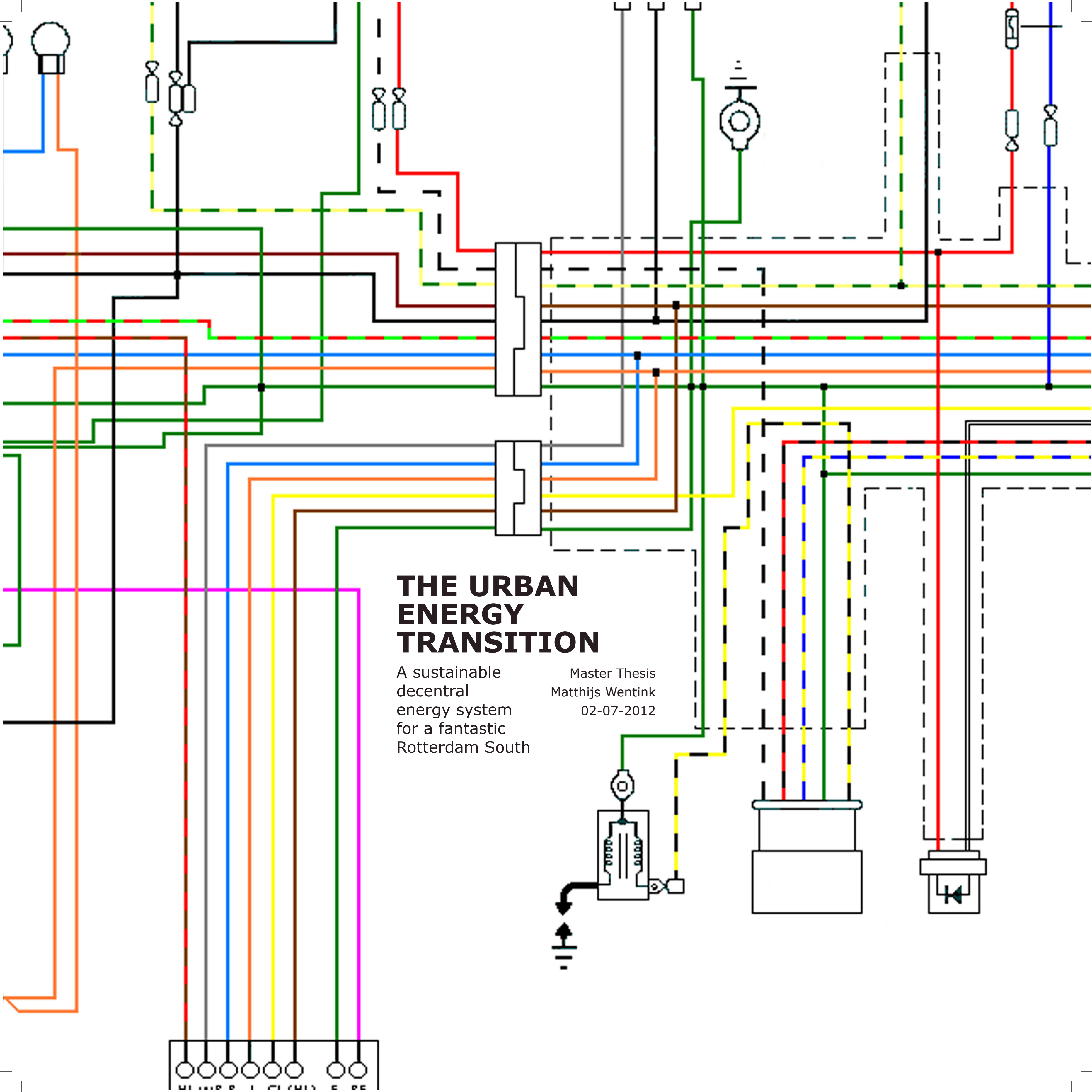

THE URBAN ENERGY TRANSITION

A sustainable decentral energy system for a fantastic Rotterdam South

Master Thesis
Matthijs Wentink
02-07-2012

“A sustainable solution will only be a success when it can compete with its non-sustainable equivalent. A sustainable solution should at least offer the same quality, or be better then the existing alternatives. People are not willing to pay more, or enjoy less for the fact a product is sustainable.”

Ruud Koornstra founder Tendris, 2009

Colophon

THE URBAN ENERGY TRANSITION
A sustainable decentral energy system for a fantastic Rotterdam South.

Master Thesis
Date 07-07-2012

Delft University of Technology

Faculty of Architecture
Department of Urbanism

Studio
Urban Regeneration
kWh/m2

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Cover: Adaptation of a drawing by Ivo Schnieder

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Acknowledgement

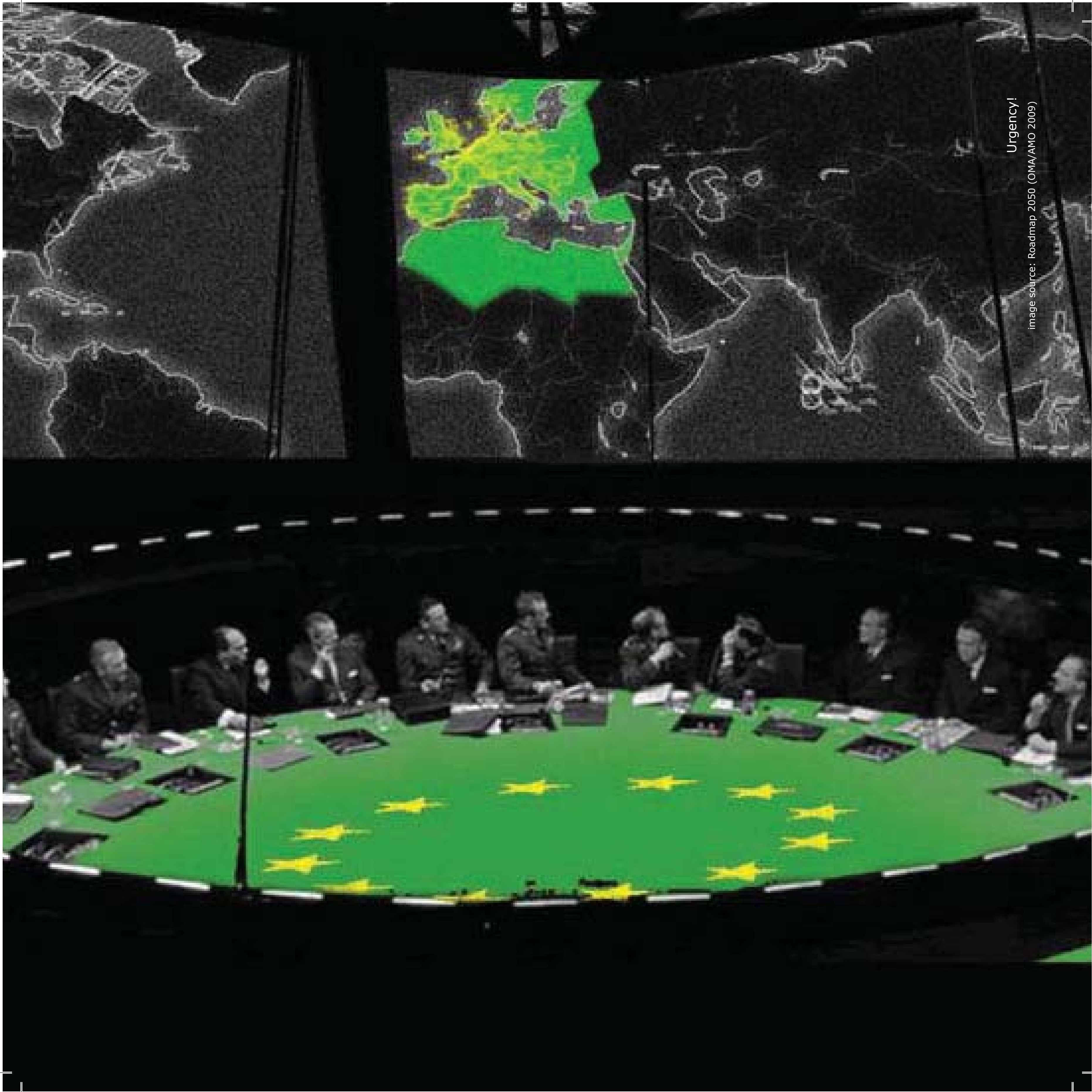
This thesis is the crown on my master Urbanism at the TU Delft. When I started the master three years ago, I found my passion for urban challenges with political and economic aspects. Therefore it is not surprising that I wrote my thesis about energy transition and the social economic implications for cities. I became more and more enthusiastic about this exiting subject and it was moreover a great opportunity to apply this challenge in Rotterdam South.

Before starting my research, I heard about the Rotterdam Climate Initiative. This initiative forces Rotterdam to pace its transition to renewable energy sources. The carbon goals are a very welcome political statement, but the actual process of making the transition is uncharted territory. This thesis is written in corporation with the municipality of Rotterdam and as part of the kWh/m2 research group. From the perspective of Urbanism, existing theories about the energy transition are explored and I've used a case study for the project location in Rotterdam. The first half of the thesis describes the theoretical framework, the second half shows the urban design which tries to incorporate the researched theories in an integral urban design.

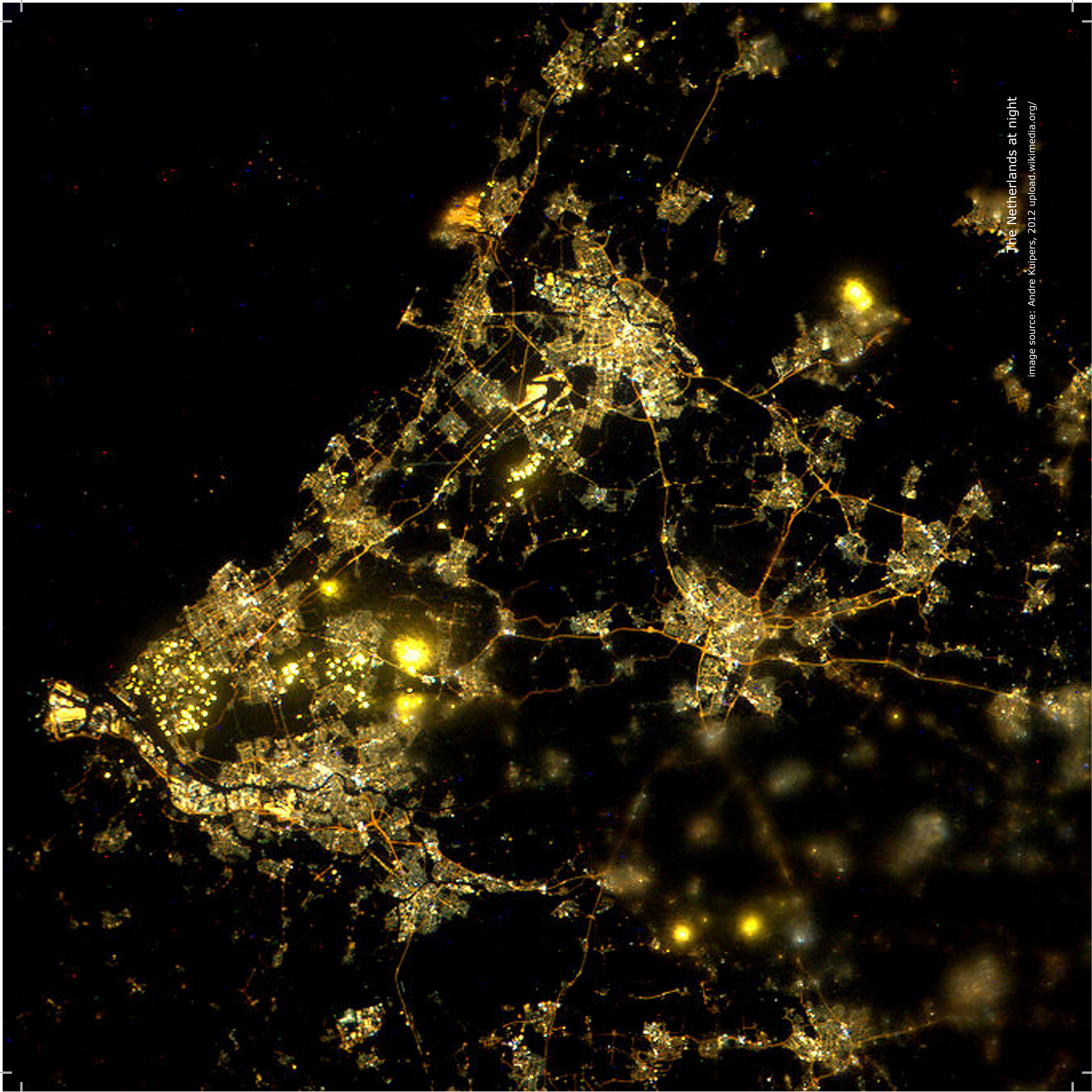
Off course I could not write this thesis on my own. At this place I would like to thank my mentors, John Westrik and Nico Tillie. Thanks for your feedback, critical notes en interesting talks. Also I want to express my appreciation to Dirk Sijmons and Adrian Hill for sharing their expertise and enthusiasm. It was a pleasure to work with you. Further I would like to thank my family and friends for their interest. And off course I'm grateful to my girlfriend Petra, for her patience and support.

