total surface of 2,573 ha. The dry biomass ended up in a CHP power plant to generate electricity and heat. By this source 38.98 TJ of energy will be produced, 22.93 of heat and 16.05 of electricity.

From the green maintenance, around 3,140 tons of dry material were harvested, by this source, a total amount of 47.98 TJ were generated, 28.23 of heat and 19.76 of electricity.

Regarding Energy crops, diverse sources took place, depending on the location, the soil and the nature limitations, rapeseed and reed were considered. In the area of the floodplains, reed is the only source considered, as it is an endemic plant that perfectly adapted to the conditions of the site and because it has a good potential to generate energy. Moreover, due to the nature and safety limitations of introducing other species on this protected area. As was explained for this BAU vision, a collaboration with neighbouring municipalities took place, in the case of reed from the floodplains, the collaboration was with the municipality of Renkum, where 32.71 ha were assigned to grow reed for energy generation producing a total amount of 4 TJ of energy, 2.36 of heat and 1.65 of electricity. In the municipality of Arnhem 338.05 ha were used for this purpose producing 41.38 TJ of energy, 24.34 of heat and 17.04 of electricity. As another source of energy crops, rapeseed was considered, the area in the north assigned for the wind parks had the optimal characteristics soil composition and groundwater level. With the idea of having a multifunctional landscape, this 2 different options (windfarm and rapeseed growth) were consider for this area. The energy crops were not highly fertilized, considering to reduce the inputs.
Using the same idea of collaboration, and with the same division as in the wind farm, a collaboration with the municipality in Ede took place. In Ede 266.71 ha were used and a total amount of 24.48 TJ of energy were generated and in Arnhem 188.33ha were used with a total amount of 17.29 TJ of energy generation.
Again, as a collaborative project, the fermentation and incineration plants were located with an improvement in the AVR Duiven site in the municipality of Duiven. In the CHP power plant, electricity and heat were generated and it was connected to the district heat network to supply the heat to the surrounding area.
As a final result from biomass in this vision, 172.47 TJ of energy were produced.

Algae

An algae park was proposed on this vision since it was consider to be one of the most promising sources for bio-fuels. The location next to the Waste water treatment plant (WWTP) in the south of the Rhine river offers the optimal characteristics of: accessibility and the proximity to the main sources needed to grow algae (water from the rhine river, nutrients from the WWTP and CO2 from the Schuytgraaf heat power plant). Open pond system was the one selected because is the one that best fits the weather conditions in Arnhem.
22 ha of land were used to produce algae that was used to generate 15.78 TJ of biogas, used in the industry sector.

Waste

It was predicted that waste will be almost not existent considering that everything will be recycled at some point. In the meantime, it was consider as another source for energy generation. In 2010 60% of the waste was able to be used as source, from this,15% as GFT (fruit, vegetable and garden) and 45% as other kind of waste that can be burned. For this purpose, a waste to energy plant was proposed to be located in the Klingelbeek neighbourhood. This plant burned the normal waste, the GFT was sent to AVR Duiven to be fermented. This plant was connected to the district heat network to supple heat to the surrounding area. In general from waste, 240.96 TJ of energy were generated. It was considered that when the waste is no longer enough due to the trends of recycling, these infrastructure can be used to another purpose to generate energy and maintain the supply to the area (e.g. CHP power plant)

Schuytgraaf plant

The heat power plant located in Schuytgraaf was kept as it was, running from bio-fuels, but it was not an auxiliary plant anymore, it was consider as one of the power plants from the whole district heat network.

CHP De Kleef

This plant was adapted to generate the necessary energy demanded from the surroundings that can be supplied efficiently without any losses (e.g. heat) there was a reduction on the energy generation when compared to 2010, but now that it is connected to other power plants like AVR Duiven the idea of a more balanced and decentralized infrastructure was proposed. It produced a total amount of 400TJ of heat and 280 TJ of electricity.

In the next page an energy Sankey diagram express how the energy flows on this vision depending on the energy carrier and the source. (Figure 8.13)

Energy systems

Considering the small potential for energy generation inside the borders of Arnhem, hybrid systems where created. They are composed by variable sources and aim to supply areas which are not connected with the heat district network besides to improve the existent systems. All the systems are interconnected by the landscape.

A diverse and decentralised energy system was proposed, considering the potential to produce energy inside the boundaries of the municipality and even with the collaboration with other municipalities. The concept of a robust system running by different sources and all of them interconnected took place. In terms of electricity, the energy is generated and it goes to the electrical grid to be supplied later. In terms of heat, this will be generated in a CHP or Heat power plant and distributed by the district heat network, unless it is out of the reachable area and the heat can be provided by individual systems, either solar collectors or heating systems using electricity or gas, as it was in 2010.
Diverse diagrams explaining the Energy systems were proposed in the coming pages.

1. General energy system diagram (Figure 8.14)
2. Energy systems 1 & 2 (Figure 8.15)
3. Energy systems 3 & 4 (Figure 8.16)

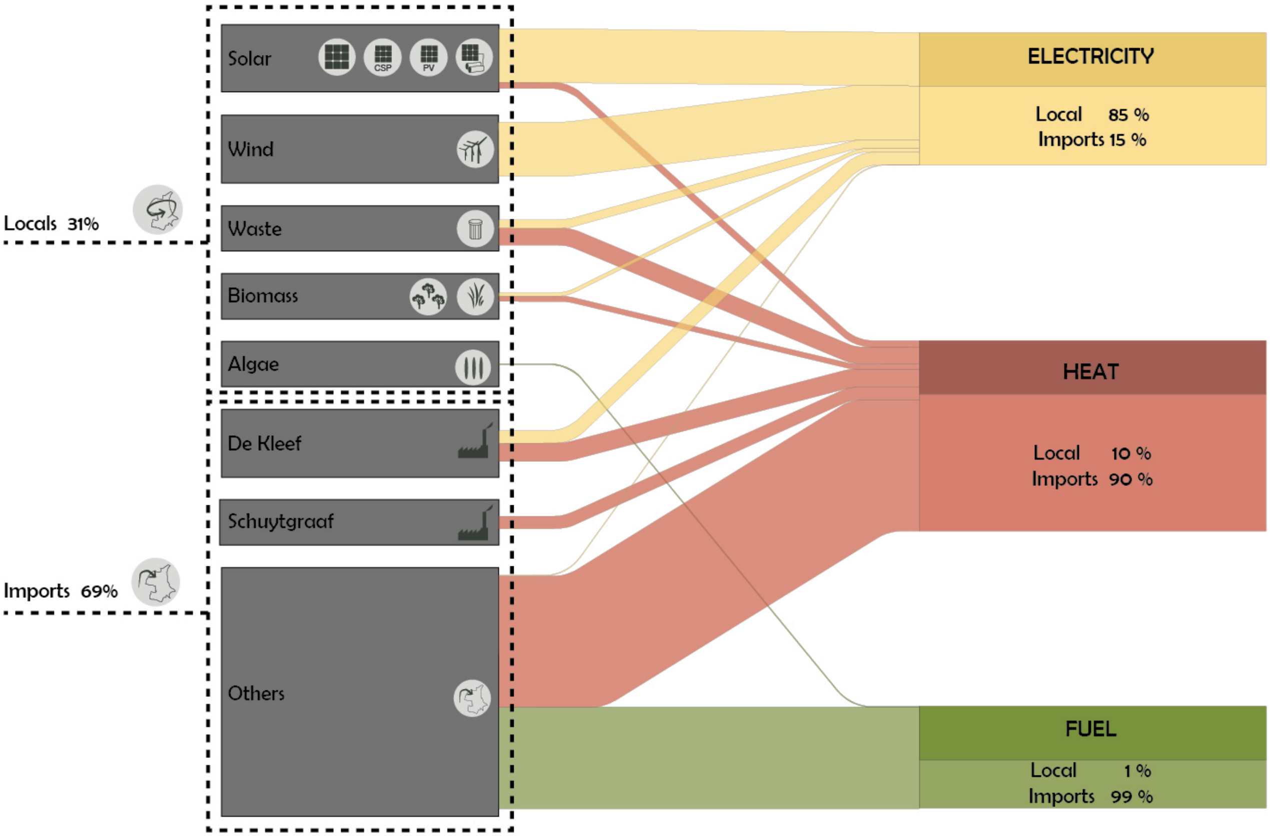


Figure 8.13. Sankey diagram, Distribution of local and imported sources and the final energy carrier

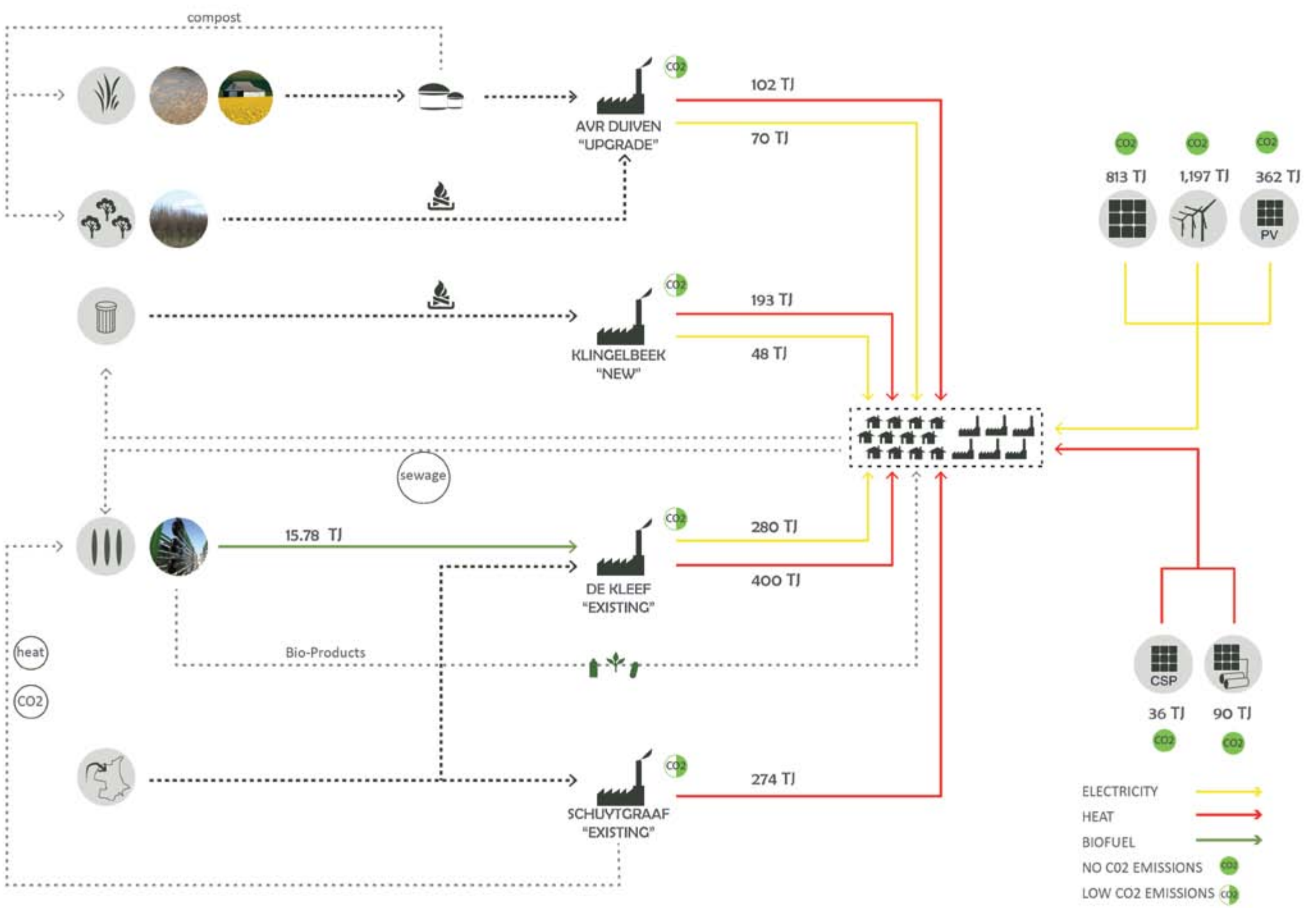
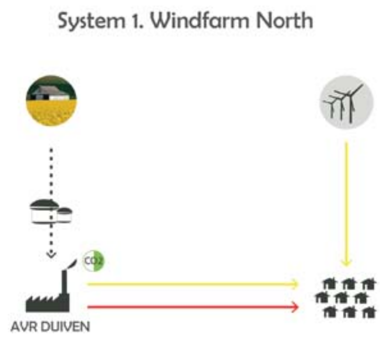