Now I'm looking for a new challenge, and I proudly present this thesis as the grand finale of my study.

Enjoy reading!



Urgency!
image source: Roadmap 2050 (OMA/AMO 2009)



The Netherlands at night
image source: Andre Kuipers, 2012 upload.wikimedia.org/

A global introduction of the transition challenge

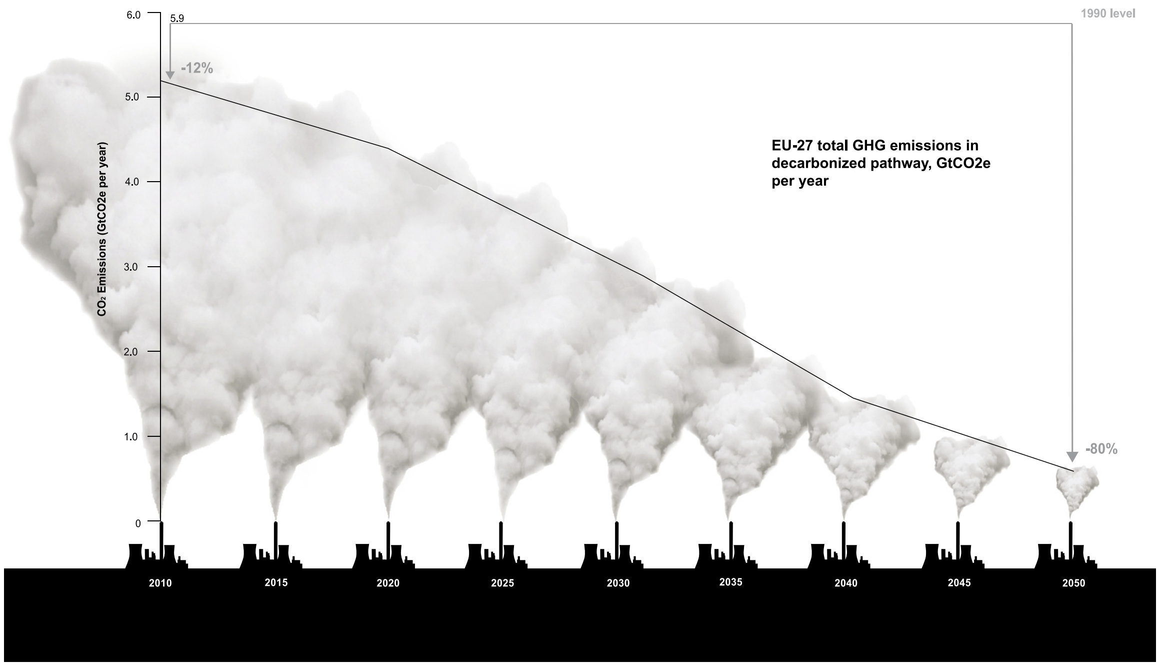
Society's energy consumption has become a hot topic in the past decade. We realize that we consume too much energy and experience adverse effects. But already since 1970 the planet's future prospects have been a topic of debate and worries. In this the role of human activity is acknowledged. 'Most of the warming that has occurred over the last 50 years is, according to the Intergovernmental Panel on Climate Change (IPCC) (2007), attributable to human activities. The result of this will be a further rise in sea levels (and an increased risk of flooding), problems around fresh-water supplies in many parts of the world, a decrease in agricultural productivity in many areas, and significant health risks' (Smith, 2008, p2). Carbon emissions caused by energy consumption are likely to have part in these greenhouse effects (Roos et al., 2007). The IPCC (2007) even suggests a direct link between the greenhouse effects and mankind's energy consumption.

Concurrently our society has become completely dependent on great amounts of inexpensive energy, and it is expected that the energy demand will only increase in the next 25 years (IEA, 2010). The energy we use mainly comes from fossil sources and these resources are finite. 'It seems possible that cheap oil (on which our cars and lorries run) and cheap gas (with which we heat many of our buildings) will run out in our lifetime' (MacKay, 2009, p5). Peak oil, the point when the oil demand exceeds the offer, has been reached in 2008 and the expectations are that energy prices will fluctuate and eventually rise in the near future. Increasing the risk of energy poverty and turning the energy issue into a social-economic issue (Dobbelsteen et al., 2009).

Besides fulfilling our energy demand, there is the interest of securing our energy supply. 'Even if fossil fuels are still available somewhere in the world, perhaps we don't want to depend on them if that would make our economy vulnerable to the whims of untrustworthy foreigners' (MacKay, 2009, p5). Without changing our energy system, our energy dependence will increase and we have to rely on political unstable world regions for our future energy supply (Homan and Geuns, 2007). An undesired situation from politic and economic viewpoints (Neuman and Siccama, 1981) and one more reason to reassess our existing energy system.

Point of departure

The global situation described in the preceding paragraph forms the main reason to write this thesis. From a climate perspective, it is required to



Carbon emission goals
image source: Roadmap 2050 (OMA/AMO 2009)

reduce carbon emissions and most of the carbon emissions come from fossil-fuel burning (MacKay, 2009). Our energy system is responsible for a large part of the fossil fuel demand, so evaluating our energy system is of great importance. Moreover, the two social-economic reasons mentioned have a common ground: the ability to be self-sufficient in our energy demand, independent from fossil resources. Not only do we have to reduce carbon emissions, we also have to become more self-reliant. Therefore, a decentral energy system comprised out of renewable energy sources becomes an interesting objective.

The issues produce a problem field of immense proportions: a global challenge that influences the future of the planet and all human beings living on it. Research reports like *Roadmap 2050* (ECF and OMA, 2009) and *Energy 2020* (ECF, 2011) address the challenge from this global perspective, but this thesis will not do so. Professor D. Sijmons from the chair of Landscape Architecture at the Technical University of Delft is working with his firm H+N+S on a book about energy transition with the working title *kWh/m2*. Professor Sijmons approaches the challenge from this global, central angle, but also from a decentral angle. This thesis is written from the decentral angle. It leaves the global challenges untouched and focuses on the smaller scale possibilities.

The relation with Urbanism

The relation with urbanism can be derived from the important position of urban areas in the transition. Half of the energy consumed in Europe is consumed in cities and a further 25 percent is needed for transportation (Herzog et al., 1996, Droege, 2008). People use the energy, but they concentrate in cities, so energy consumption is concentrated here as well. Therefore our cities have a task in the energy transition. The environment of the city has to deal with the added spatial pressure, resulting from renewable energy production and the environment has to assist in reducing existing energy consumption.

The interest of the author lies in the spatial implications of the energy transition. A more sustainable energy system is likely to have impact on our living environment because energy structures partly determine the shape of cities (Benton-Short and Short, 2008). Also, the living environment plays a role in the amount of energy people consume; certain environments can reduce energy consumption and therefore make the transition easier. This thesis will reveal that a dense

Energy consumption

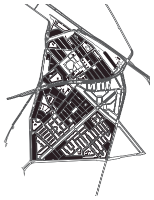
data source: CBS, 2011

Energy demand average Dutch household

Gas	1550 m3 (NUON, 2012)
Electric	3480 kWh (NUON, 2012)
Car	1

Energy demand average household Afrikaanderwijk & Bloemhof

Gas	1300 m3
Electric	2450 kWh
Car	0,5



Energy demand project area

Area	120 ha
Inhabitants	21.296
Households	9965
Density	83,0 hh/ha
Gas	135,96 GWh/yr
Electric	24,41 GWh/yr
Car	74,46 GWh/yr
Total demand	234,83 GWh/yr
Spatial pressure	1,96 GWh/yr/ha

urban area can offer such a living environment.

The case of Rotterdam South

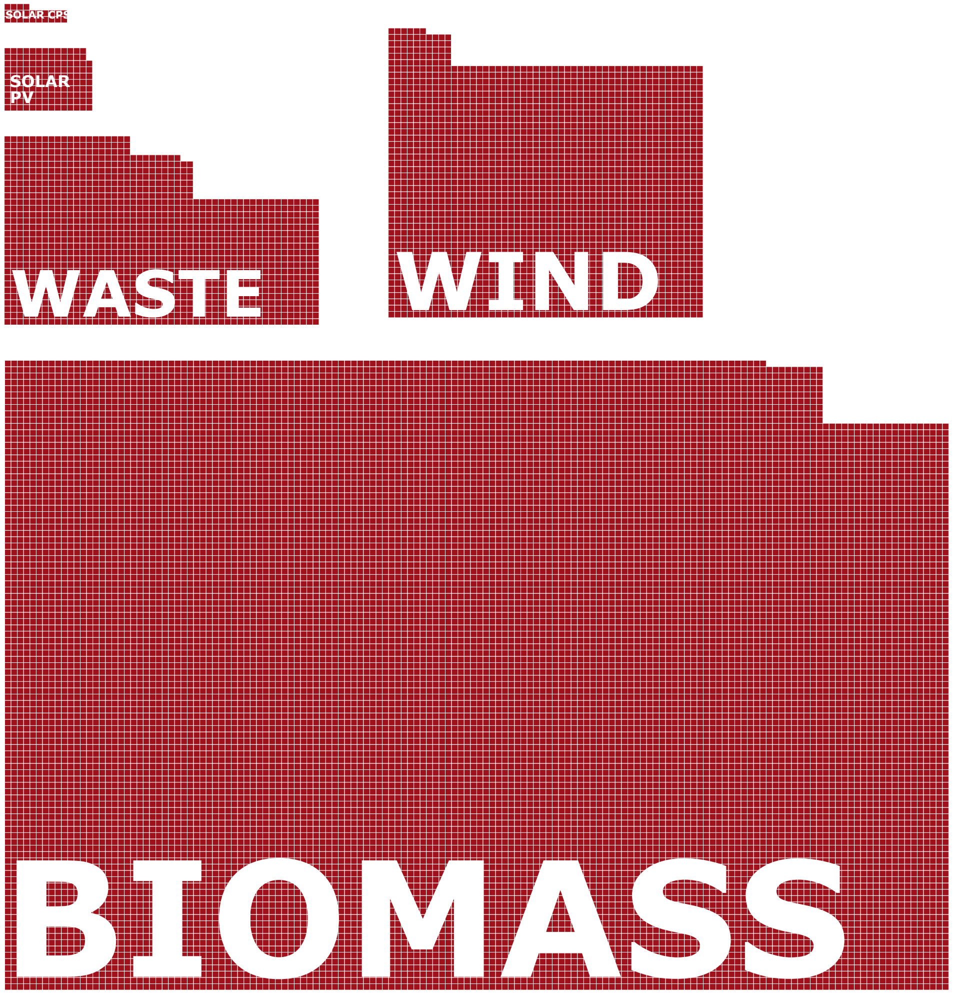
The generic transition challenge is applicable on every urbanized region in the world, so why the specific choice for Rotterdam South? One reason for choosing Rotterdam South is the Rotterdam Climate Initiative (Programmabureau Rotterdam Climate Initiative, 2009). Rotterdam wants to go ahead in the energy transition and reduce its carbon emission with fifty percent in 2025. The initiative urges the city and its inhabitants to make the transition, so Rotterdam can use an energy transition strategy.

Another reason to choose Rotterdam South is the 'weak' social economic position of the area. The area has high concentrations of vulnerable social classes typified by all the standard markers: high ethnic diversity, low education levels, high unemployment rates and high concentrations of low-income groups. Because of these characteristics, the expectations are that if energy prices will rise, this area will be disproportional affected. The groups living in this area do not have the capacity to deal with the added economic expenses and thus their prosperity will be affected. It is sensible to offer these groups an environment that is energy poverty proof. Also, the climate ambitions of The Rotterdam Climate Initiative can be combined with the existing refurbishment ambitions of Rotterdam South. This combination makes the project very relevant for the city and hopefully ensures a broad interest.

From an academic viewpoint it is interesting to do a specific case study into the spatial consequences of the energy transition. Most research in the field of energy transition is very abstract and lacks a realistic context. They do not show the impact of the transition ambitions on an actual urban area and the immense scale of the required interventions stays hidden. But when the energy footprint of an individual urbanized region is calculated, a specific case can be drawn. Data from the existing energy situation can be analysed and potential interventions explored. Based on the H+N+S methodology, the added spatial pressure resulting from renewable energy sources can be visualized and a concrete spatial assignment arises. Every urban region can expect problems with the added spatial pressure, but the solutions are likely to be local. By exploring the necessary interventions, the actual impact of the energy transition can be visualized and a spatial designer can try to manage the spatial consequences.

In this thesis, calculations for the neighbourhoods

The red areas below show the space necessary for sustainable energy production. The red areas are superimposed on a grid of a hundred by a hundred meters and have the same scale as the Rotterdam map.



Required space for renewable energy production

image source: author

Afrikaanderwijk and Bloemhof are made. Compared with the Dutch household average, these areas perform relatively well on energy consumption. Gas consumption, electricity use and car ownership are relatively low. The specific causes for the low energy demand are not part of this study, but generic explanations can be sought in the size of the houses, the housing typology and relatively low income rates.

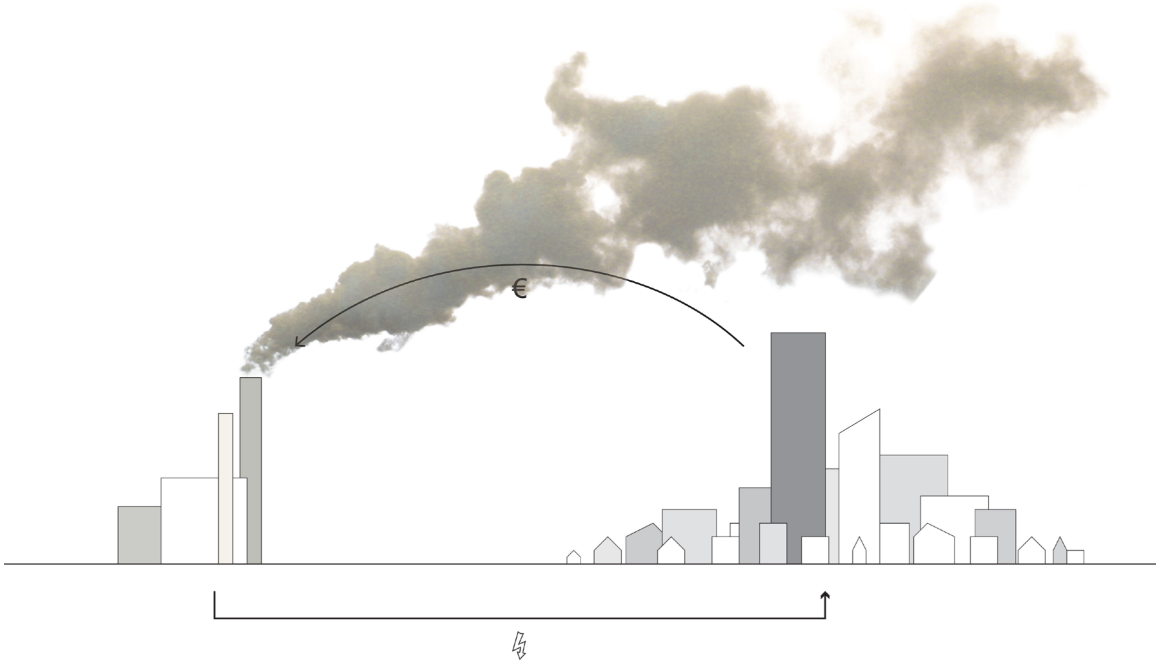
The spatial visualization of the energy demand, when produced sustainable, unmistakably shows a problem: renewable energy production requires a lot of space and it is dubious if this space is available in the Rotterdam region and if the available surrounding space should be dedicated to the production of renewable energy. This question can evolve into a serious problem: allocating space to accommodate renewable energy production. Plainly there are two ways to deal with this problem: accept that renewable energy production requires space or reduce the current energy consumption of the area. These two issues apply for the project location.

Problem statement

Cities in the Netherlands are fully dependent on great amounts of inexpensive energy from fossil resources. This dependence is not desired based on environmental, economic and political grounds. The expectations are that fossil resources will deplete within a lifetime and when this happens the functioning of our cities is jeopardized. The question is not if we have to switch to alternative energy sources, but when and how.

Rotterdam has the political ambition to lower carbon emission with 50% in 2025 (Programmabureau Rotterdam Climate Initiative, 2009). This political decision forces Rotterdam to reconsider its energy system and it urges the city and its inhabitants to make the transition to renewable energy sources. But it is questionable if this transition is actually possible, if the city can reduce carbon emissions and rely for its energy supply on sustainable energy sources.

Rotterdam wants to make the transition to a more sustainable and less carbon emissive energy system, but it is not yet known how the transition will be executed and how the transition will affect urban areas. The initiative misses an overall strategy. Moreover, the municipality's refurbishment ambitions should be incorporated into the energy transition, so the deprived neighbourhoods of Rotterdam South can benefit from the energy transition.



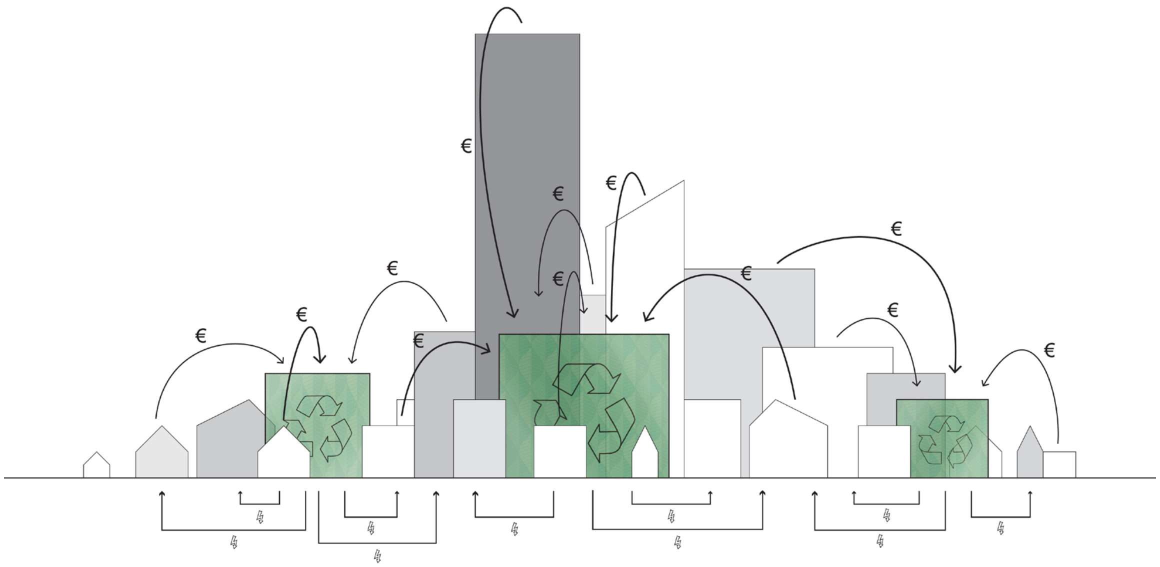
Objectives

The main objective is to develop strategies enabling the project area to make the transition to a more sustainable and less carbon emissive energy system. The energy transition itself is the main objective, but simultaneously the transition should be beneficial for the deprived neighbourhoods within the project area.

The first sub-objective is to analyze the existing energy system of the project area in Rotterdam South and study the consequences of this energy system on the urban area, including its inhabitants. It is interesting to study the existing system and energy demand, because this will be the point of departure for the transition.

The second sub-objective emerges from the hypothesis of a decentral energy system for urban areas. The second sub-objective is to transform the project area's existing central energy system, into a renewable and decentral system. Simultaneously reducing carbon emissions and limiting the area's dependence on fossil resources and therefore achieving the main objective. With a decentral energy system, an independent urban area arises which fulfils its own energy demand. It is expected that this system will generate economic advantages, because energy related financial flows will stay inside the urban area and will hopefully generate new job opportunities.

The third sub-objective is to research if the transition is technically possible. To make the transition possible, the area's energy demand should be limited, the energy efficiency should be increased and the remaining energy demand should be produced within the area itself. Moreover, rhythm problems due to sustainable energy production (intermittency) should be solved within the project area as well. The sun does not always shine and the wind does not always blow, therefore storing energy is essential for a renewable energy system (Scheer, 2008). From an energy perspective, the aim is not to invent new methods to make the transition, but to apply existing methods in an integral way and thus come up with a new energy system for Rotterdam South. In addition to this technical quest, the aim is to research if modifications to energy structures can be used as a planning and design instrument and improve the existing situation. The design should improve the area's spatial and social-economic conditions and incorporate the refurbishment ambitions of the municipality into the energy transition.



Central/decentral energy system
image source: author

Research question
The structure of the thesis is defined according to one main and three sub research questions.

Main research question:

> What are strategies for an existing urban area to make the transition to a more sustainable and less carbon emissive energy system and how can this transition be beneficial for the deprived neighborhoods within the urban area?

To make the energy transition possible, a few challenges arise. The first challenge is to make the transition technically possible and to implement these technical principles into an existing urban context. Further the transition should lower the energy footprint and reduce the fossil fuel dependency of the urban region. These are two independent objectives, because methods to reduce fossil fuel dependency do not automatically reduce the energy footprint. And ways to reduce the energy footprint (and thus the carbon emissions) do not automatically reduce the fossil fuel dependency.

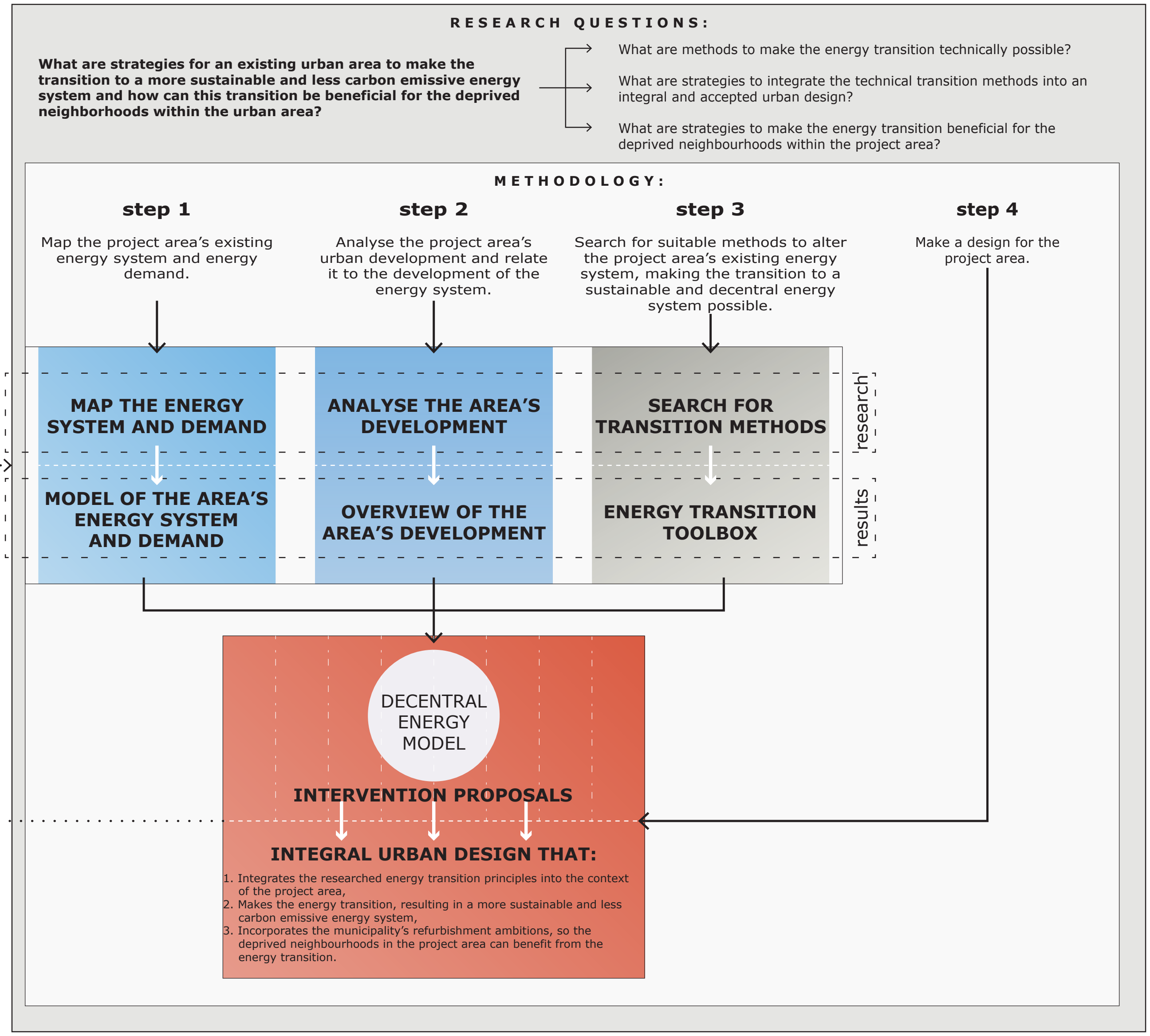
The second challenge is integrating these methods in a good, functional and accepted urban design. Energy measures often have a technical nature with a limited scope; they offer specific solutions for a specific problem in a rigid context. Mono interventions miss a solid connection with the complex urban world and therefore have a limited return and a low acceptance rate (Sijmons, 2011). With the result that inhabitants reject, instead of embrace the interventions.

The third challenge is to make the energy transition beneficial for the deprived neighbourhoods of Rotterdam South. The transition is expected to have spatial, social and economic implications and these implications should improve the existing neighbourhoods, not make them worse.

Sub research questions
The three sub research questions follow logically from the challenges mentioned above.

1. What are methods to make the energy transition technically possible?
2. What are strategies to integrate the technical transition methods into an integral and accepted urban design?
3. What are strategies to make the energy transition beneficial for the deprived neighbourhoods within the project area?

Methodology
The methodology is structured according to four



Research model
image source: author

steps. The first two steps will explore the existing situation of the project area and define the context and starting situation:

1. Map the project area's existing energy system and energy demand.
2. Analyse the project area's urban development and relate it to the development of the energy system.

The third step will research the methods necessary to make the energy transition technically possible, according to sub research question 1.