Figure 8.14. Diagram of the general energy system



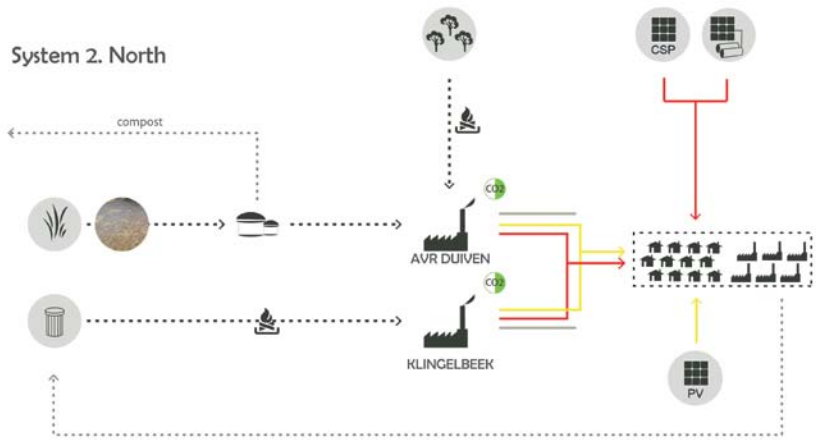
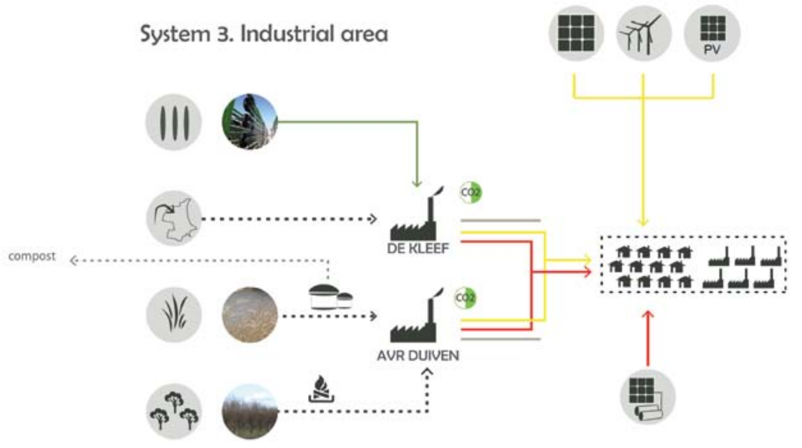


Figure 8.15. Energy diagrams of systems 1 & 2



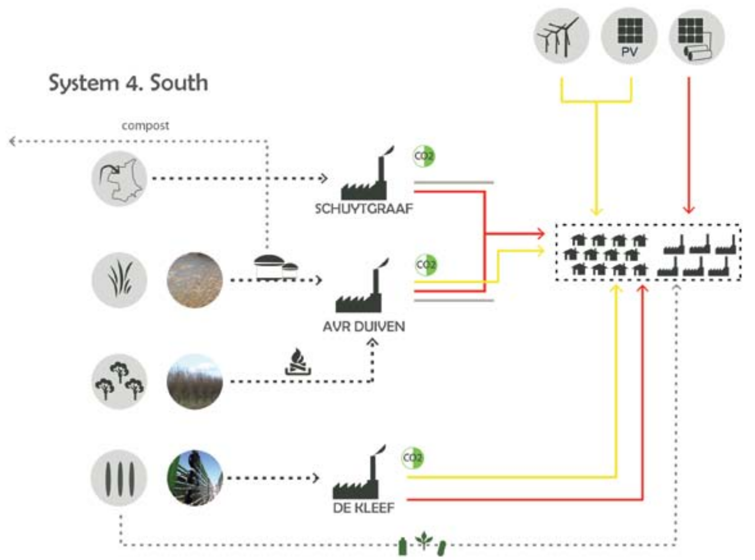


Figure 8.16. Energy diagrams of systems 3 & 4

8.3 Phasing of implementation

First Decade (2012-2020)

As Lysen (1996) proposed on the Trias Energetica concept, one of the most important points on the energy transition is the saving of energy or the reduction in the consumption. This was the first step to be implemented and was during this decade when most of the interventions in terms of savings took place. Strong campaigns followed by incentives and subsidies took place in order to reduce the energy consumption. For instance, by improving the insulation of buildings, especially the old ones in the old city centre. The expansion of the heat network and the connection of it with the existing one in Duiven and Westerpoort took place during this decade.

In terms of land use, an impulse to regenerate and improve the city centre in the south part (Arnhem Zuid) received special attention, but the connection between both city centres, North and South. In relation with nature, an expansion starts to take place especially in the northern part of the municipality.

Most of the near future development projects took place during this decade.

It is important to mention that in this decade begin all the negotiations, campaigns and policy changes for the energy transition implementation in the further decades.

Second decade (2020-2030)

During this decade, the next step for energy generation by renewable sources took place. This is the first of the 2 decades where the big implementations for energy generation occur, starting with the implementation of the waste incineration plant in Klingelbeek and its connection to the district heat network. The re-adaptation of the AVR Duiven to incineration and fermentation plants for biomass and the re-adaptation of CHP de Kleef to the new values and state of the art technologies.

The first wind farms will be implemented, those along the Rhine river, in both locations, the Kleefse Waard and the one next to the waste water treatment plant (WWTP). Concerning transportation, the shift to electric vehicles (EV's) took place and the infrastructure for them in the urban context appeared for the first time in different parts of the city.

In terms of land use, the development of the area around the harbour in Kleefse Waard starts taking place, by reconstructing the harbour, and also new industries appear in the industrial area. The nature expansion continues in the north and in the floodplains.

Third decade (2030-2040)

On this decade it was expected that technologies would become more efficient and affordable. Under this idea, the implementation of other technologies took place. The algae park with open race ponds appears next to the WWTP in the south. The third windfarm, the one located inside the municipality borders in the north part, took place. The rapeseed growth in the same area as well as the wind farm was implemented in order to turn into a multifunctional landscape. Concerning solar technologies, the first solar farms arise, those located in the empty plots in the north part and the one located in the Ijssel kop, next to the Kleefse Waard.

In terms of transportation, during this decade a strong impulse for the expansion of the trolleybus system took place. The expansion of the infrastructure for EV's continued as there were more vehicles running by this source.

Regarding land use, the new developments for housing and business in the Kleefse Waard developed.

Fourth decade (2040-2050)

During this decade, most of the technologies within the boundaries of the municipality were implemented. The fourth wind farm located in the municipality of Ede was implemented in this period due to the policy and economic reasons. As in the third wind farm, the growth of rapeseed as a source of biomass will be implemented. The last stage in terms of solar systems, and expecting that the technologies were affordable for almost everyone, the use of available roofs for PV panels or solar collectors took place. The renovation of the first two wind farms occur in this period.
In terms of transportation, the full expansion of the trolley bus system was developed, also the implementation of 2 new train stops and the continued growth of the EV's system.

	2010	2020	2030	2040 – 2050
ENERGY	INSULATION BUILDINGS SAVING CAMPAIGNS EXPANSION HEAT NETWORK	BIOMASS FERMENTATION PLANT BIOMASS INCINERATION PLANT WASTE INCINERATION PLANT WINDMILLS SOUTH OF RHINE WINDMILLS INDUSTRIAL AREA CHARGING STATIONS FOR EV's UPDATE OF DE KLEEF CHP PLANT	ALGAE PARK WIND FARM NORTH ARNHEM RAPE SEED CROPS NORTH ARNHEM SOLAR FARM KLEEFSE WAARD SOLAR FARMS OPEN LAND SOLAR THERMAL POWER PLANT CHARGING STATIONS FOR EV's	WIND FARM EDE RENOVATION WINDMILLS RHINE AND INDUSTRIAL AREA SOLAR SYSTEMS IN ROOFS RAPE SEED CROPS EDE
OTHERS	RESTRUCTURE OF 2 CITY CENTRES CONNECTING CITY CENTRES NATURE EXPANSION	RESIDENTIAL AREA EXPANSION KLEEFSE WAARD HARBOUR KLEEFSE WAARD INDUSTRY EXPANSION NATURE EXPANSION SWITCH TO ELECTRIC VEHICLES	SWITCH TO ELECTRIC VEHICLES KLEEFSE WAARD NEW DEVELOPMENTS KLEEFSE WAARD INDUSTRY EXPANSION EXPANSION OF TROLLEYBUS SYSTEM	BUILT OF 2 NEW TRAIN STOPS EXPANSION OF TROLLEYBUS SYSTEM

Figure 8.17. Timeline of the phasing of implementation of inteventions

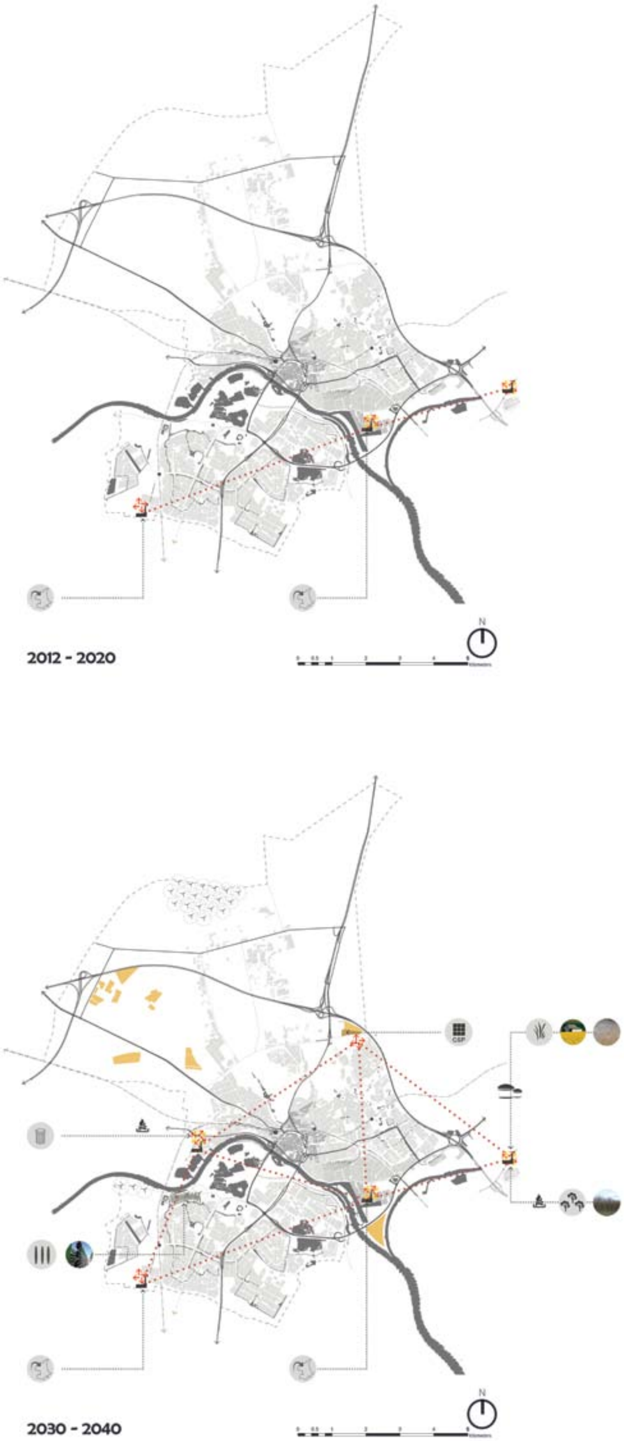


Figure 8.18. Plans of phasing of implementation from 2012 to 2050

8.4 Contribution to CO2 neutrality

In comparison to 2010 the reduction of CO2 emissions in 2050 is about 57% (Figure 8.19).