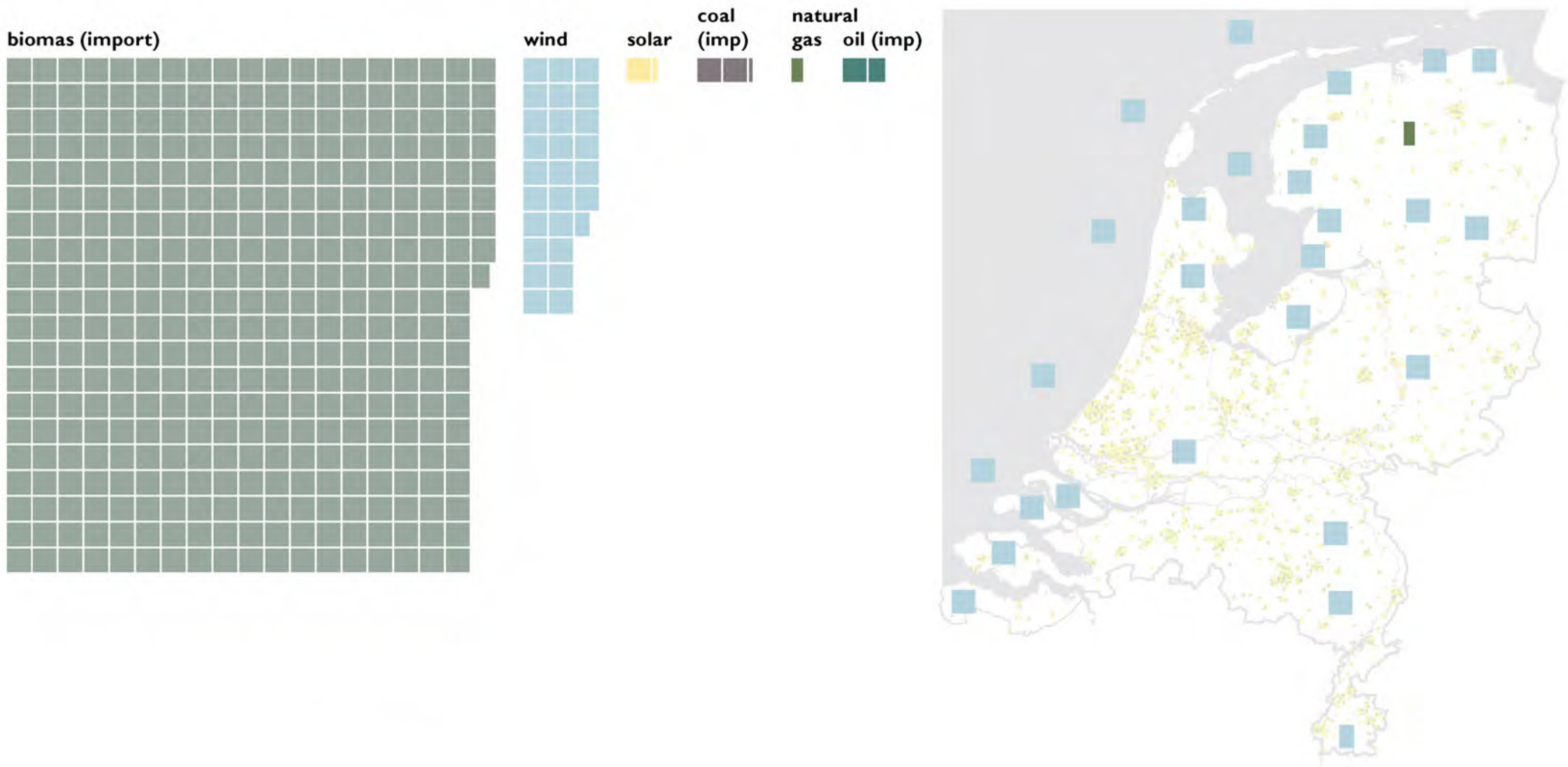
3. Search for suitable methods to alter the project area's existing energy system, making the transition to a sustainable and decentral energy system possible.

The last step of the project will be the design phase. This phase will test the transition methods and will research if the energy transition is possible. Further this phase will study if the energy transition can be integrated into an integral urban design that is beneficial for the deprived neighbourhoods and incorporates the refurbishment ambitions of the municipality. All according to sub research question 2 and 3.

4. Make a design for the project area that:

- Integrates the researched energy transition principles into the context of the project area
- Makes the energy transition, resulting in a more sustainable and less carbon emissive energy system
- Incorporates the municipality's refurbishment ambitions, so the deprived neighbourhoods in the project area can benefit from the energy transition.

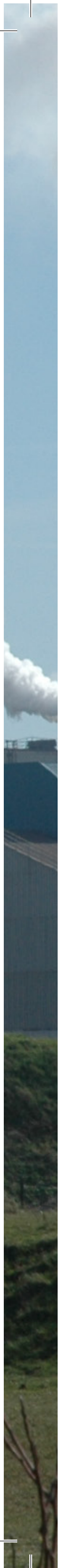
Model set-up and structure
Research steps 1 and 2 are specific for the project location and will result in an analysis of the project area, from both the energy and the urbanism perspective. Research step 3 will have a more generic character and will focus on ways to influence an urban energy system. The design phase, initiated by step 4, will eventually propose interventions for the project area in Rotterdam South. The design and research phase have a strong relation. During the process there will be a continuous transition from design to research and vice versa. This research will be tested in the design phase and hopefully this design will result in new insights that can be used in the research phase.


biomas (import)
wind
solar
coal (imp)
natural gas
oil (imp)

Spatial translation of the Dutch energy demand

image source: H+N+S (2011)

Power plant
image source: www2.natuurenmilieu.nl



Definitions

Energy
In this thesis energy refers to the amount of energy that is needed for a city to operate on a daily basis. This is the energy needed for heating, cooling, warm water, lighting, use of electrical appliances and transportation; on both household and city level. As a result, embedded energy and energy necessary for construction are not included in this study. The choice for this limitation is based on the argument that this results in a clear, tangible and manageable research subject. It is clear and tangible, because everybody can understand that our way of living requires energy. It is manageable because the amount of operating energy can be measured based on the flow approach (Benton-Short and Short, 2008). Further the required data on energy use is available as gas and electric usage. Also REAP (Tillie et al., 2009) and LES (DRO, 2011) use this approach.

The only exception is traffic. The exact amount of energy used for traffic is hard to determine and the effects of traffic interventions are hard to predict. This does not mean that traffic will be left out, but the research and interventions will not be underpinned with numerical data and will be based on theoretical principles only.

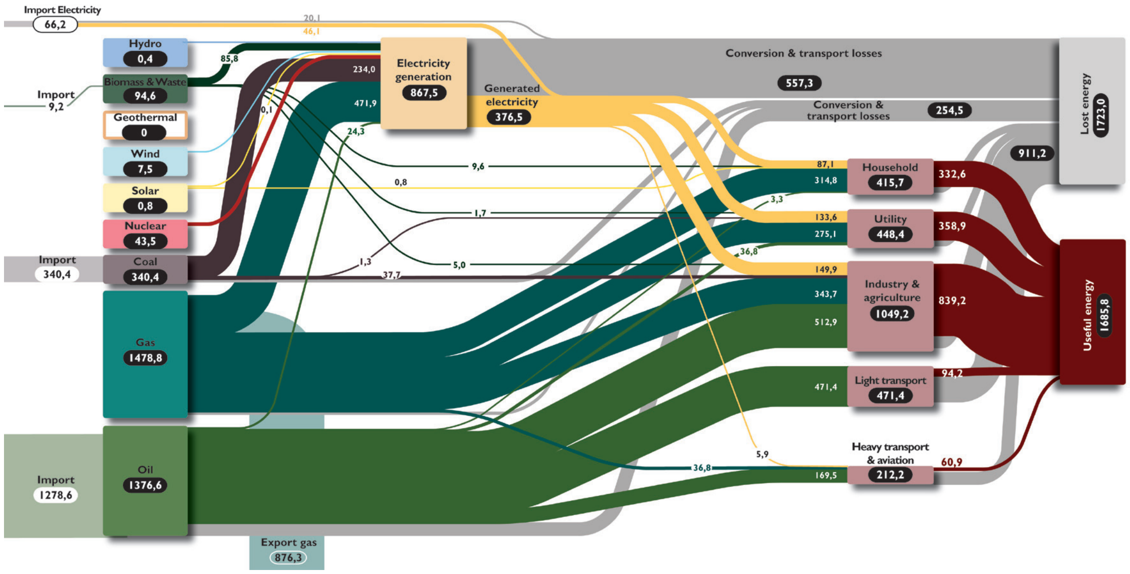
Energy units
For the energy calculations the following units will be used:

- Energy use will be measured in Joule.
- Electricity use will be measured in kWh.
- Natural gas use will be measured in cubic meters.

Conversion table:
1 kWh = 0,0036 GJ = 0,0949 m3 gas
1 m3 gas = 0,038 GJ = 10,54 kWh

Energy system
An energy system includes all the structures needed to fulfil an area in its energy demand; energy consumers, energy producers, networks and economic structures.

Energy footprint
The ecological footprint refers to the total area of land needed to support an ecosystem. ‘The ecological footprint of an urban region includes all the land necessary to support the resource demands and waste products of a city.’ (Benton-Short and Short 2008, p144) If this notion is translated to the energy issue, the following definition arises: the energy footprint of an urban region includes all the space, resources, networks and economic means



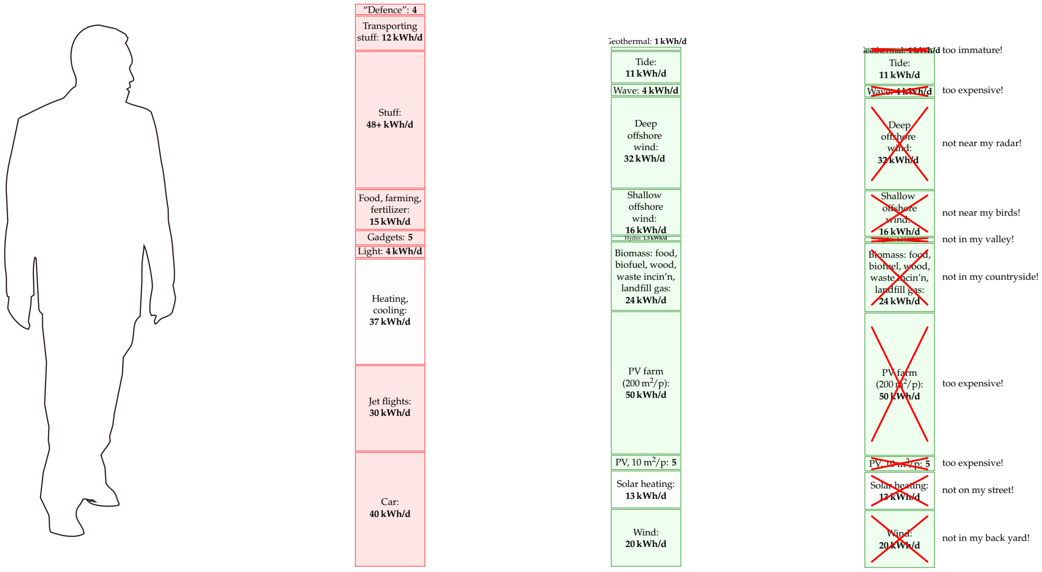
Energy system of The Netherlands in 2008
image source: presentation kWh/m2 (H+N+S 2011)

necessary to support its energy demand.

Perspective

It should be realized that the energy consumption of households and personal transport is only a small part of the total energy consumption. The Sanky diagram of the energy system of The Netherlands illustrates this clearly.

Energy consumption per person
image source: MacKay, 2009



Cities and energy

People consume food, desire warmth and require energy for transportation and communication, so energy is intertwined in daily life. Mackay (2009) explores the daily energy consumption of a person in Britain and comes to the inventory shown in the figure above. The daily consumption of a person consists of much more then the processes attributable to a city alone. It is interesting to see that the processes that can be directly contributed to the build environment (heating/cooling, car, light) are only 42 percent of the total energy demand. Especially when realized that the processes that can be contributed and influenced by behaviour (car, flights, heating/cooling, gadgets, food, stuff) form almost 90 percent of the total energy demand. Therefore it should be realized that the build environment can only play a marginal role in reducing the total energy demand and behaviour holds greater potential.

Because people concentrate in cities energy consumption concentrates here as well. 'Urbanization itself accounts for a vast amount of energy resources. Buildings can account for 40–60% of total urban energy consumption. [...] Transporting goods and services typically account for about 25% of energy consumption and may increase during the shift from rural to urban lifestyles' (Marcotullio and Schulz, 2008, p56). In the UK 'it is estimated that energy use in buildings is responsible for around 29% of all energy consumption compared with 37% for transport.' (Baker et al., 2010, p129) The numbers in the examples differ, but they all point out that buildings and transportation account for a large part of the total energy consumption. By optimizing the build environment a substantial reduction could be achieved.

To supply cities in their demand for energy, a comprehensive system of both a widespread network and large central power plants is constructed. "Centralized electricity supply structures arose not because they were more economical per se but essentially because electricity can be transported significantly faster and more cleanly than fuel. This is a particularly important factor for energy supply for cities" (Scheer, 2008, p22). Historically, fossil energy production within urban areas was undesired. Therefore Edison's concept of a decentralized energy system, which required fossil fuels to be delivered to households, was rejected. 'But the conditions that led to the model of a universally networked electricity supply with large power stations as production centres tend not to apply in the case of renewable energies.' (Scheer, 2008, p22) Renewable energy sources do not need

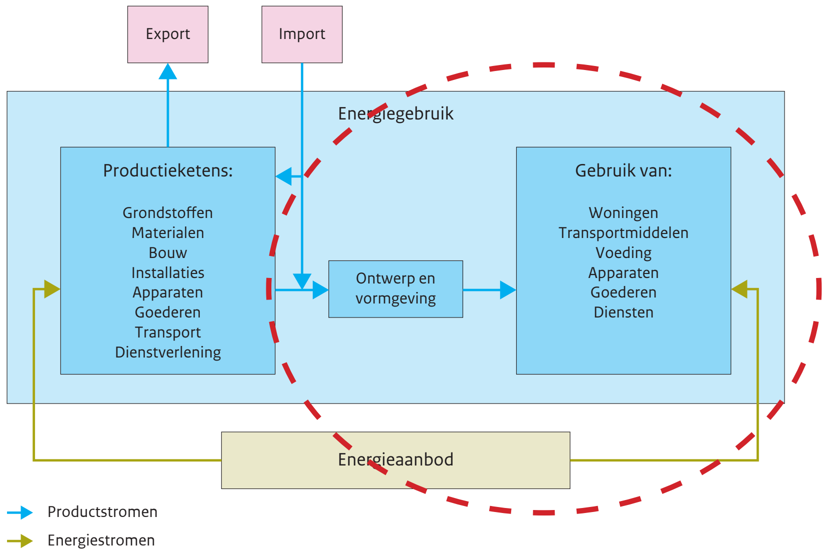


image source: Naar een schone economie in 2050 (PBL, 2011)

to be transported into the city, as wind and solar energy potentials are naturally present. Further the conversion of these renewable sources into usable energy does not cause the same health and safety risks as fossil sources historically did. Therefore the main arguments for a centralized fossil energy system do not apply for a renewable energy system.

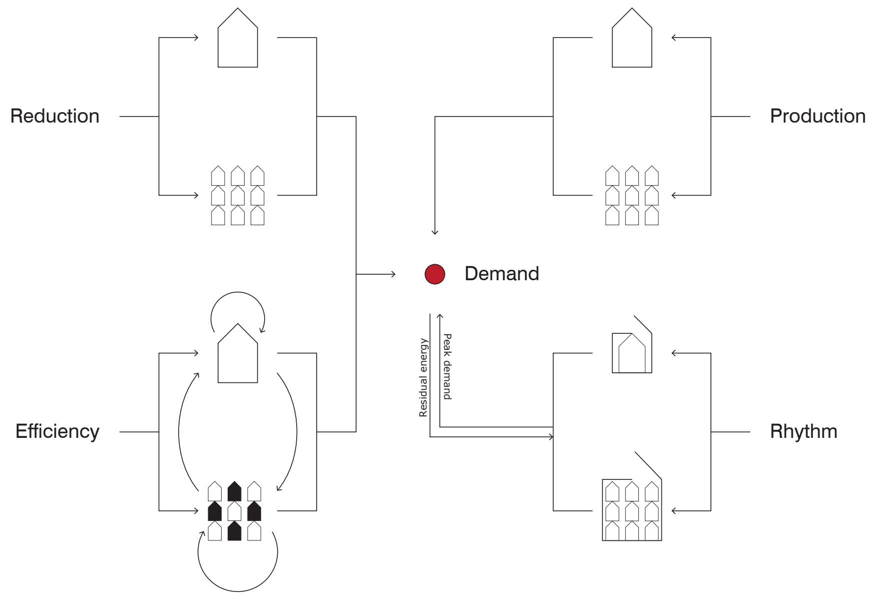
System and users

The actual energy demand depends on two factors; the way people behave (1) and the way the system, products or services are designed (2) (PBL, 2011). Influencing the energy demand requires action on both levels. The system should be designed in an energy efficient way; maximizing the return on produced energy and simultaneously stimulating users to behave energy efficient. Because the way people behave determines the actual energy consumption, technical interventions can only set the environment, but will not produce the desired results on their own.

An energy system involves producers, networks and users. These three factors together determine the energy demand, efficiency and harmful side effects of an energy system. As a result of the abundance of fossil energy sources, efficiency has never been a factor of great importance and this shows in the return of the existing energy system which is unable to pass fifty percent (H+N+S, 2012). In order to change an energy system, interventions need to be executed on all three levels. But the importance of and balance between the three factors can be contested and from the perspective of urbanism, the 'user' factor is the most interesting. Production and network interventions have a very technical scope and lack a strong relation with urbanism. Users on the other hand, especially because of their behaviour, do have a strong relation with urbanism. Behaviour is partially determined by the living environment and urbanism can influence this. Urbanism can determine the way daily processes function and therefore impact the behaviour of energy users.

The flow approach

The conference paper Scale hierarchy, exergy maximisation and urban efficiency of Salat and Bourdic (2011) defines cities as 'complex open systems [that are] almost entirely fed by flows coming from the outside'. This definition describes cities as entities that require water, air, food and energy from outside and emit waste and greenhouse gasses as a result. Hence creating a system based on flows that can be measured. The New Step Strategy (Dobbelsteen et al., 2009) introduces a



Transition steps
image source: author

methodology to approach the energy flows passing through the city and a way to grasp the energy transition. The New Step Strategy (NSS) is based on the Trias Energetica, but changes the steps a bit. This result in a theory that fossil fuels become superfluous.

The changes result in the following steps:

- Reduce the energy demanded
- Improve the systems efficiency (use energy from waste flows; energy cascading, smart combinations)
- Generate energy sustainable

In theory the NSS creates an environment in which fossil fuels are no longer needed. All energy is obtained by renewable sources and energy cascading. The technical energy part of this thesis will follow the NSS to structure the study.

The vision of a decentral energy model

To structure this research and design, the vision of a decentral energy system is introduced. This vision is based on the hypothesis that a sustainable dencentral energy model is the goal of the energy transition. This means that an urban area is completely independent for its energy supply. Ideally with the ability to deal with rhythm fluctuations, such as peak demand and intermittency problems related to renewable energy production. The Danish *Samso Island* can be seen as a precedent for such an energy system, with the exception that the island is still connected to the main grid to counter intermittency.

Further it is expected that financial flows resulting from a decentral energy system will (partly) stay inside the urban area. These financial means can be used to make investments in the urban area itself and will hopefully result in new job opportunities, from which the inhabitants can profit. And with the expectation that fossil energy prices will rise in the near future, a self-sufficient energy system can become a strategic advantage.

Landscape resulting from peat harvesting
image source: static.nationalgeographic.nl/pictures/

Transitions

The dependence of cities on external energy sources has a long history and in the past century this dependence only increased. Wood, peat, coal and natural gas have provided the energy cities needed and the harvesting of these recourses has left traces in the surrounding landscape. The availability of large amounts of inexpensive fossil energy sources influenced urban growth: ‘The dramatic rise in external energy inputs due to low energy prices has allowed the emergence of energy greedy structures. Crazy urban sprawl has been coupled with a drop in urban density and compacity: both transport and building need more energy’ (Salat and Bourdic, 2011, p3). Low energy prices and the availability of extensive networks for gas and electricity have enabled cities to grow extensively without considering energy consumption and energy efficiency.

From an urbanism perspective, the urban growth was enabled by principles developed by the modernist movement. Tree-like structures where used to guide urban extensions and these structures became of great importance in post war city planning (Alexander, 1966). Together with rising levels of car ownership, the development of road transport provision and the location decisions of individuals and businesses in and around cities, unlimited city extensions became possible and desired. This new freedom of transportation, with ‘the dominance of the car as the principal, or sometimes sole, form of transport to access everyday activities’ (Ferguson and Woods, 2010, p53) made traditional urban structures redundant. It created new urban forms typified by the decentralisation of activities and unstructured urban expansion into the countryside (European Environment Agency, 2006). Resulting in low dense urban sprawl with fossil fuel based transportation.

Buildings and city form

The relation between energy consumption and building (or urban) form is debatable (Baker et al., 2010, Larivièr and Lafrance, 1999). The gradual energy transition of the last hundred years, from wood burning stoves to low temperature under floor heating, did not fundamentally change dwellings or building blocks. Buildings from over a century ago still perform fine this day, only the technical part changed significantly. One could state that buildings and urban structures easily adapted to the transition and that building concepts have hardly been affected. But a footnote should be added to this statement as Salat and Bourdic (2011, p3) state that: ‘The historical urban structures that have survived until now are among the most efficient ones. They are pedestrian friendly and require less energy for transport. They are compact and require less energy for heating and/or cooling.' This implies a survival of the fittest mechanism (partly) based on energy efficiency and buildings that were unable to adapt did not survive the transitions.

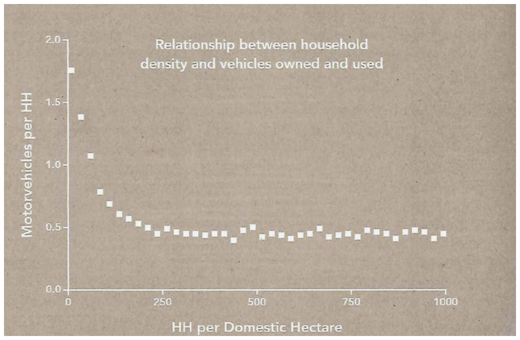
Baker et al. (2010) are sceptical about the relation between urban form and energy use. Their article questions the relation and states that energy use depends more on users then urban form. For future developments, Baker et al. (2010, p131) make an interesting observation: 'However, crucially, as heat loss standards improve, the benefits of medium to high densities will be far less significant in this respect, while the disadvantages of very high densities and the lack of natural light, though mitigated, will remain.' This is a very relevant observation, because when all buildings are isolated to the highest standards, morphology will be of very little influence on energy consumption. The building itself will require as limited energy as possible, only the size (total floor area) will be of influence, so a smaller building will result in a smaller energy demand.

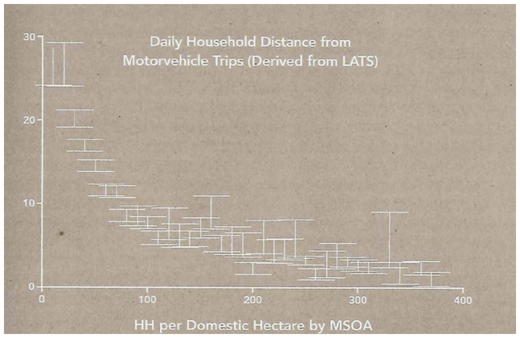
From this perspective, users (people) will be the main factor determining energy consumption. 'The determinants of energy use are not simply determined by the nature of the built form as it is recognised that life style and the dynamic effects of occupant behaviour, in particular appliance use, and of retrofitted energy efficiency measures, are likely to obscure static physical influences.' (Baker et al., 2010, p131) So the way a building is used will determine the energy demand, not the building itself or the urban structures.

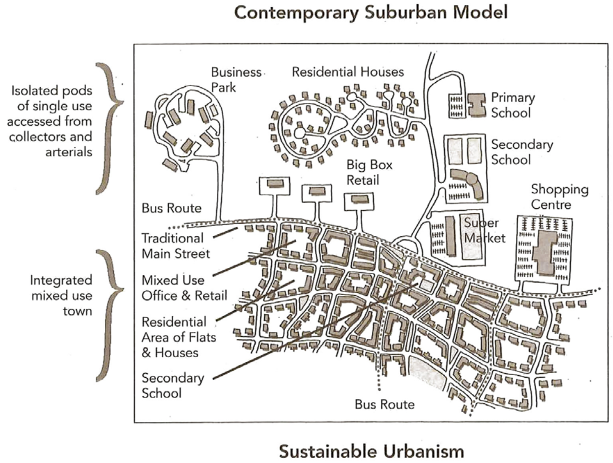
Urban structures and transportation

Although the relationship between urban form and energy use is not that strong and still under academic debate, there seems to be a stronger relationship between urban structures and transportation volumes. Research by Newman and Kenworthy (1989), Chu (2002), Bhat and Gio (2007), Dittmar (2008) and others imply that urban composition, density, program mix and proximity of public transportation are of influence on transport behaviour. Transportation is responsible for a significant part of the energy consumed in cities and vehicular, personal transport is largely based on fossil fuel. Groups like *the New Urbanists*, the *Urban Villages Campaign* and the *Urban Task Force* promote the return of traditional urban forms with high density housing, mixed land use, proximity to public transportation and grid pattern road layouts,

Man carries coal with a sled in 1946
image source: www.gemeentearchief.rotterdam.nl







Tree and semi-lattice structure

image source: Transport and Neighbourhoods (Dittmar, 2008)

based around the traditional block with provisions for walking and cycling (Panerai et al., 2004). The groups claim that 'these urban forms will reduce travel by car by encouraging walking and cycling to local amenities and the use of public transport for longer journeys' (Ferguson and Woods, 2010, p54).