The most relevant reduction was related to the electricity generation (-83%) due to important implementations of CO2 neutral technologies, like Wind turbines and Solar panels. Even though the increase of the consumption due to the shift to EV's

The lowest reduction was in heat(-30%). That is because still 90% of it was generated from imported sources.

In terms of fuel, there was a relevant reduction (-45%) in the emissions but that is due to the shift to the EV's rather than to the generation of the fuel.

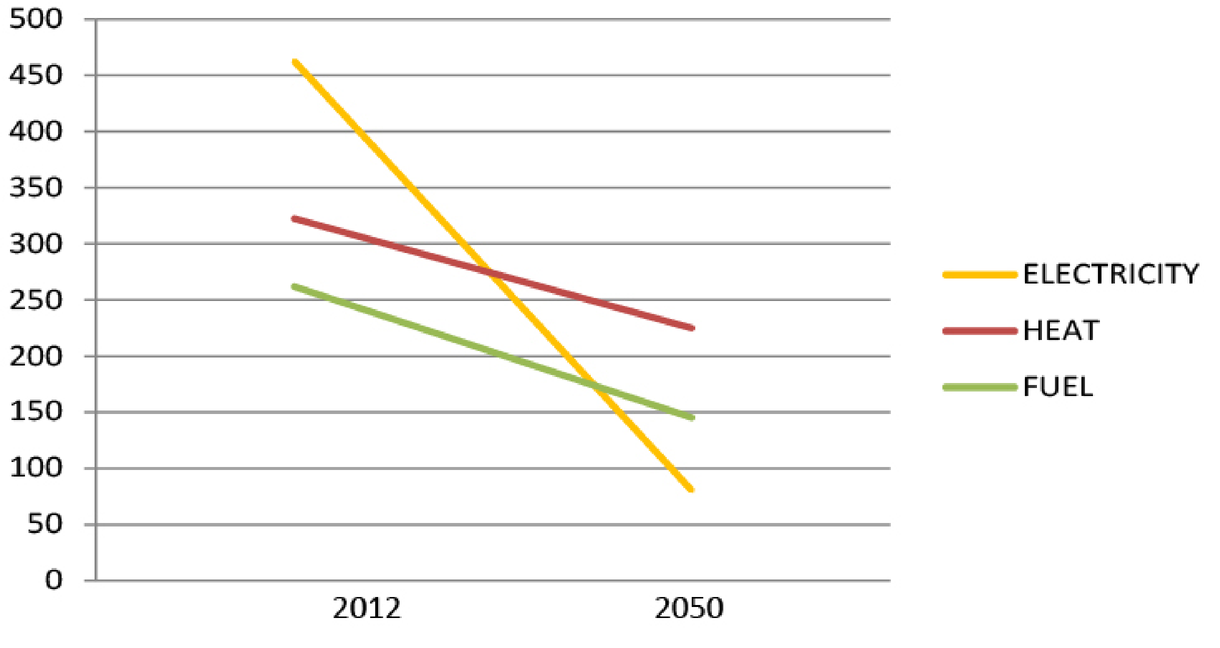


Figure 8.19. Graph showing the CO2 reduction by energy carrier from 2012 to 2050

8.5 Conclusion of energy vision

As a conclusion under the BAU vision, I realized how important it was to achieve the main goal of this thesis, to have a strategic energy vision master plan. Different aspects and areas of expertise have to work correlated.

Regarding the energy in Arnhem, possibilities were found inside and outside the boundaries. Besides, Arnhem cannot provide the total amount of energy sources to become self sustainable, based on the energy consumption levels of the BAU vision. Therefore it was important to advocate for a robust energy system.

The technologies implemented in this proposal show the possibilities that Arnhem has to have a sustainable energy landscape. The impact of the interventions implemented was considered when choosing the technologies to be used. This will be more notorious when the wind turbines appear for the first time in the landscape of Arnhem in the decade of 2020 – 2030.

Diverse interventions were implemented comprising all the different districts in the municipality. Was taking into account the cultural and natural limitations, but as well the urgent demand to implement new technologies to generate the energy. The most relevant limitations were found in the nature areas and in the historical buildings basically in the old city centre.

To create a robust energy infrastructure, transcending boundaries is important, by the connection to different robust systems at different scales.

8.6 Site selection + Landscape Analysis

The selected site is located in the east of Arnhem in the area known as Kleefse Waard & Koningspleij Noord and between the Rhine and Ijssel river on the area known as Ijsselkop . It is located on the right border next to Duiven municipality, divided by the Ijssel river. Different conditions and characteristics make this area a special place with a lot of potential in terms of development and energy generation. According to the BAU vision, this location is a good place to be developed (Figure 8.20). In order to have a clear understanding of the characteristics of the place, the layer approach (abiotic, biotic and anthropogenic) will be analysed and described below.

Abiotic

Regarding this layer, the ground water level was considered when making the proposal, especially in the areas Ijsselkop and Koningpleij Noord, the elevation is not high when compared to the water level.

Biotic

The green and blue structure had an important role in this proposal due to the total surface they have in relation with the site.
The green structure was composed by the floodplains who embrace and protect the industrial area of Kleefse Waard, and the dyke that shelters the harbour area. The area known as Ijsselkop, is located in the division point of the Rhine and Ijseel river. In this area, the only agricultural land was found. This area was surrounded by a dyke due to the low elevation when compared to the limits of safety against the floods. In the same way, an urban green structure existed, but was not relevant.

Regarding the blue structure, and as mentioned before, the Ijssel and Rhine rivers embrace the area. Besides, the harbour that had access through the Rhine river was composed by a main and a small lateral canal. The latter was blocked in 2012. The main canal was used for the industrial boats and for the freight traffic; also to provide shelter to the touristic boats during the winter season

Anthropogenic

Regarding this layer, it is relevant to mention that the area was only used for industrial purposes. Companies related to the sustainability and energetic sector settled their headquarters there. The CHP de Kleef was also in this area, generating heat and electricity and supplying the heat by the district heat network to the surroundings. The place was not completely occupied by 2012.
The location was optimal for the industrial purposes due to its accessibility by different means of transportation: by boat from the Rhine river, by train due to the expansion of the railway to reach the area, and by road traffic, due to its proximity with the N-325 that runs on this area at the edge of the municipality from NE to SW.

Figure 8.20. Site location "Kleefse Waard, Koningpleijn-Noord and Ijsselkop"(Google earth)

8.7 Design proposal

Under the idea of a long term vision and a gradual transformation in Arnhem for an energy transition, a proposal took place on the site selected. The site, as explained before, was the one that best fits the BAU vision: to develop and express the possibilities that Arnhem has in terms of energy. Other elements which were considered relevant for the city were its growth and expansion, and its effect on the landscape and spatial planning.

Regarding energy and following the concept of trias energetica by Lysen (1996), the three strategies were considered. The first one, which refers to saving measures, was considered on those constructions built before 2012. The second one, referring to the consumption of energy produced by renewable sources, took place on those constructions that were built after 2012. Technologies were implemented to generate energy in the area. Last but not least, the third strategy says that the use of fossil fuels should be as clean and efficient as possible. This concept was extremely important; Arnhem itself is not able to generate 100% of the energy necessary (and) from renewable sources. Imports in relation with energy still occurred, but the efficiency of the way we used it was extremely important.

With the aim to develop a multifunctional place in which housing, business, industry, recreation, nature and especially in this case, energy saving and generation took place. Inspired from projects from all around the world, such as the industrial harbours of Puerto Madero in Buenos Aires, in Argentina (Figure 8.21) and the Old Harbour in Hamburg (Figure 8.22), where the multifunctional land use and public spaces co-exist. Moreover, with the aim of recovering the public space used for transportation, and inspired by projects like the City Dune in Copenhagen (Figure 8.23) by SLA Architects or the Arnhem Centraal Train station (Figure 8.24) by UNStudio, different functions and means of transportation were overlapped in a layer system Following the idea of the municipality, therefore to improve the waterfronts by improving the connection between the water and the river, some cases were considered as inspiration; for instance, the one proposed for the Rijnboog area that was already been explained in **Chapter 5** Near future developments**.**

Finally and regarding transportation, different concepts have to be followed in order to generate a good strategy that connects the place by diverse means of transportation. Following the Trias energetica concept, a system should be implementedwith the following steps: (1) low demand of energy, (2) use of renewables as the main source of energy, (3) and when is not possible the use in the most clean and efficient way of energy from fossil fuels.

Reference cases


Figure 8.21. Puerto Madero, Buenos Aires, Argentina (Latido Buenos Alres)


Figure 8.22. Hafencity, Hamburg, Germany(MIMOA)


Figure 8.23. "The city dune"Copenhagen, Denmark (SLA)


Figure 8.24. Arnhem Centraal, The Netherlands (UN Studio)

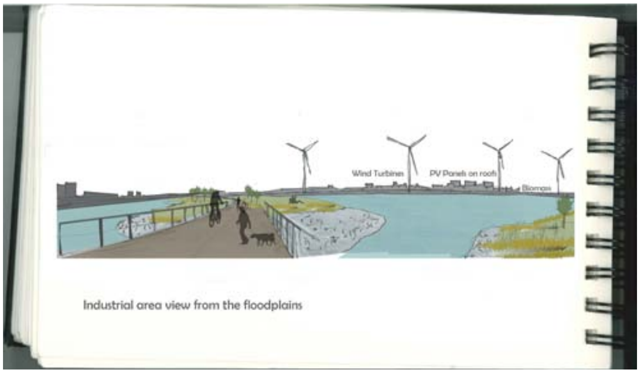


Figure 8.25. View of industrial area from the south part of Arnhem

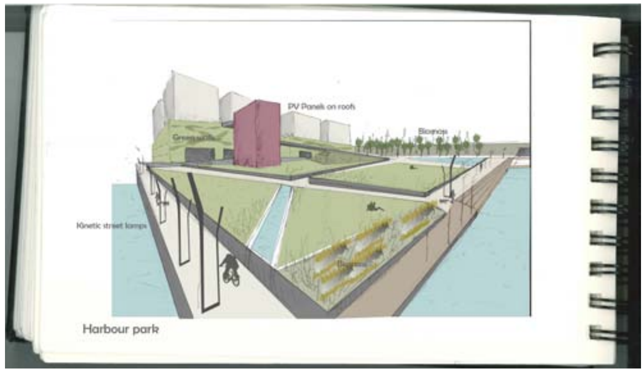


Figure 8.26. View of the Waterfront Park

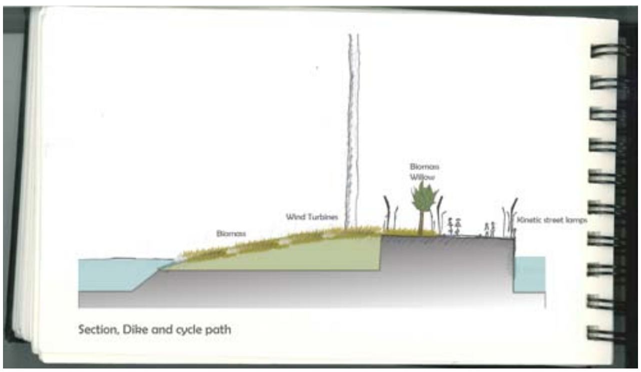


Figure 8.27. Section of the dike and the new boulevard

Figure 8.28. Solar farm, biomass growth and wind turbines at the back

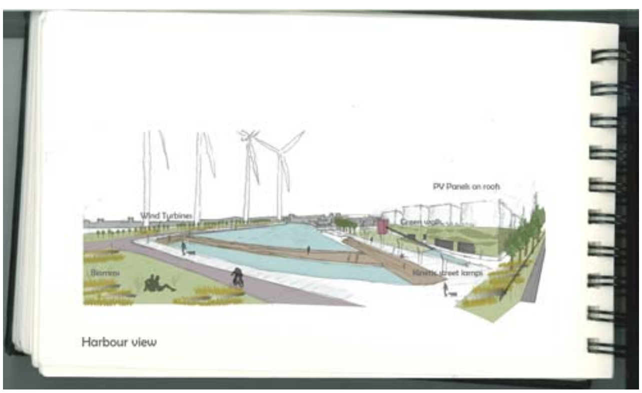


Figure 8.29. Harbour area from the road N-325

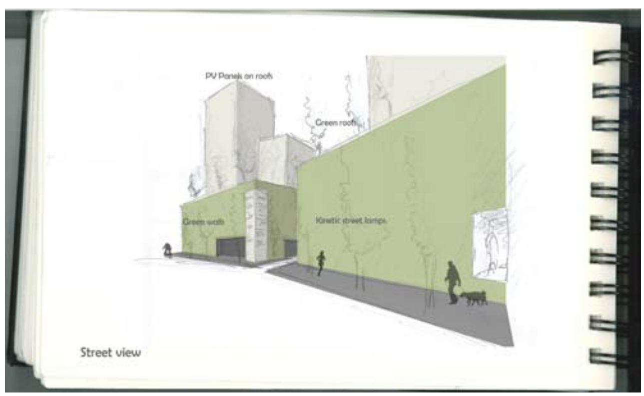


Figure 8.30. New developments on the Koningspleijn -Noord

Describing the proposal for the selected site requires a brief introduction that needs to be done in general terms in order to later on get introduced to the energy topic.
Based on the BAU vision and the design principles and concepts, a proposal comes up. (Figures 8.25 to 8.30) The proposal consisted on the development of the area by combining land uses: industry, commercial, residential and nature. This mixed use had the purpose to provide a more diverse and dynamic environment to the area. For its development, according to the BAU vision and compared to the BAU scenario (Figure 8.31), the land use with the highest presence is the industry. It was originally the only function of the area. It was located in the area developed but not fully occupied in 2012 known as Kleefse Waard.
The next land use in order of importance is nature. The area of the floodplains was considered suitable for nature development, the material dump area was converted to provide space to nature development as well, and a reinforcement in the green structure on the urban context took place. A park was proposed in the Koningpleijn Noord area, next to the harbour and to the new developments, providing space for leisure and recreation that was one of the new functions introduced for nature under the BAU vision. Different energy crops were conforming the design of the landscape of the park as a way to make people aware of them.
On this proposal, one of the most relevant concepts was that nature would be accessible for the citizens; people can be part of it. Not only for recreational purposes, but also for being aware and being in contact with all the different systems and sources to generate energy. That will be explained below:

The third land use is business; under the BAU vision this was predicted to grow fast and Arnhem was not an exemption. Part of the new companies and business to be settled in Arnhem were proposed to be settled here. A development made in the area of Koningpleij Noord, (next to the park proposed) and in combination with the residential land use, make this area a dynamic place
As mentioned before, regarding the residential land use, this was settled in the same area as the business sector.
This development was designed by taking into consideration the most efficient or suitable orientation to receive the sunlight in the interior of the buildings, as well as to receive the technologies with solar potential. Another characteristic of this development was the interior patios, providing shelter from the noise of the urban context, an improving the quality of the public space

Regarding the harbour area, it was decided to integrate the lateral canal to the main one, giving space to store more boats since the population of the area was predicted to increase. Private and commercial boats were able to be there, and there was also considered an area for some floating houses. Mention something about the expansion of the harbour, that will host more boats, possibly floating houses, the new harbour also provides a promenade next to the river, that will be used as a cycle path, that permits the access to the wind turbines.
For the understanding of the differnet actions to be doneand where they has to be done, an analysis at different layers was made. (Figures 8.32 to 8.37)

Energy saving

In terms of energy saving, different measures has been proposed (Figure 8.36). Those buildings existing before 2012 received special attention to achieve certain energy saving standards. The rest of the constructions built after that period were constructed under the highest standards

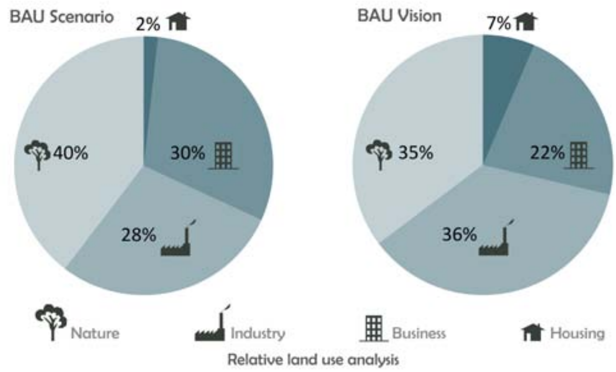


Figure 8.31. Comparative of relative land use BAU Scenario and BAU Vision

Figure 8.32. Green & blue structure

Figure 8.33. Road infra-structure

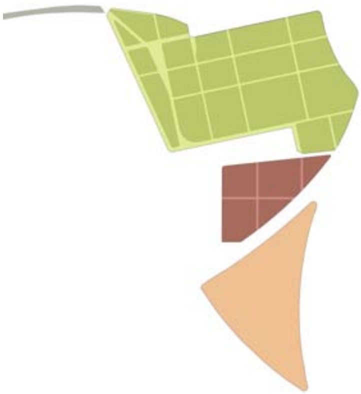


Figure 8.34. Land use

Figure 8.35. Built area

Figure 8.36. Energy saving

Figure 8.37. Energy generation

Layer approach BAU vision plans

for energy saving. As a general intervention, it was decided 30% of the roofs were to be covered with green roofs. This system was implemented due to its efficiency for insulation, especially during warm periods, that reduced the cooling demand. In the same way, 50% of the facades were decided to be covered by green walls. Besides, different benefits can be achieved using this systems: (1) capture particles in the atmosphere (2) reduce the noise and air pollution, (3) help mitigating the Urban Heat Island Effect (UHI) (4) provide a new way of advertisement and (5) improve the quality of the urban landscape.
In terms of transportation, diverse means of sustainable transportation were implemented. An expansion of the trolleybus line reaching this area, the proximity with the new train stop in Arnhemse Broek and the new cycle path through the dyke reducing the distance with the city took place. Moreover, as the trend under the BAU vision is the shift to electric vehicles (EV's), load poles were considered as part of the infrastructure to be provided.

Energy storage

In terms of energy storage, as in the proposal at the regional scale, the possibilities were considered but not developed. Opportunities of storing energy in combination with electric vehicles were the only ones considered in this area.
Regarding heat and cold exchange with the river, the system was proposed to be implemented on the buildings surrounding the river and/or canal.

Energy generation.

Concerning energy generation, several sources were considered to be used to generate energy. (Figure 8.37)

Wind

5 medium size wind turbines of 3(MW) were considered. As described before in the sub-chapter 8.2 energy vision, they were located in the dyke that protects the harbour forming a line.At a small scale, independent systems like kinetic lamps were implemented runned by wind. These lamps were also located in the dyke, illuminating the cycle path.

Solar

Regarding solar potential, 70% of the roofs of the area were used to install PV panels to generate electricity (the other 30% are green roofs as described before). A solar farm in the former agricultural land, known as Ijsselkop was considered. This system has an elevated structure to allow other functions to happen below, such as grazing or growing crops with low demand of sunlight. This structure is also considering the low elevation of the area compared to the safety limit against flooding. it was surrounded by a dyke that keeps the place safe but also has a road for diverse activities like cycling or running. It also allows to have access by car, to give maintenance to the solar panels.

Biomass

Concerning biomass, the floodplains were considered the main source, providing mainly reed and some willow trees, but in a small scale. In the same way, biomass from the green maintenance was considered.
As mentioned before, a mixture of different energy crops was implemented on the design of the park, for getting people in contact with the energy transition. As explained previously, the new function of recreation was added to nature areas.

Kleefse Waard

As mentioned before, the CHP was adjusted to the heat demand of the area. This was by considering that the new buildings were constructed under strict energetic standards . Besides the expansion of the system after the connection with the AVR Duiven CHP power plant.

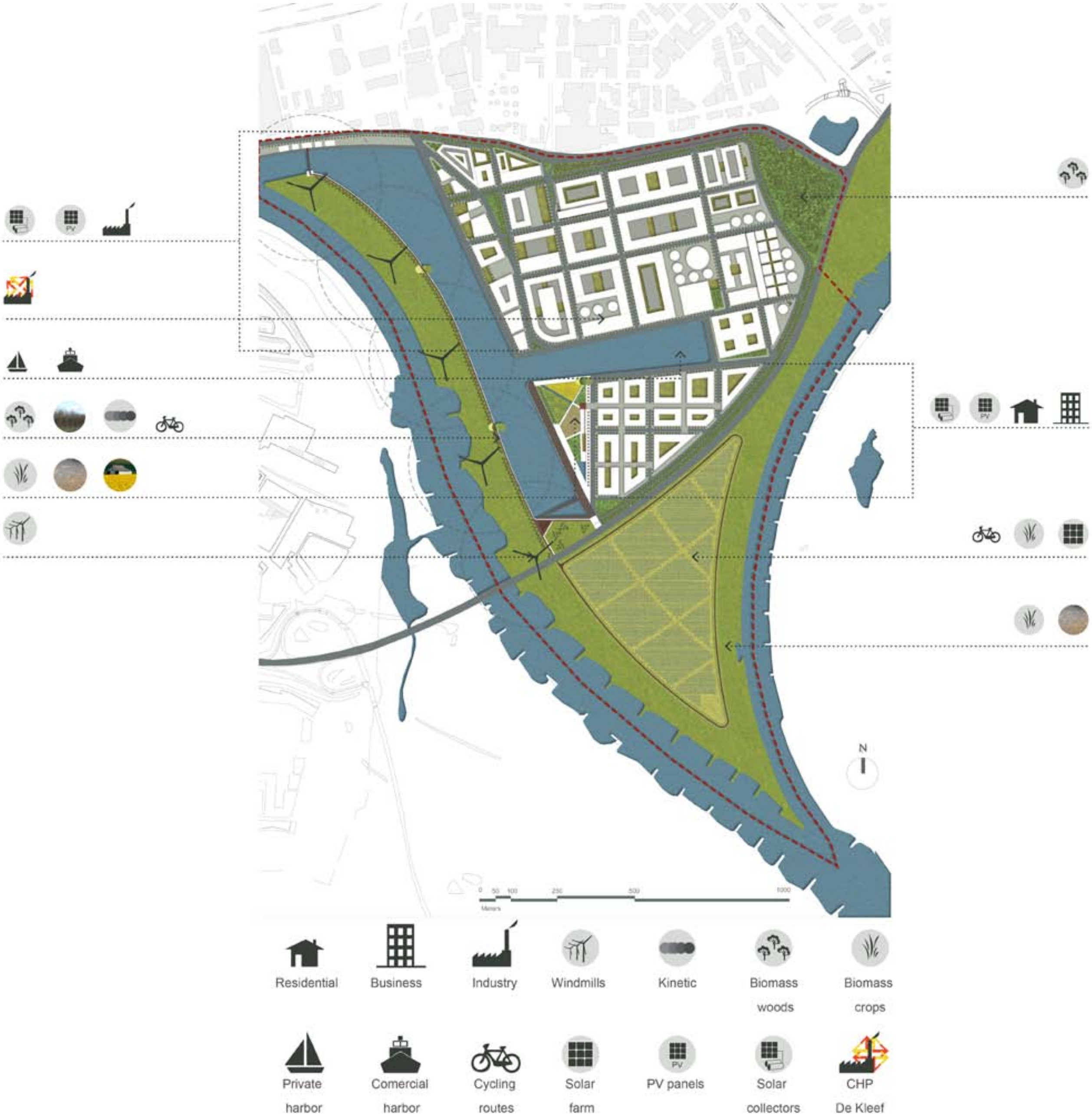


Figure 8.38. Master Plan, "Kleefse Waard, Koningspleij Noord and Ijselkoop" .