There are a few documented principles and conditions that claim vehicular transportation reduction. First urban areas should offer viable local amenities and adequate public transport stops. For an urban area to offer these conditions accessible on foot, a population threshold of 7,500 inhabitants with a minimum density of 100, or better 150 households per hectare is required (Urban Task Force, 1999). Further ´the distances between home and local amenities and public transport stops should be walkable and the area should be located along an existing public transport route or, if this is not the case, the installation of such a public transport route should become viable due to the achievable population size' (Frey and Bagaeen, 2010, p168). The research originated by Newman and Kenworthy (1989) sets higher urban densities as the most important factor for lowering the distance travelled by motor vehicle. Their research on transportation in relation to urban densities clearly shows that an increase in density results in a decrease in mileage travelled by vehicular transport.

Another way to reduce transport emissions is to develop low or zero carbon transport technologies (Dittmar, 2008). The electric car for example does not emit greenhouse gasses and has a four time better efficiency then a conventional gasoline powered car (DRO, 2011). These technical innovations can help improve the efficiency of vehicle transport, but when and how is hard to predict and cities should be flexible enough to adapt to these new technologies. On the other hand, roads should be designed for pedestrians and cyclists, instead of cars. Giving the street a place status instead of a movement status (Department for Transport, 2007) and offering space in which slow transportation can flourish.

The next principle that needs to be discussed is the structure of street patterns. Alexander's famous paper 'A city is not a tree' (Alexander, 1966) argues against the use of tree like structures in city planning. He pleads for a 'living city' based on a 'semi-lattice' structure. His reasoning is based on the same city principles Jane Jacobs (1961) describes in *The death and life of great American cities*. From a technocratic perspective, the tree structure has long been seen as the most efficient city structure (Salat and Bourdic, 2011) but recent

Place and movement status
image source: Manual for Streets (Department for Transport, 2007)

research by Dodds (2010) and Corson (2010) argue that Alexander's semi-lattice structure is far more durable. Having the capacity to adapt better to changes in urban program and not being as vulnerable as tree structures. This in accordance to the theories by the New Urbanists, the Urban Villages Campaign and the Urban Task Force.

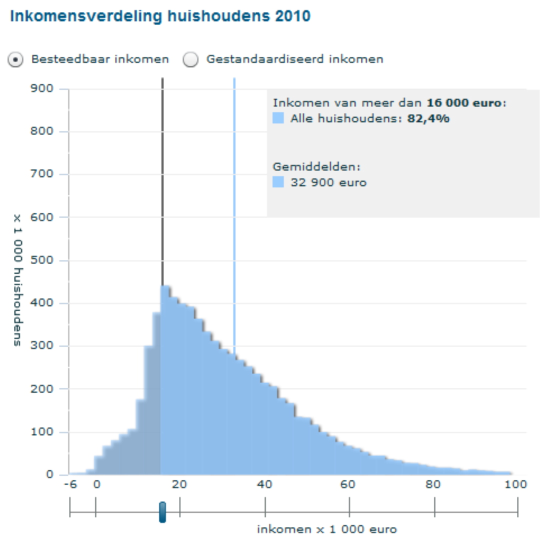
Other morphological research by Salat (2009) shows that various urban structures use different amounts of energy. And again, modernistic morphological structures use more energy than pre-war and historic inner-city urban structures. 'There is a growing recognition that a lot of modernist urban structures fail in optimising energy use for transport especially, but also for buildings." (Salat and Bourdic, 2011, p3) In the debate about the preference for tree or semi-lattice structures, Dittmar as part of the New Urbanist movement also argues in favour of the semi-lattice structure. He argues for a city with an intricate, semi-lattice street network in combination with high densities, a diverse mix of functions and good public transportation services (Dittmar, 2008). These conditions also has the intention to reduce the need for vehicular transportation and to enable public means of transportation.

Next to the plea for semi-lattice structures in Urbanism, it is interesting to see that the electricity network is moving towards a semi-lattice grid as well. The electricity grid always depended on strong tree like structures, but with the introduction of the so called smart grid a semi-lattice structure is introduced. Mostly for reasons related to reliability, but also to offer the possibility of a 'two way' electricity net and to counter rhythm fluctuations caused by sustainable energy production.

Current discussion in literature

Not all literature agrees on the principles that claim to reduce transportation. Ferguson and Woods (2010) question these claims on four grounds:

- The ease and flexibility offered by the car can favour vehicular transport over other means of transportation.
- The time and cost saving gained by using local amenities may lead to additional travel for other purposes.
- The reducing principles are based and organised around the residential location and other, for example work related travel may not be influenced by these principles.
- The personal preference for vehicular transportation. If someone prefers car travel, he might go to urban areas that offer the



Afrikaanderwijk 2008	
Households (hh)	3.220
Density	79,6 dwellings/ha
Average Income/hh	€ 14.300,-
Unemployed	24 %
hh under poverty line	27%
Average CITO score	530,6
Bloemhof 2008	
Households (hh)	4.940
Density	81 dwellings/ha
Average Income/hh	€ 14.300,-
Unemployed	22 %
hh under poverty line	27%
Average CITO score	529,0
Hillesluis 2008	
Households (hh)	3.960
Density	57 dwellings/ha
Average Income/hh	€ 14.600,-
Unemployed	22 %
hh under poverty line	26%
Average CITO score	529,6

Average income project area
image source: CBS 2012

best accommodations for this means of transportation and this person will not choose to live in high dense urban areas designed to reduce vehicular transportation.

Further it is found that income has a relation on trip making behaviour. ´Households with an income of less than £10,000 are found to make fewer trips overall and trips by car than households with an income of between £20,000 and £30,000.´ (Ferguson and Woods, 2010, p63) Wealth in general plays an important role in energy consumption. With the growth and development of society, the demand for energy grew as well. Historically ‘the availability of increasing energy supplies enabled humans to develop a societal structure more complex than that of the early hunter-gatherers’ (Pimentel and Pimentel, 2008, p1). But with further growth of prosperity, energy consumption continued to grow and this process is still continuing. Increase in wealth and a growing energy demand are still related till this day, as is seen in Rotterdam where the more wealthy households consume significantly more energy than the less fortunate ones (Casanueva, 2010). Therefore reducing our energy consumption creates the risk of reducing our wealth and we should be wary that the transition does not affect quality of life.

Conclusions based on the literature review

Based on the literature review a few conclusions can be drawn.

- People consume energy and because they concentrate in cities, energy consumption is concentrated in cities as well.
- The build environment and personal transport account for a large part of the total energy consumption (40-60 percent).
- A lot of the measures to reduce energy consumption have a technocratic nature.
- Behaviour and lifestyle strongly influence energy consumption.
- A dense, mixed urban area can reduce the energy consumption per capita.
- Wealth is related to energy consumption.

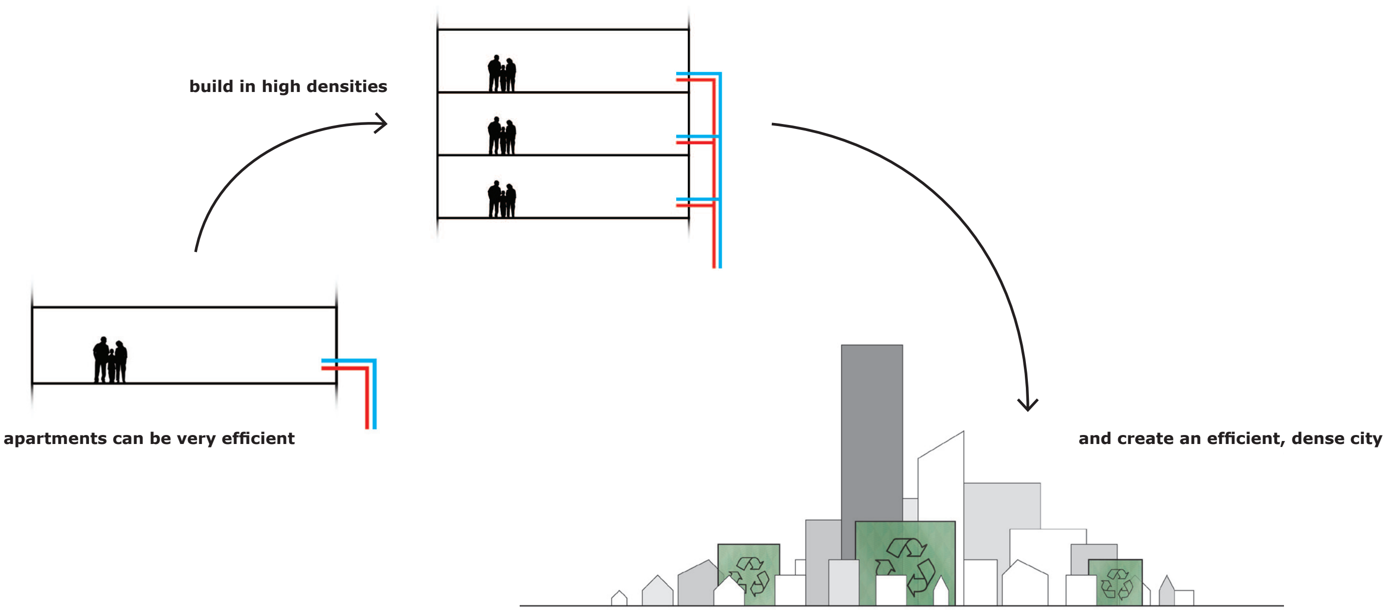
In my opinion Urbanism has the role to offer a setting in which the energy transition can become a success. A lot of the technocratic measures miss this first step and strange things like energy efficient strip-malls arise. An unfortunate situation because the living environment plays a key role in energy consumption and a smart living environment can stimulate the energy transition and minimize the adverse affects. Urbanism can determine the living environment and this should be the role of the profession: creating environments in which people can life energy-lean while retaining quality of life.

Towards a strategy

Energy efficiency strongly relies on human behaviour. Certain urban typologies can set the environment in which people can behave energy-lean, while maintaining quality of life. On a generic level there are two typologies which offer an energy-lean lifestyle. The typologies offer diverse, almost opposite, living environments and result in two entirely different lifestyles. But the two typologies are not mutually exclusive and are not as clear divided as they seem at first sight. All sorts of combinations and variations are possible. The typologies are based on the reasoning that every household needs a certain amount of energy to function, just as the *Mackay* reasoning. The exact amount of energy depends on the household's characteristics and is therefore hard to predict. Maybe future innovations cause a dramatic decline in energy consumption, maybe growing wealth will produce a growing energy demand. This is uncertain and of little significance in this study. Far more interesting is the fact that households always need energy and this energy needs to be provided. Here the two typologies can be implemented.

Integrated typology

The integrated typology is based on the hypothesis that cities are the answer to the energy transition challenge. Cities offer the possibility to integrate everything, by creating smart designed communities at high densities. Research shows that people living in high dense environments use less energy per capita than people living at lower densities. The benefits of high densities boil down to two points. It offers the opportunity to implement smart (technologic) systems that can significantly increase the efficiency of energy systems. Methods like energy cascading, smart energy combinations or the drilling of geothermic wells all require urban mass at a certain density. Without density, these methods will not work or be economically viable. Another reason for creating high densities is the expected decrease of (vehicular) transport. High densities with a good mix of functions show a decrease of travelled miles. The need for daily commuting is reduced and trips can more easily be made on foot or by bike. Moreover higher densities offer the possibility for a viable public transport system that offers an energy efficient way for travelling long distances and proving access to jobs and wealth.



Integrated typology
image source: author

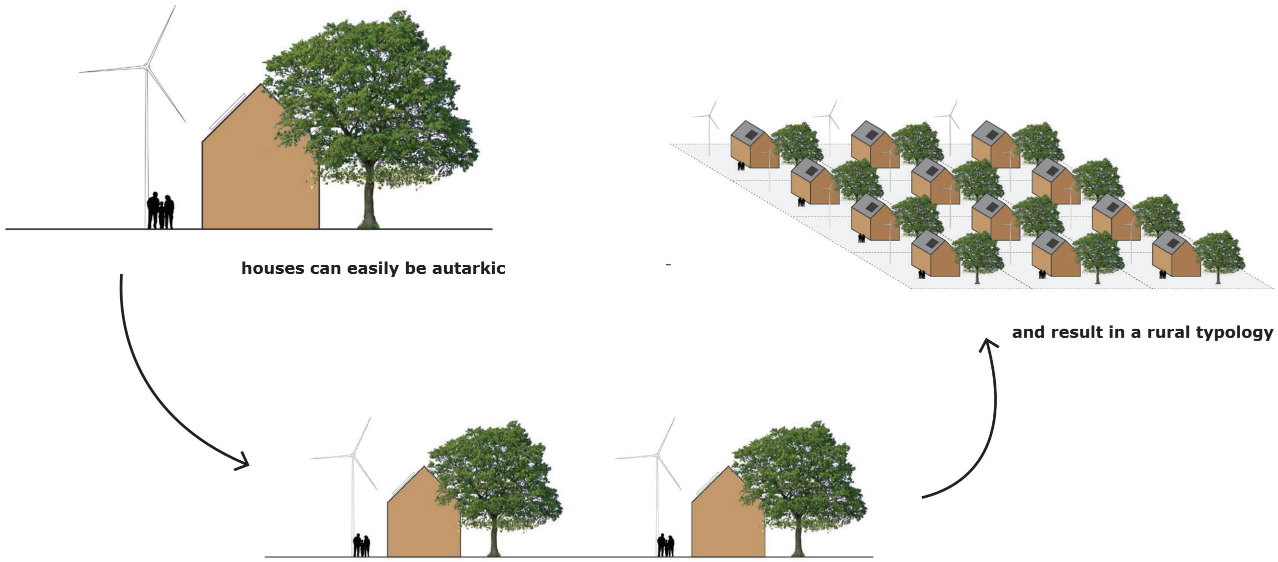
The book *Green Metropolis; why living smaller, living closer, and driving less are the key to sustainability* (Owen, 2009) highlights the possibilities of the integrated typology. 'Placing one and a half million people on a twenty-three-square-mile island [of Manhattan] sharply reduces their opportunities to be wasteful, enables most of them to get by without cars, encourages them to keep their families small, and forces the majority to live in some of the most inherently energy-efficient residential structures of the world; apartment buildings. It also frees huge tracts of land for the rest of America to sprawl into' (Owen, 2009, p4). Next to the system advantages this typology stimulates energy-lean behaviour, while offering a normal living environment. An advantage that holds great promises.

Owen also argues in favour of attractiveness. 'Planting trees along city streets, always a popular initiative, has high environmental utility, but not for the reasons that people usually assume: trees are ecological important in dense urban areas not because they provide temporary repositories for atmospheric carbon – the usual argument for planting more of them – but because their presence along sidewalks makes city dwellers more cheerful about dwelling in cities.' (Owen, 2009, p12) This example perfectly illustrates the importance of quality and the dilemma of the decentral energy model. On one hand it is important to use all the energy potentials available, but on the other hand it is very important to make cities as attractive as possible to attract dwellers. Big wind turbines or solar panels are according to today's standard not very attractive and quality-enhancing.

Autarkic typology

The second typology is based on the hypothesis that every household should provide its own energy. For a home to provide its own renewable energy, space is needed. The resulting densities are lower than the integrated model's densities and therefore this model creates a different living environment. The autarkic model results in a suburban society consisting of self-sufficient houses. This typology is far less complex than the integrated model and does not depend on new technologic innovations. It creates an individual society with passive housing [which is already available] and an adapted, energy efficient lifestyle. But the required lifestyle looks like the rural lifestyle from a hundred years ago, a self-sufficient lifestyle where household grow their own food and supply their own energy. With the important modification that PV cells, solar heat collectors and small wind turbines provide the energy instead of a wood burning stove. This

Autarkic typology
image source: author



typology seems like a step back instead of a step forward, and has one mayor disadvantage: it does not give a solution for transportation, so the access to jobs and wealth is limited.

Both typologies can be pushed to the limit to produce utopian future scenarios, but the integrated typology seems to be more suited for the near future. The UN outlook predicts a highly urbanized society, which fits the integrated model better. There is also another reason for choosing the integrated typology. Unless new technologies solve the transportation issue, the autarkic typology seems already full grown. It does not offer exiting promises and will probably result in a fall back to more historic lifestyles. Suited for certain groups, but not fit for an urbanizing world. The integrated typology on the other hand is only in its infancy. This typology seems to hold great promises for further development, offering new urban lifestyles that take a step forward.

The Dutch situation

Although reasoning favours the integrated typology, the current Dutch housing market does not. High dense apartments are forced out by the wish for gardens and newly constructed apartment buildings stay vacant (also due to economic uncertainties).

Still there is an important claim in favour of creating integrated living environments: when energy becomes more expensive, the poorest classes will be affected first. These groups need an environment in which they can still live according to normal standards. The integrated typology offers a living environment in which people can live without the need to consume great amounts of energy. So if energy poverty becomes a serious problem, this typology can offer the living environment in which people can still function normal.


Will this be our future...


...or this?

Generic principle precedent

image source: Foster & Partners (Topos, 2011)

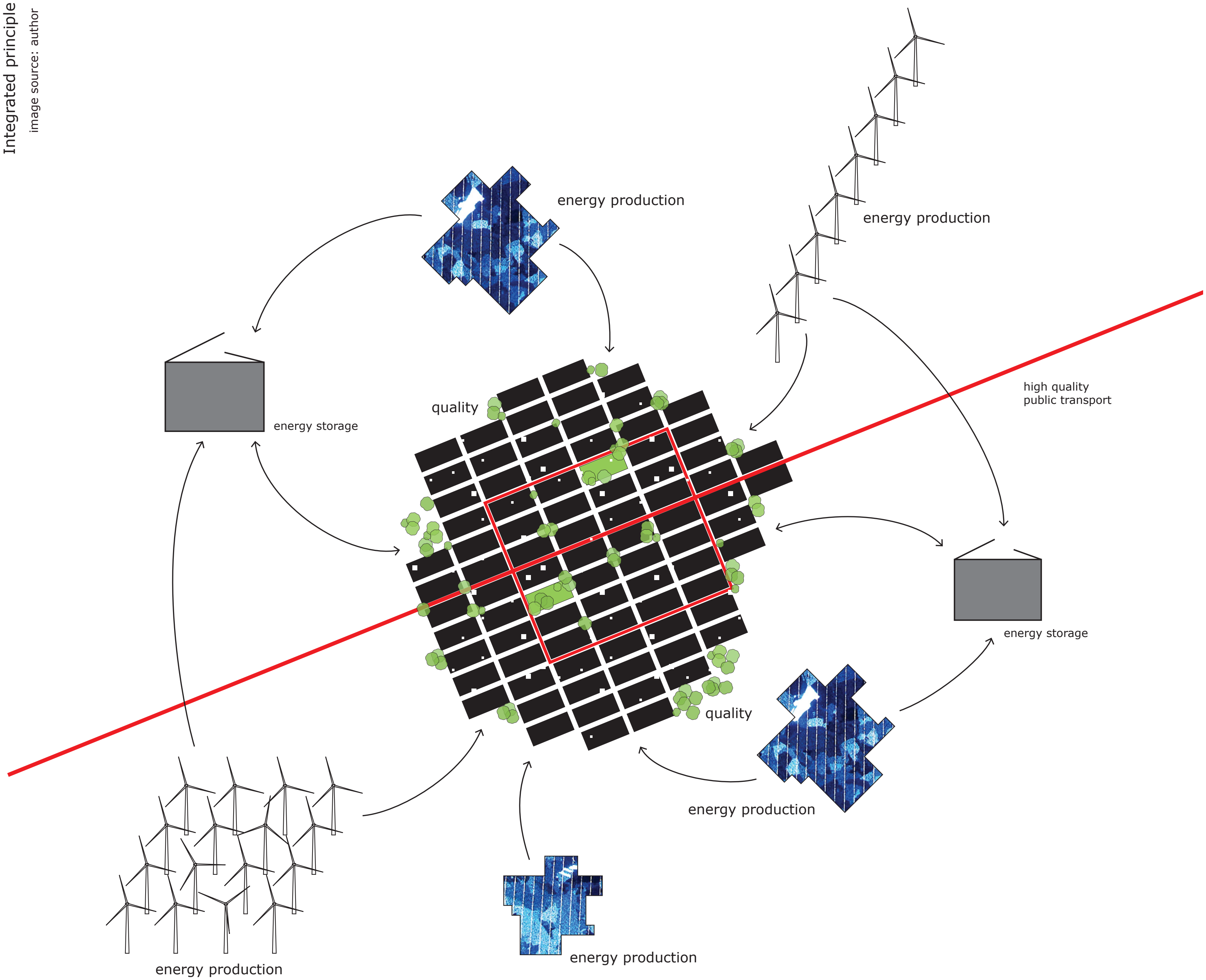
Generic integrated strategy

The theory and reasoning result in a generic city principle following the *Masdar City* precedent of Foster & Partners. This principle suggests a dense city based on the integrated typology, that offers an environment in which the energy transition can be become a success. Following the principle: the better the city becomes, the more space is freed outside to produce energy and food.

1. Offer a living environment that stimulates energy lean-lifestyles while retaining the current standards in wealth and quality of life.
2. Make this environment as efficient as possible.
3. Make use of the local energy potentials (production and intermittency).
4. Make it attractive! We should live in it!

The case study of Rotterdam demonstrates that it is important to offer the whole concept: energy reduction, efficiency and renewable energy production. All these aspects are needed to reach the climate goal and the role for urbanism involves designing the living environment. The urbanist should envision what this environment could be and how it can work. Especially making the environment attractive and attracting dwellers to the dense environment.

Integrated principle
image source: author



Municipality of Rotterdam
image: Google maps

Regional scale

Energy transport
image source: www.bam.nl/sites/bamnl/files/site_images

An energy strategy for Rotterdam

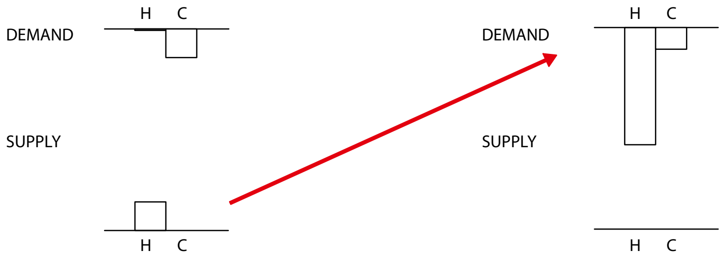
The objectives of the integrated energy strategy are clear: offering a living environment that stimulates energy-lean lifestyles, making the environment as efficient as possible, using the available energy potentials and making the living environment attractive. In the specific case of Rotterdam South these objectives need some nuance, because the ratio between city related energy demand and total energy demand is imbalanced. The enormous energy demand of the harbour dwarfs the energy demand of the city and therefore is it questionable if it is smart to combine both in one carbon reduction goal, as the Rotterdam Climate Initiative suggests. The harbour uses energy for industrial processes, so city strategies do not apply here. As a result the harbour area is excluded from the case study, with the exception of waste energy exchange from harbour to city. This has great potential to reduce the energy demand of the city and is therefore included.

The energy strategy for the project area in Rotterdam South is based on the integrated typology and is structured according to the following steps: living environment, efficiency and local energy potentials (production and intermittency). Or according to the NSS: reduce – reuse – produce. The objective of urbanism is to allow all the different processes to flourish and create an attractive living environment that stimulates people to live energy-lean lifestyles.

Living environmnet

The first and most important step of the energy transition is creating a living environment in which people can live energy-lean. Reduction depends on system and behaviour; the living environment should facilitate both. Offering a context for the techniques to prosper and creating a fantastic living environment in which people can life energy-lean. According to the integrated typology, the resulting environment is a high dense city according to the following set of characteristics:

- A preferred density of a 100 – 150 dwellings per hectare (Newman and Kenworthy, 2008).
- Grid pattern road layouts, in a semi lattice urban structure based around the traditional urban block (Alexander, 1966; Panarai et al, 2004; Dittmar, 2008).
- A mix between dwellings, offices and amenities with a good hierarchy. With the aim to create a Jane Jacobs' like city life.
- Roads and public space designed for slow traffic to encourage walking and biking (The Department for Transport, 2007; Dittmar, 2008).



Smart combinations
image source: REAP (Tillie et al., 2009)

- A (already existing) dense public transportation network that is accessible by foot or by bike (within 5/10 minute walking range or 5/10 minute biking range, 400-800-1600 meter radiuses) (Frey and Bagaeen, 2010).
- An attractive living environment to ensure the willingness of dwellers to live in the created city and live an energy-lean lifestyle. (Koornstra, 2008; Owen, 2009).

Efficiency

Within a dense urban area a highly efficient energy system can be created. Most of the system interventions to increase efficiency require urban mass. A high dense urban area offers this mass. The interventions largely have a technical scope and are therefore not part of the urbanism specialization, but a city should be flexible enough to accommodate these technical interventions.

Reduction

Reducing the energy demand of buildings is mostly an engineering assignment. Urbanism has not much influence on the energy performance of buildings and measures such as insulation, heat recovery and solar water heaters are all limited to the scale of the building or block. The city should be flexible enough to assimilate all these future refurbishments and innovations.

Reuse

The key to enhancing energy efficiency is making full use of an energy source's entropy. The existing energy systems are not efficient when it comes to entropy and does not reuse waste energy. For example: big power plants are located near the sea (Eemshaven) and the residual heat energy is disposed into the sea. This results in squander, because the heat energy can be reused to heat thousands of houses. Energy cascading is a way to use this redundant heat energy. It uses waste [heat] energy based on cascading principles and transfers the energy to adjacent heat seekers. A power plant that produces waste energy of 90 degrees can transfer this energy to a residential neighbourhood that uses the energy to heat buildings.

Energy cascading requires a heat network (district heating) and a waste energy source. The harbour area of Rotterdam has great potential to become a waste energy source and supply the city with redundant heat energy. A large network is required for this goal.

Smart combinations

Different urban programs have their own energy profile. Some functions demand warmth when other functions demand cold. When making clever combinations, different urban programs can fulfil each other's energy demand. This principle requires a mix of different functions, consistent to the reduction principles for transport and behaviour.