Figure 8.39. Electricty

Figure 8.40. Heat

Figure 8.41. Transportation / Fuel

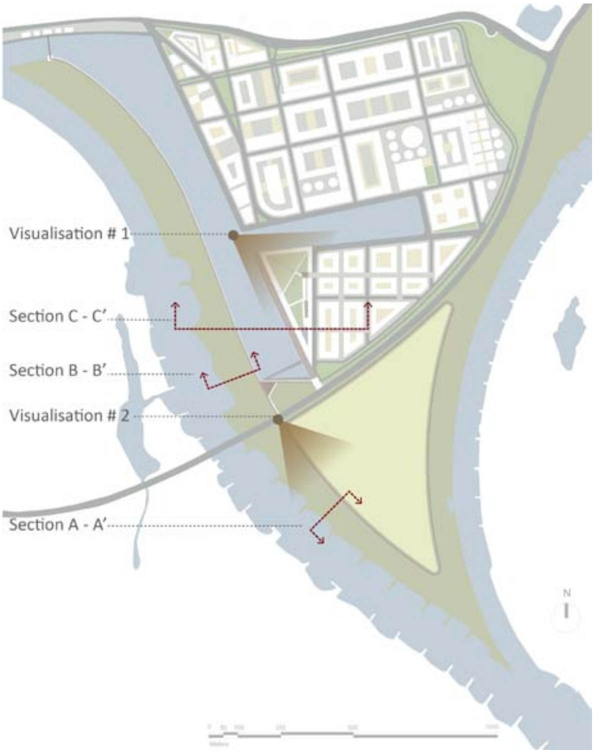
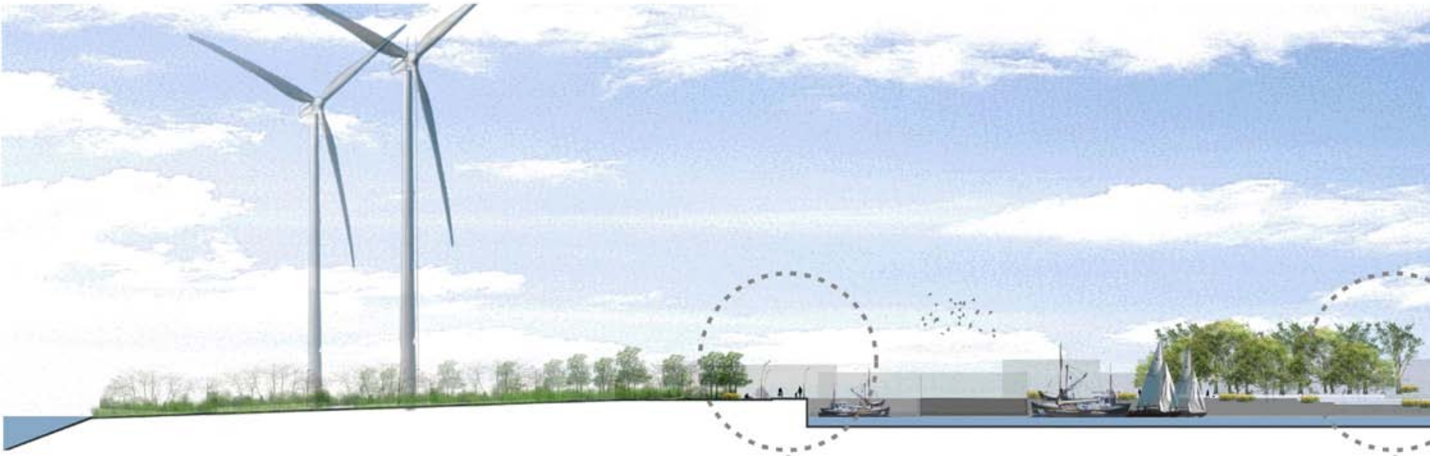
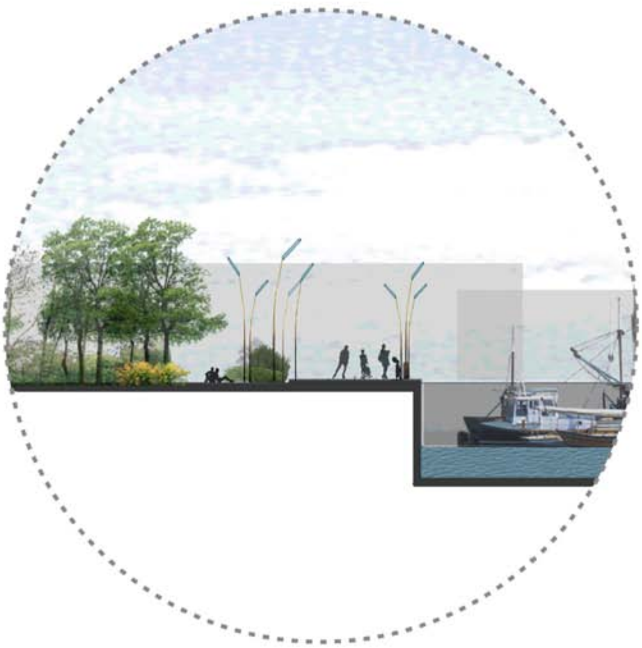


Figure 8.42. Map locating sections and visualisations

Figure 8.44. Section A - A', Multifunctional landscape in Ijsselkop, solar farm, protective dike, cycling route, nature, recreation and biomass growth.

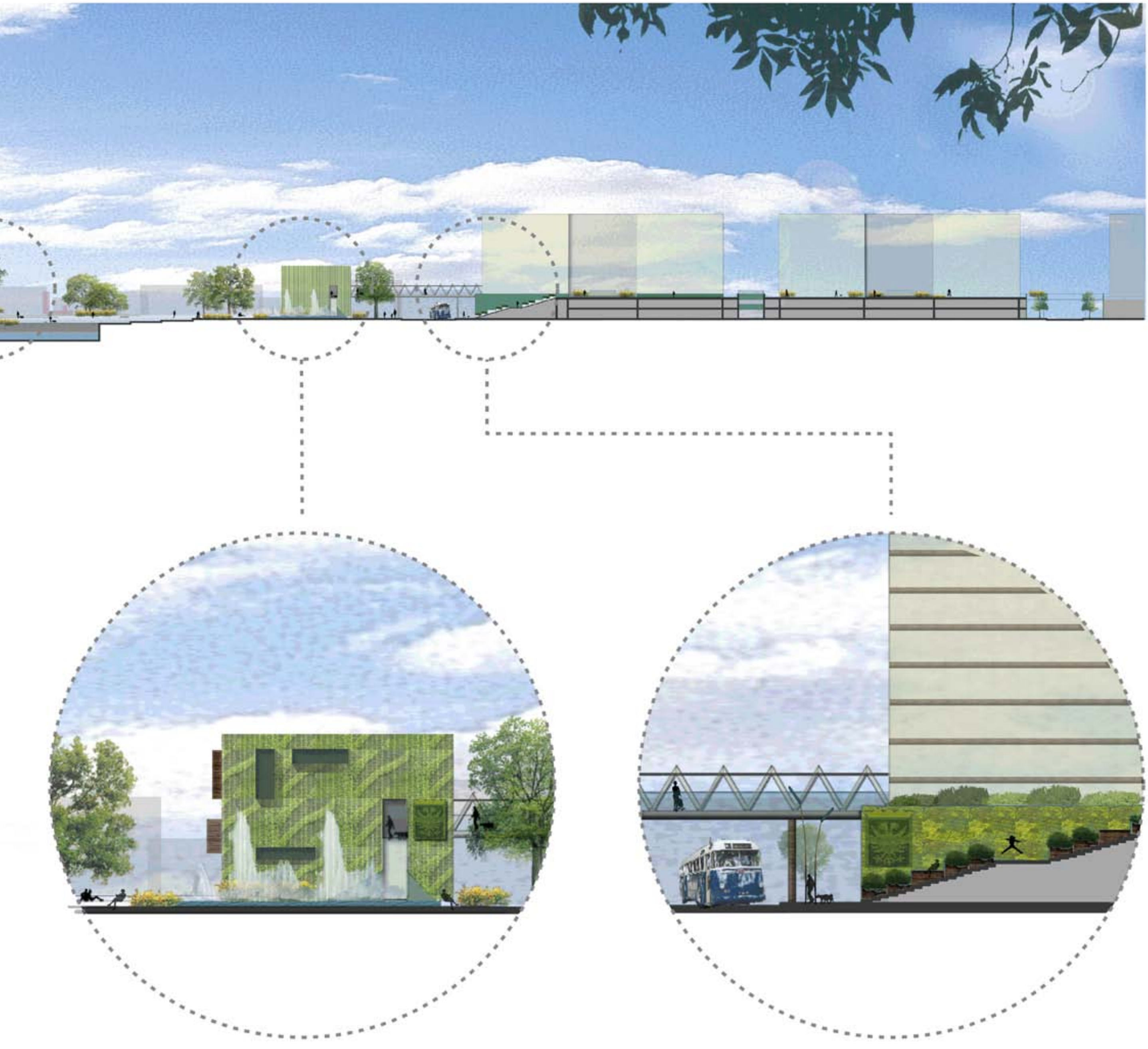
Figure 8.43. Section B - B', Dyke protecting the harbour and giving space for biomass growth, wind turbines and other functions like cyclying routes.





Boulevard, cycling and pedestrian route and biomass growth in the dike

Waterfront park - terraces and outdoor facilities



Commercial and recreational areas

Trolley bus system, and pedestrian infrastructure

Figure 8.45. Section C - C', Diverse functions through the landscape of the harbour area and the waterfront park in "Kleefse Waard"

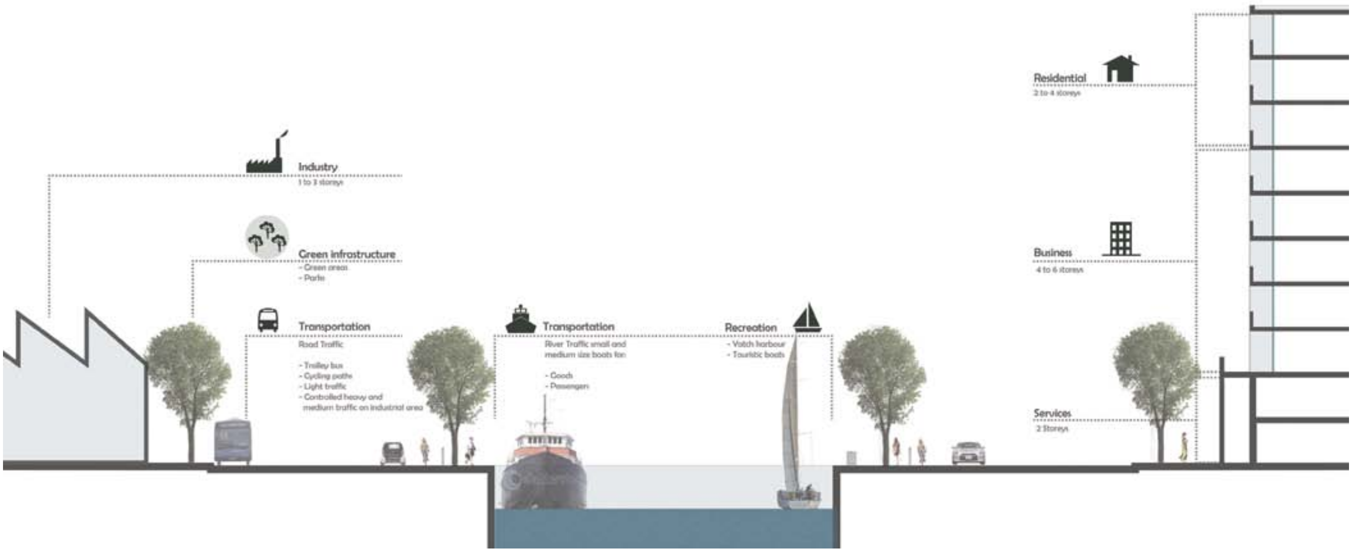


Figure 8.46. Cross section Harbour area

Figure 8.47. Aerial view of the area in 2050 (Flickr : Picture by Siebe Swart)

Figure 8.48. Waterfront Park in Koningpleijn-Noord in Arnhem

Figure 8.49. Solar farm, cycling route and floodplains at the Ijjselkop

8.8 Conclusion of design proposal

The design proposal was based on the desired future for the BAU vision, with the aim of the energy transition and the reduction of CO2 emissions. This goals were visibly considered on the intervention proposed.

In the design proposal, energy saving and energy generation were 2 of the main steps considered. In terms of saving, due to the fact that this area was almost empty for 2012, all the new developments were built under strict measures to achieve this goal. Besides, other interventions were implemented like the green walls and green roofs providing as well nature elements in the urban context. The technologies implemented for the energy generation were integrated as part of the design of the multifunctional landscape. People would be in contact with them to be able to understand the meaning and function of the energy transition. The main sources that were considered to be used in this area are solar, wind and biomass from the floodplains and the heat and cold exchange with the river. Some of these technologies were possible to be implemented here due to the available land and open space for these technologies to work efficiently. For example wind turbines, were possible to be implemented here due to the minimum required distance to the housing areas.

Regarding the 80 % CO2 reduction for 2050, this area (Kleefse Waard, Koningspleij-Noord and Ijsselkop), collaborate on this reduction due to the kind of technologies implemented that are considered as CO2 neutral for the energy generation. At the same time, diverse strategies to reduce the emissions were considered like different means of sustainable transportation. Understanding that this concept would work only when people who live or work on this area use them.

Aside from the energy transition perspective, this area was chosen to receive great part of the growth of the city. And many developments took place for different purposes.

The outcome was to show the possibilities to work in a long term vision with the energy transition perspective to create a sustainable energy landscape for Arnhem.

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Chapter IX

Evaluation & Discussion

During the eight chapters of this thesis, we applied the 'Five- Step Approach' proposed by Stremke (2010). By doing so, we were able to collect information and analyse how Arnhem works regarding energy consumption and CO2 emissions. The potentials found in the city were explored according with theories such as Trias Energetica and the Low-EX . With the introduction of two different socio-economic scenarios, we were able to define pictures of the possible futures to Arnhem. Finally on the **chapters 07** and **08**, we correlated all the data in order to propose two visions and interventions for the city.

In the **chapter 09** we will discuss and compare the two visions in order to identify the feasible measures which would be applied independently of the possible future. Moreover, we will access the requirements of the KWh/m2 studio as well as from the municipality of Arnhem presented on the first Chapter. The perspective of policy makers, researchers and Landscape Architects will frame the conclusions.

Figure 9.1. (previous page) Sonsbeek park, Arnhem

9.1 Discusion

When dealing with the challenge to design sustainable energy landscapes rather than (fossil fuels) energy landscapes the concept of 'energy –conscious planning and design' explained by Stremke (2010) should be addressed. According with the author, the concept implies "(a) increasing the assimilation of renewables, and (b) reducing energy consumption in the built environment" (Stremke, 2010, p. 76).

During the last two chapters we explored the possibilities found in Arnhem to shift the current fossil fuels to sustainable energy systems. Based on different socio economic scenarios, the two visions were designed in order to revel different ways to reach a desired future rather than propose ideal futures.

In one vision, 'Less is Better' the focus remained inside the borders of the city, while the second vision there was the possible connection with the next municipalities. Even though both cases stressed the importance to use as much as possible local solutions, the limitations of the landscape where considered. The intension was not to make a proposal where 100% of the energy consumed in the city would be generated locally, but to propose measures to turn Arnhem less dependent of fossil fuels next to be resilient during an energy crises period. As Andy van den Dobbelsteen (2012) affirms, the full self-sufficiency is not necessarily the goal when we work on the scale of a city.

By doing so, energy conscious design principles were made. We applied a theoretical framework based on the Trias Energetica (Lysen, 1996) and the Low-Ex concept (Stremke et. Al. ,2011, and Andy van den Dobbelsteen ,2012). Four stages for energy transition where identified:

1. To reduce the consumption of energy by saving
2. Focusing on measures to store and exchange energy (decrease exergy)
3. Generate as much as energy by renewable sources
4. Use of high-exergy sources for high-grade process

In order to discuss the design principles we made, environmental concepts related with renewable energy according with Stremke and Koh (2011) we will accessed. They are closely related with the theoretical framework, and were defined from the perspective of landscape architects. Therefore, mitigations of periodic fluctuations, adaptation to low energy carriers and optimization of energy utilization will be briefly discussed.

Mitigation of periodic fluctuations: these measures involve concepts of storage, biorythm and diversity.

In the Less is Better Vision the potential to heat and cold storage in aquifers and vertical systems where evaluated. The densely populated areas in the south of Arnhem presented the best potential. The BAU Vision focused on the use of, salt molten tanks would be implemented near the solar parks. Moreover, Both visions proposed the use of the flood plains to produce biomass. We considered the periodic changes on this environment while use of the area to biomass production. As a result the biorhythm of the flood plains was respected and the pressure on land use reduced. The large scale use of solar energy and wind turbines was mixed with a diversity of potentials made the energy systems more resilient to periodic fluctuations. The partial conversion of the light vehicles fleet to electric vehicle was also a measure to store electricity. Heat and cold exchange with the river was also proposed by the two visions.

Adaptation to low energy carriers: source – sink relationship and system size

Both visions based the implementation of new systems as well as the extension of existing networks according with the relation between sinks and sources areas in Arnhem. For instance, in the northern districts, local implementations where proposed. The distances to transport the biomass were another factor considered. In general, the size of a system was established with the amount of energy delivered and the distances between the generator plant and the place where it would be consumed.

Energy utilization: food chain, symbiosis and differentiation of niches

In the Less is Better Vision, the promotion of sub-centres in each district has also the objective of increase the potential energy exchange between buildings. Moreover, residual land or areas ‘waiting for development’ where considered as niches for energy technologies implementation. As well, The BAU Vision proposed the use of vacant areas where, for instance, solar PV cells and biomass production where implemented. The use of the flood plains for both visions comprises also a niche differentiation.

The following concepts will be briefly discussed based on: mitigation of periodic fluctuations, adaptation for low energy densities and optimization of energy utilizations.

Therefore, we conclude, independent on the scenario, the importance to comprise environmental concepts on the design of sustainable landscape. The measures to turn Arnhem less dependent of imports should combine all these concepts and be applied in different layers of the landscape. Our task now ill be to identify the most robust interventions for Arnhem.

9.2 Comparison

In order to evaluate which of the interventions proposed are the most robust, the comparison of each technology will be made according with the location implemented and the amount of energy generated. The robustness of the systems is identified when an intervention is comprised for both visions (Stremke, 2010). (Figure 9.2 to 9.8)

In general the technologies proposed were the same. The main differences are the amount of land used by each one of them in different scenarios. Both visions agree the first measure should be energy savings. According with our proposals, between 30% and 40% of the current energy demand can be saved in the city. Besides savings, the investments to improve the existent energy network, rearrange efficiently sinks and source areas, to evaluate the possibilities of heat and cold exchange and storage will be essential.

Considering Arnhem does not have so much available land, the robust systems are mainly placed on marginal lands such as empty plots, waiting for developments. For instance, the areas in the industrial park and in Schuytgraaf would be used for the installation of wind turbines, solar panels and energy crops. The exactly area differs according with the vision. Moreover, it is essential the dialog between the government, private parties and social representations.

In order to implement renewable energy sources, EROEI (EROEI=energy Output/energy Input *or* energy Produced/ energy invest), the life span of a technology and the consultancy of specialists are necessary. Moreover, regarding the CO2 emissions, the detailed evaluation of each biomass used should be done. During this research we assumed a short life cycle for the crops and the consequent CO2 neutrality of the system.

9.2.1 Policy makers

After have compared the technologies, we will now access the requirements Arnhem made for us. We were asked for a proposal which would be made Arnhem 80% CO2 neutral by 2050. According with the two scenarios analysed and the visions proposed we achieved almost 57%.

As introduced, the investments on saving measures are essential. Since Arnhem has very limited renewable sources of energy savings would contribute with a large percentage of CO2 reduction. Furthermore, the negotiation with private parties and social representations will be extremely important when dealing with acceptance (e.g. NIMBY reactions) and ownership issues. For instance, in the case of using the plots in the industrial area and Schuytgraaf, the implementation will be possible only after the inclusion of the two other parties, private and social, on the discussions. Considering the urgency of measures for energy transition, these discussions should take place still during this decade.

In order to explore the major possibilities to store energy, the studies regarding the heat and cold exchange and storage in aquifers, besides to advice the large consumers to be self-sufficient energetically should be emphasized.

Another important advice is the conversion of existing power plants, such as De Kleef, to run by renewable energy sources. Nevertheless, the shift from fossil fuels to renewables should consider losses due to the importation of fuels. Therefore, the identification of possible sources and relations with the sustainable energy landscape on the regional scale has to be done.

By following this strategy we assume the challenge of 80% reduction of CO2 can be achieved on the long term.

9.2.2 Researchers

In order to guide our research we defined one main research question:

How the landscape in Arnhem will look like when energy transition is considered? *and* How these interventions will contribute to CO2 neutrality in the city?

In order to answer this question we were guided by the methodology of the 'five- Step approach'. Moreover the utilization of a Theoretical framework helped us on the structure of the report, the way we would "tell our story".

Although we had a very good frame, the collection of data presented barriers. We were in contact with enormous amount of information regarding each technology we were studying. On the other hand, we faced very incomplete documents, which were incompatible with many others referring to the same topic. Hence, details were assumed based on the general knowledge gained with the data.

Regarding the research question, it was clear, during the chapters 07 and 08, the relevance of the material collected during the previous chapters. The design of a sustainable landscape to Arnhem is strictly based on the research.

9.2.3 Landscape Architects (review kwh/m2? + theoretical lens)

The definition of our Theoretical Lens, in the first chapter of this research, had the aim to make it clear the task, we Landscape Architects have regarding energy transition.

Our contribution for energy transition goes beyond the simple placement of wind turbines. In order to face the shift from designing 'fossil fuels' energy landscapes to sustainable energy landscapes, the knowledge about energy-conscious design principles in order to (re) organize the landscape are essential.

During the research, our fascination by studying energy landscapes made us eager for knowledge. For more than one time we found ourselves emerged on deep information regarding some of the technologies and how they are related on the landscape. A clear image of our profession was then important to make us focus on how we as landscape architects will contribute for the challenge of energy transition and CO2 neutrality. The overview of all the potentials is essential since we believe on the work in multidisciplinary teams.

As a conclusion, we it was extremely important to make understand the challenges of a project by researching objectively and subjectively the topic. We reinforce the importance to 'use of research' as an instrument for design.

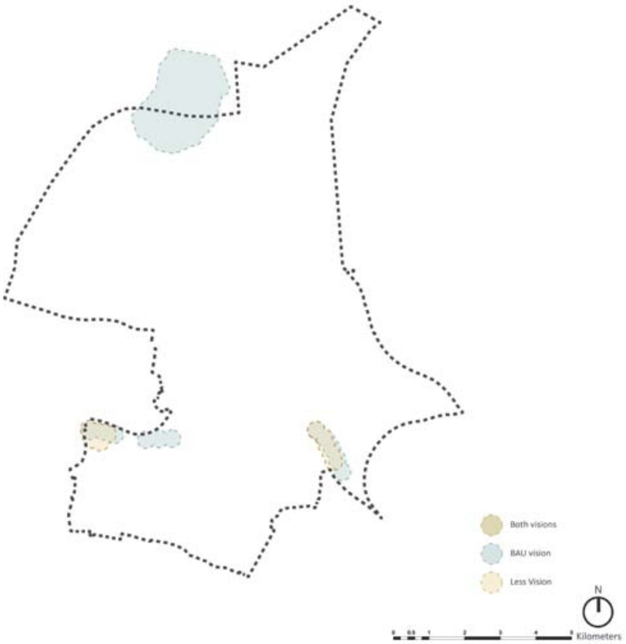


Figure 9.2. Wind turbines

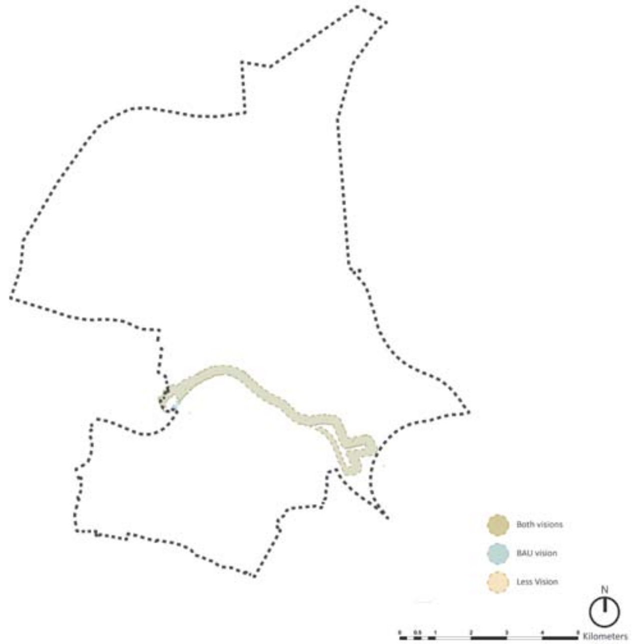


Figure 9.3. Heat & Cold exchange with the river

Comparative analysis maps of technologies implemented between BAU andLess vision

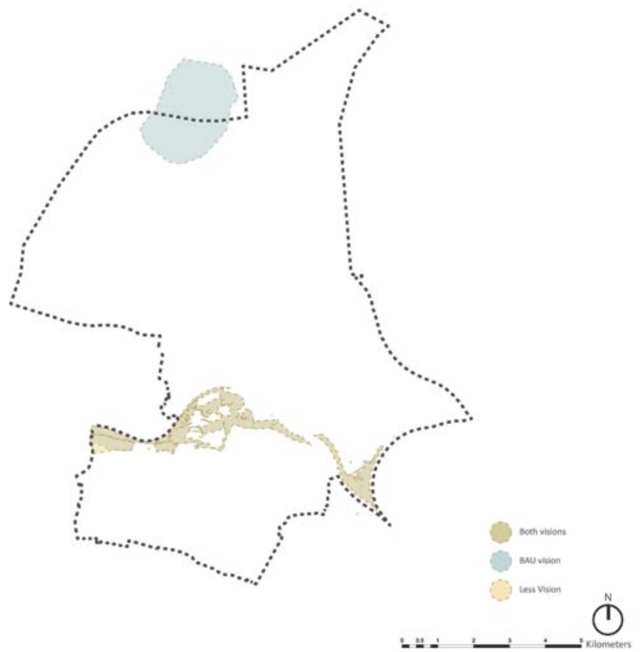


Figure 9.4. Biomass - Energy crops

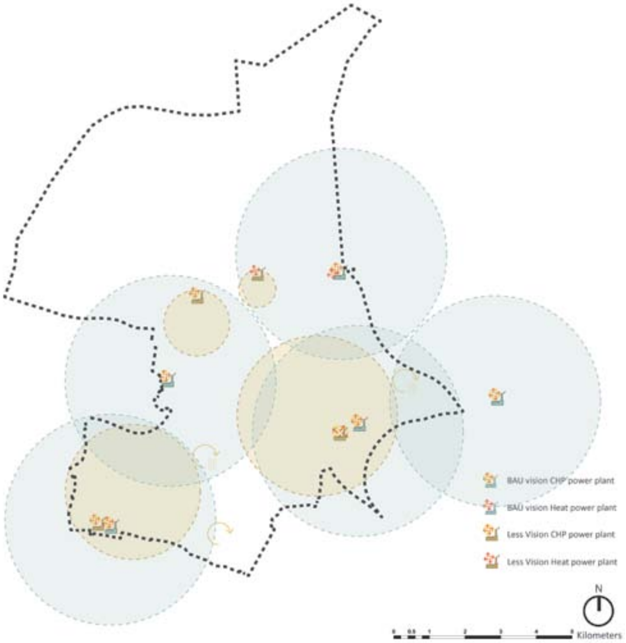


Figure 9.5. Heat network

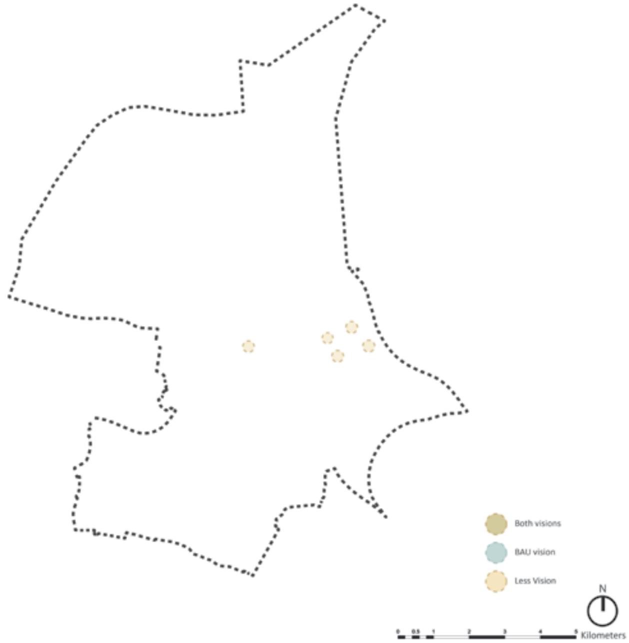


Figure 9.6. Hydro power

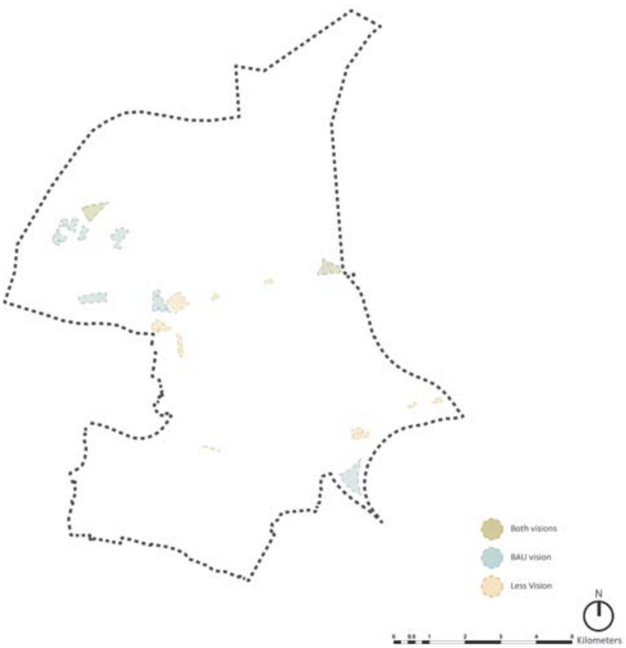


Figure 9.7. Solar

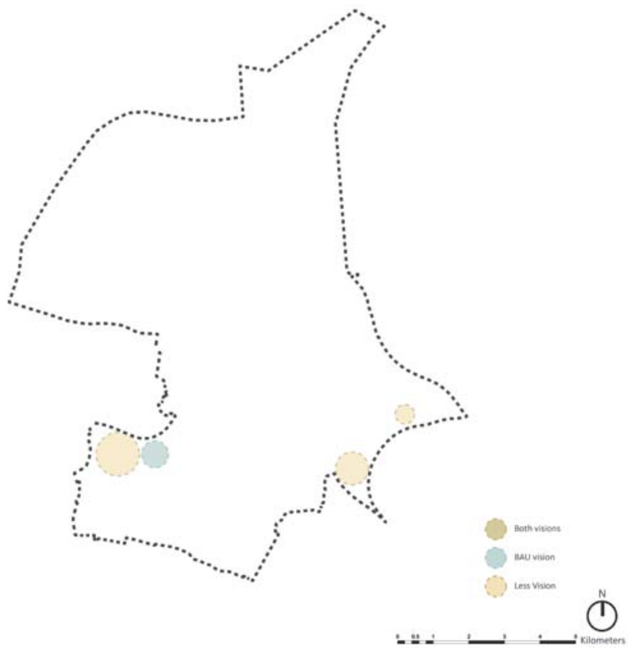
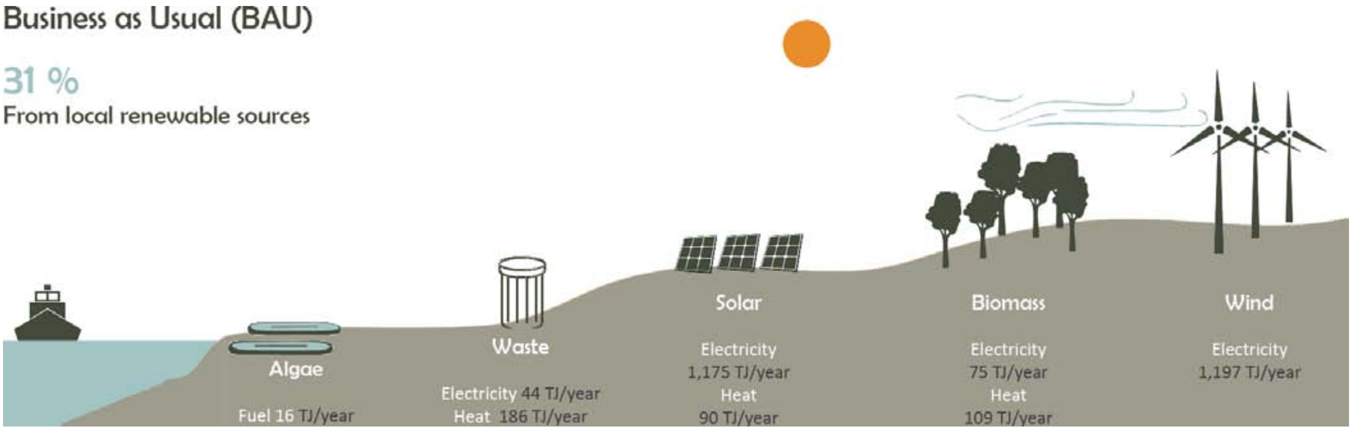


Figure 9.8. Algae

Evaluation		BAU		Less	
technologies	location	TJ	area (ha)	TJ	area (ha)
wind					
wind turbine 3MW	Industrial area	105	80	105	80
	Schuytgraaf	126	96	105	80
	Park North	420	190		
	Park North Ede	546	247		
sub-total		1197	613	210	160
sun					
solar PV roof		362	67	278	43
solar collector roof		90	38	115	26
solar farm PV	Industrial Park	200	37	162	30
	North- empty plots	613	114	292	54
	South- Along the dike			1	0
CSP	North- empty plots	35	13	89	33
sub-total		1301	269	937	186
algae					
algae park	Industrial plots			50	70
	Schuytgraaf	16	22	31	43
sub-total		16	22	81	113
biomass					
biomass wood		39	2573	43	2,959
crops flood plain		44	300	24	200
biomass maintenance		48	690	53	759
miscanthus	Schuytgraaf			1.5	10
willow	Schuytgraaf			5	30
reed	Schuytgraaf			5	50
forest	Schuytgraaf			0.2	10
rape seed	Schuytgraaf			0.5	10
	Park north Arnhem	17	188		
	Park north Ede	24	267		
sub-total		172	4018	132	4028
waste					
waste		230		171	
GFT		11		13	
subtotal		241		184	
heat cold stor/exch.					
HCS				160	
sub-total				160	
others					
hydro	brooks			0.3	
sub-total				0.3	
Imports					
Schuytgraaf (CHP)				432	
Schuytgraaf (HP)		274.00			
De Kleef (CHP)		680.00		1230	
sub-total		954		1230	
Total without imports		2927	4922	1704	4487
Total with imports		3881	4922	2934	4487
TJ / ha without imports		0.59		0.38	

Figure 9.9. Comparison table of technologies implemented, the location and the energy generated between Less and BAU visions



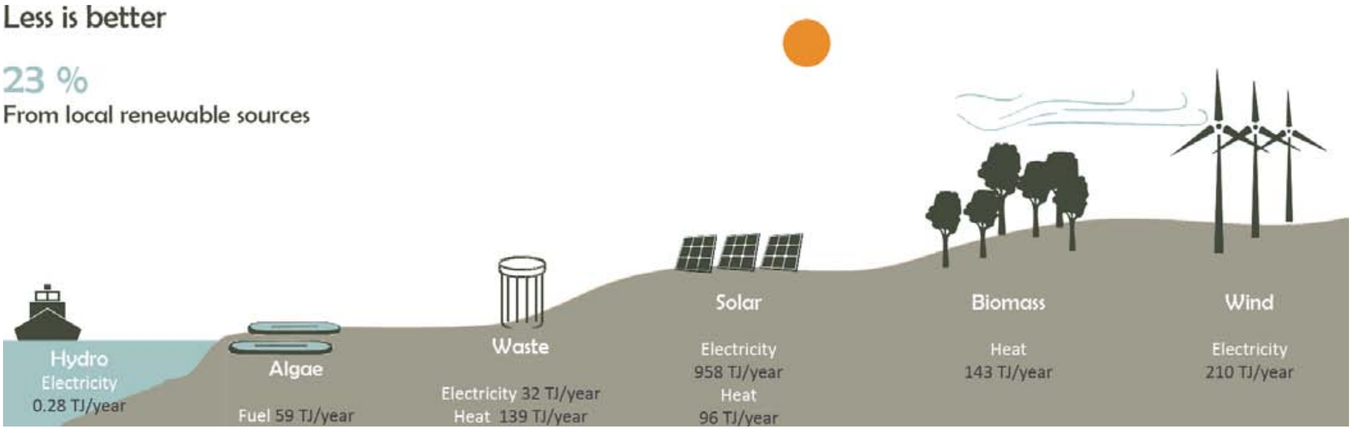


Figure 9.10. Diagrams comparing potentials of both visions

Appendixes

Figure 10.1. Wind Turbines in Eemshaven, The Netherlands (J. Gómez)

Less is Better vision final calculations

electricity						
source	total TJ/year 35%	area (ha)	TJ/ha/year	tonnes/year	tonnes/ha	TJ/ton
Solar PV cells roofs (1)	325,4	42,84	7,60	-	-	-
Solar PV cells farms north(2)	469,8	87,00	5,40	-	-	-
Solar PV industrial farms	162,0	30,00	5,40			
Along the dike (south)	1,1	0,20	5,40			
biomass-wood from pruning (5)	0,0	2958,95	0,0000	2803	0,9	0
biomass-green maintenance (6)	0,0	759	0,0000	3450	4,5	0
biomass-crops on flood plains-reed	0,0	200	0,0000	1600	8,0	0
biomass willow schuytgraaf	0,0	30,00	0,00	300	10,0	0
biomass reed schuytgraaf	0,0	50,00	0,00	400	8,0	0
forest Schuytgraaf	0,00	10	0,0000	10	1,00	0
waste GFT (green, fruits,rests gardens)(5)	0,0	-	-	9173	-	0,0000
mixed waste household (5)	32,3	-	-	26407	-	0,0012
hydrological(4)	0,28	-	-	-	-	-
wind turbines schuytgraaf (5x3MW)	105	80	1,3125	- -		-
wind turbines river (5x3MW)	105	80	1,3125	- -		-
Total electricity	**1200,9**	4328	26,4214	44142,66	32,49	0,0012

Heat						
source	total TJ/year	area (ha)	TJ/ha/year	tonnes/year	tonnes/ha	TJ/ton
Solar collectors roofs (8)	95,6	25,70	3,7195	-	-	-
biomass- wood from pruning (5)	45,4	2959	0,015	2803	0,95	0,0162
biomass-green maintenance(6)	55,9	759	0,074	3450	4,55	0,0162
biomass-crops on flood plains-reed	25,9	200	0,130	1600	8,00	0,0162
biomass willow schuytgraaf	4,9	30	0,162	300	10,00	0,0162
biomass willow industry	2,34	13	0,180	130	11,00	0,0180
biomass schuyt_miscanthus	1,62	10	0,162	100	12,00	0,0162
biomass reed schuytgraaf	6,5	50	0,130	400	8,00	0,0162
forest Schuytgraaf	0,16	10	0,016	10	1	0,02
waste GFT (green, fruits,rests gardens)(5)	14,1	-	-	9173	-	0,0015
mixed waste household (5)	138,6	-		26407	-	0,0053
Storage (HCS) max. potential	160,00	-	-	-	-	-
Total heat	**551,0**	4056,65	4,5879	44372,6600	55,4924	0,1382

Biodiesel						
source	TJ/year	area (ha)	L/ha/year	total L/year	TJ/ha/year	TJ/L
algae schuytgraaf(11)	30,84	43,00	20.000,00	860.000,00	0,72	0,00003586
algae industrial park	28,69	40,00	20.000,00	800.000,00	0,72	0,00003586
Total Biodiesel	59,53	83,00	40.000,00	1.660.000,00	1,43	0,00007172

Imports CHP						
source	total TJ/year 50%	area (ha)	TJ/ha/year	tonnes/year	tonnes/ha	TJ/ton
De Kleef (imports) electricity	651	0,00	0,00			
Schuytgraaf (imports) convertion CHP electricity	194,8	0,00	0,00			0
Residual heat from Schuytgraaf(9)	274,0					
Residual heat from CHP De Kleef (9)	579,0					
Total Biodiesel	1.698,80	0,00	0,00	**0,00**	0,00	0

0,219741272 21% of co2 netrality can be achieved by shifting the fossil fuels of the chp to biofuels

(1) 15% efficiency of solar PV cells ; usage of 30% of the potential roofs available; 1000kwh/m2 in The Netherlands
Source:http://re.jrc.ec.europa.eu/pvgis/cmaps/eu_opt/pvgis_solar_optimum_NL.png and KEMA, 2009
(2) placed on former agriculture fields near the A12
(3) Considering the development will not be implemented 100%
(4) Source: Gemente Arnhem, 2010
(5) Source:BTG MRA Studie in KEMA, 2009;Wolter Elbersen-personal communication, 2011
(6)Source:BTG MRA Studie in KEMA, 2009; Wolter Elbersen-personal communication, 2011;http://www.ecn.nl/phyllis/
(7)Source:http://www.ecn.nl/phyllis;Wijffels and Barbosa, 2010
(8)1000kwh/m2 in The Netherlands; Source:http://re.jrc.ec.europa.eu/pvgis/cmaps/eu_opt/pvgis_solar_optimum_NL.png; KEMA, 2009; used on insulated houses
(9)source: Kema, 2009; system depended of imported biofuels

The CHP efficiency was considered as 35% electricity; 50% heat; 15% losses
Source:

Electricity + heat+fuel- Less is Better			
Type of energy	TJ/year	R.E TJ/year	possible %
Electricity	1.888,16	1200,9	63,60%
Heat (excluded electricity sources)	3.184,00	551,0	17,31%
Fuel	2658,75	59,5	2,24%
Total TJ	7730,91	1811,5	**23,43%**
		Dependence	**76,57%**

Compared with the current situation			
Type of energy	TJ/year	R.E TJ/year	possible %
Electricity (without alagae)	2789,0	1200,9	43,06%
Heat (without alagae)	6368,0	551,0	8,65%
Fuel	4041	59,53	1,47%
Total TJ	13198	1811,5	**13,73%**
42% savings			**41,42%**
		Dependence	**44,85%**

Observation: the potentail for heat can be raised by using geothermal technologies and heat cold exchage with the river

Business As Usual vision final calculations

electricity						
source	total TJ/year 35%	area (ha)	TJ/ha/year	tonnes/year	tonnes/ha	TJ/ton
Solar PV cells roofs(1)	361,85	67,01	5,400	-	-	-
Solar PV cells on wind farm(2)	0,00	0,00	0,000	-	-	-
Solar farm industrial park	200,02	37,04				
Solar PV cells agricultural land	613,45	113,60				
Wind turbine River	126,00	96,00				
wind turbine industrial area	105,00	80,00		-	-	-
wind turbine park north (3)	420,00	190,00	2,211	-	-	-
wind turbine park north (3) (Ede municipality)	546,00	247,00				
hydrological	0,00			-	-	
mixed waste household (4)	43,57			35567	-	0,0012
biomass-wood from pruning (4)	16,05	2573		2548	0,99	0,0063
biomass-green maintenance (5)	19,76	690		5227	7,58	0,0038
biomass-crops on flood plains-reed	17,04	300		-	-	-
biomass rape seed wind farm Arnhem	7,12	188,33				
biomass rape seed wind farm Ede	10,08	266,71				
waste GFT (green, fruits,rests gardens)(5)	4,39			11856	-	0,0004
Kleefse Waard	280,00					
algae (6)*	0,00	22	0,000	4960	80,00	0,0000
Total electricity	2.490,33	4.870,70	7,61	60.157,80	88,57	0,011675

Heat						
source	total TJ/year 50%	area (ha)	TJ/ha/year	tonnes/year	tonnes/ha	TJ/ton
Solar collectors on roofs	90,01	38	0	0	0	0
Solar collector on agricultural land	35,28	13	0	0	0	0
Residual heat from Schuytgraaf(7)	274,00	0	0	0,00	9,40	0,0180
Residual heat from CHP De Kleef (7)	400,00	0	0	0,00	9,40	0,0180
mixed waste household (4)	186,73	0	0	35.567,10	0,0000	0,0053
biomass- wood from pruning (4)	22,93	2573	0	2.548,00	0,00	0,0090
biomass-green maintenance (5)	28,23	690	0,0409	5.227,00	7,58	0,0054
biomass-crops on flood plains-reed	26,69	300	0	0	0	0
biomass rape seed wind farm Arnhem	10,17	188,33	0	0	0	0
biomass rape seed wind farm Ede	14,40	266,71	0	0	0	0
waste GFT (green, fruits,rests gardens)(5)	6,27	0	0	8.264,00	0,0000	0,0008
geothermal potential	0,00	0	0	0	0	0
Heat and Cold Exchange with river	0,0	0	0	0	0	0
algae (6)*	0,00	22	0,0000	4.960,00	80,00	0,0000
Total heat	420,71	4.090,69	0,04	56.566,10	106,38	0,056409

Biodiesel						
source	TJ/year	total L/year	area (ha)	L/ha/year	TJ/ha/year	TJ/L
algae (11)	15,78	440.000	22	20.000,00	0,72	0,00003586
rape seed	0,00	682.560	455,04	1500		0,00003586
Total Biodiesel	15,78	1.122.560	477,04	21.500,00	0,72	0,000072

(1) 15% efficiency of solar PV cells / usage of 24% of available area on roofs/ 1000kwh/m2 in The Netherlands
Source:http://re.jrc.ec.europa.eu/pvgis/cmaps/eu_opt/pvgis_solar_optimum_NL.png; KEMA, 2009
(2) avarage speed of 6.m/s/ wind turbine 3MW/ efficiency 22%
Source: www.knmi.nl/klimatologie/normalen1971-2000/index.html m_NL.png; KEMA, 2009
(3) Source: KEMA, 2009
(4) Source: Gemente Arnhem, 2010
(5) Source:BTG MRA Studie in KEMA, 2009; Wolter Elbersen-personal communication, 2011
(6)Source:BTG MRA Studie in KEMA, 2009; Wolter Elbersen-personal communication, 2011;http://www.ecn.nl/phyllis/
(7)Source:BTG MRA Studie in KEMA, 2009; Wolter Elbersen-personal communication, 2011
(8)Source:http://www.ecn.nl/phyllis;Wijffels and Barbosa, 2010
(9)1000kwh/m2 in The Netherlands; Source:http://re.jrc.ec.europa.eu/pvgis/cmaps/eu_opt/pvgis_solar_optimum_NL.png; KEMA, 2009
(10)Source:CBS in KEMA, 2009
(11)Source:Kema, 2009; this CHP is runing by fossil fuels, thus, it should be converted into biofuels sources

The CHP efficiency was considered as 35% electricity; 50% heat; 15% losses

Source:

*efficiency 35% electricity

**efficiency 50% heat

***The district heating Schuytgraaf and the CHP De Kleef should import 100% of the biofuels
we didnt consider the overlap of wind turbines and solar farms

Electricity + Heat + Fuel BAU vision			
Type of energy	use/demandTJ/year	R.E TJ/year	possible %
Electricity	2930	2490	85,01%
Heat (without sun)	4202	421	10,01%
Fuel	2257	16	0,70%
Total (TJ)	9388	2927	**31,18%**
		Dependence	**68,82%**

Compared to the current situation			
Type of energy	consump. TJ/year	R.E TJ/year	possible %
Electricity (without PV)	2789	2490	89,29%
Heat	6368	421	6,61%
Fuel	4041	16	0,39%
Total (TJ)	13198	2927	**22,18%**
		Dependence	**77,82%**