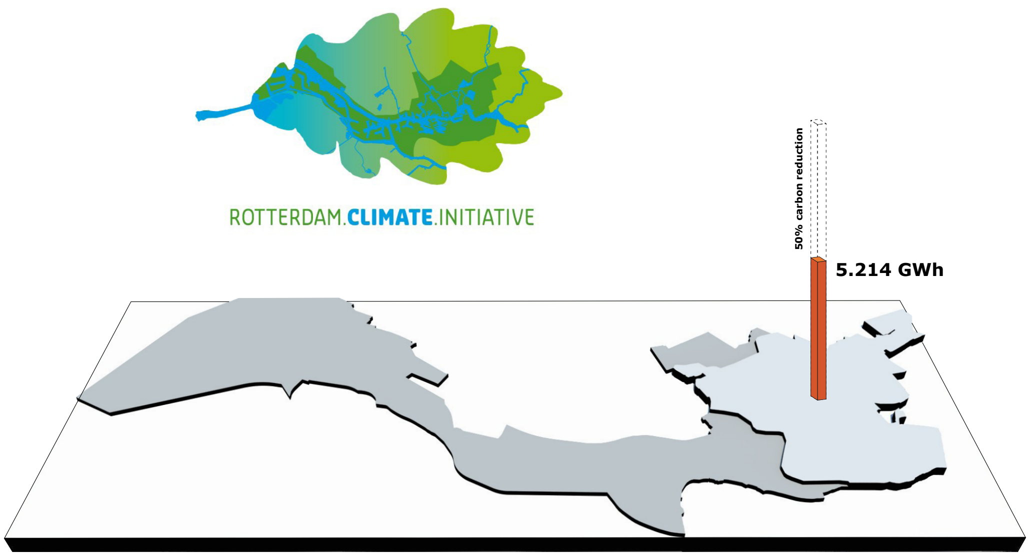
Energy potentials
Even the most efficient urban areas need energy to function and this energy has to be produced. Renewable ways of energy production are space consuming. The big challenge is to allocate this space. Energy production is welcome in the integrated high dense typology, every Watt produced is beneficial, but under one strict precondition: the energy production should improve the attractiveness of the urban area. If a form of renewable energy production is harmful, noisy, smelly or just plain ugly, it is undesired and should be placed outside the urban area. If a production form complies should be judged per situation and it is not possible to generalize this. Standards differ per region and time period and (future) innovation can change the criteria.

Interesting production sources for Rotterdam are large wind turbines, solar PV cells and geothermic wells. Each source has its own characteristics and the potentials of these energy sources will be explored in the *interventions* chapter.

Intermittency
The last problem to solve in a renewable energy system is intermittency. Energy demand is not a constant factor and the demand varies during the day, week and seasons. The energy demand consists of a constant base demand and a fluctuating peak demand; ten per cent of the time demands fifty per cent of the capacity (DRO, 2011). In addition to an unstable energy demand, renewable energy production (wind and solar) is unstable as well. Therefore a solution has to be invented to bridge the phase differences. This can be sought in tuning the energy demand or creating buffers to overcome the rhythm gaps. The introduction of the *'smart meter'* is seen as the first step to a more flexible demand and is expected to influence the behaviour of consumers. Energy buffers, on the other hand, are in development. It could be that technological innovations come up with the answer, or maybe these buffers introduce new (urban) program that needs to be implemented.

Rotterdam has the unique potential to store energy in its redundant port basins. The morphology of these basins makes it possible to use the basins as energy lakes that can be drained and filled to store energy. Next to this technical potential, a port basin with a fluctuating water level can offer a spectacular environment. In the *intervention* chapter this potential is further explored.

Reduction goal
image source: author



Interventions

When reviewing the area from the municipal scale, two distinct areas stand out. One area filled with houses and the other accommodates the harbour. According to the integrated theory the area filled with houses should be dense, efficient and attractive. The surrounding area should be used for production and a pragmatic landscape should arise. But when the spatial footprint of the existing energy demand of Rotterdam is projected on the area, a serious problem occurs. The spatial pressure creates an impossible mission: there is just not enough space to produce the required renewable energy. Future technologies should dramatically improve the return of renewable energy production or people need to reduce their energy demand, otherwise the transition challenge becomes infeasible. Especially the additional spatial pressure due to biomass production becomes an insoluble challenge and can be seen as unrealistic. Therefore it is interesting why biomass is such a hot and political pushed topic...

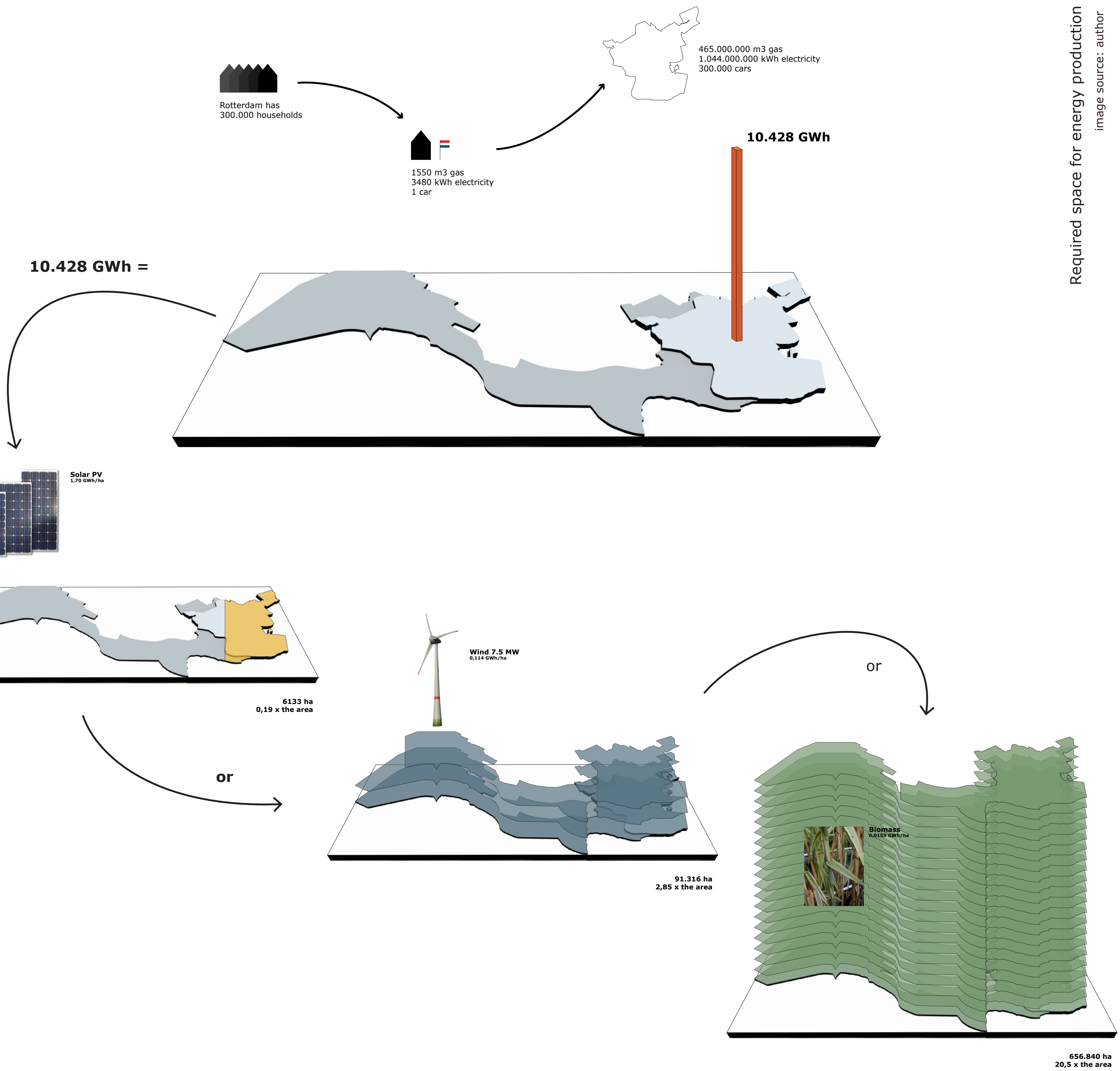
In addition to the economic limitations of building a renewable energy production system of this magnitude, the spatial impact of such a system is just too big to solve in a realistic case. Reduction is essential and the current energy demand of Rotterdam becomes the Achilles heel of the transition. To attain a renewable energy system the energy demand has to be reduced. This requires a living environment that stimulates behavioural changes and therefore interventions on the city scale. The goal of the Rotterdam Climate Initiative states a carbon reduction of fifty percent in 2025. Using crude reasoning this results in a reduction/ renewable production wish of 5.214 GWh.

Starting on the municipal scale, several energy potentials are explored.

Wind turbines

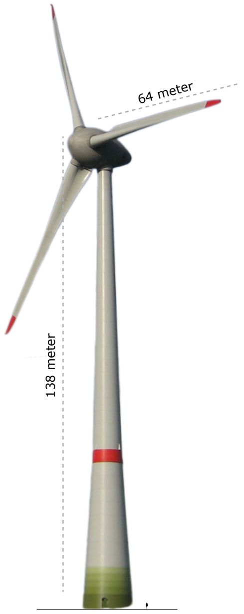
Placing large wind turbines in the harbour forms an interesting energy potential. The harbour area has a very large and inhuman scale, which suits wind turbines well. Wind turbines become more efficient when their size increases and the harbour area has the size and scale to accommodate the largest type. Big turbines have a big footprint and are hard to place without causing nuisance. That is why I propose to erect 56, 7.5 MW turbines along the highway. The 140 meter wind turbine is the biggest available and produces the highest return possible. Placing them in a line or field requires a minimum distance of 750 meters between each turbine. Because the harbour is filled with dense industrial program, placing the turbines in a line

Required space for energy production
image source: author



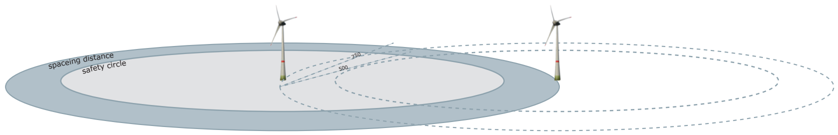
Wind energy potential

image source: author



Enercon E-126

power	7.5 MW
height	140 meter
amount	56
costs	€ 11.000.000
investment	€ 616.000.000



Wind turbines
image source: author

is the easiest. The highway offers such a line and therefore forms the best place to put them. Also aesthetic arguments give a good reason to place them in a line. Placing large turbines in a line results in a majestic site; a snake of mega wind turbines crawling through an industrial landscape.

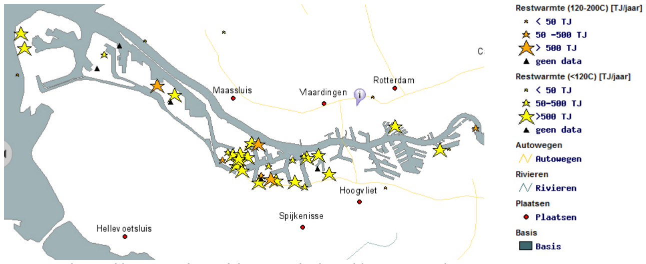
The wind turbines produce 639,8 GWh annually, which is 12 percent of the Rotterdam climate goal. A small return for such a big intervention, but I believe that Rotterdam should make a statement to show it is serious about the climate ambitions. The business case behind these wind turbines is quite interesting. Based on a Belgium precedent, the 7.5 MW Enercon E-126 cost €11.000.000 each. With the return they have in Rotterdam, this proves to be profitable and the money part of this business case forms no barrier for erecting them (based on a €0,22 kWh rate).

Waste heat
The harbour houses a lot of heavy industry and the Energieatlas of Agentschap NL shows the energy potential of this industry. The harbour can offer a great amount of residual heat, giving Rotterdam a great opportunity to use the harbour in a climate positive way. The city can use the energy to heat houses, but to harvest the energy a large network has to be constructed that transports the energy from harbour to city. The water structure of the Maas forms an opportunity to accommodate this network, because big pipes can easily be placed on the bottom of the Maas. When the network reaches the city, the energy has to be transferred to the (new) district heating net and maybe a buffer should be introduced that can store the energy.

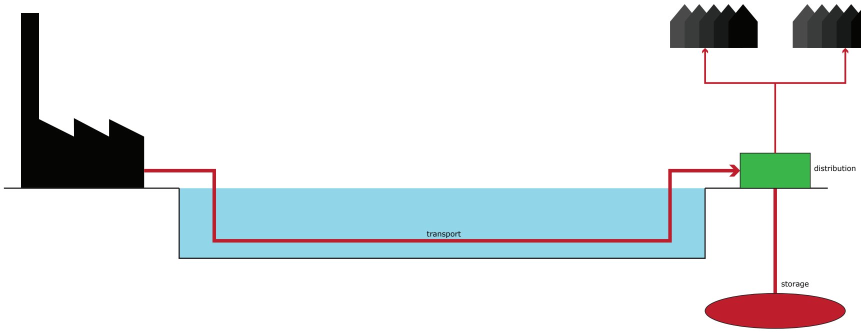
The harbour's waste energy has great potential and can theoretically offer all the necessary warmth for Rotterdam. Therefore the existing gas consumption can be drastically reduced. For this example a fifty percent reduction of existing gas consumption is assumed.

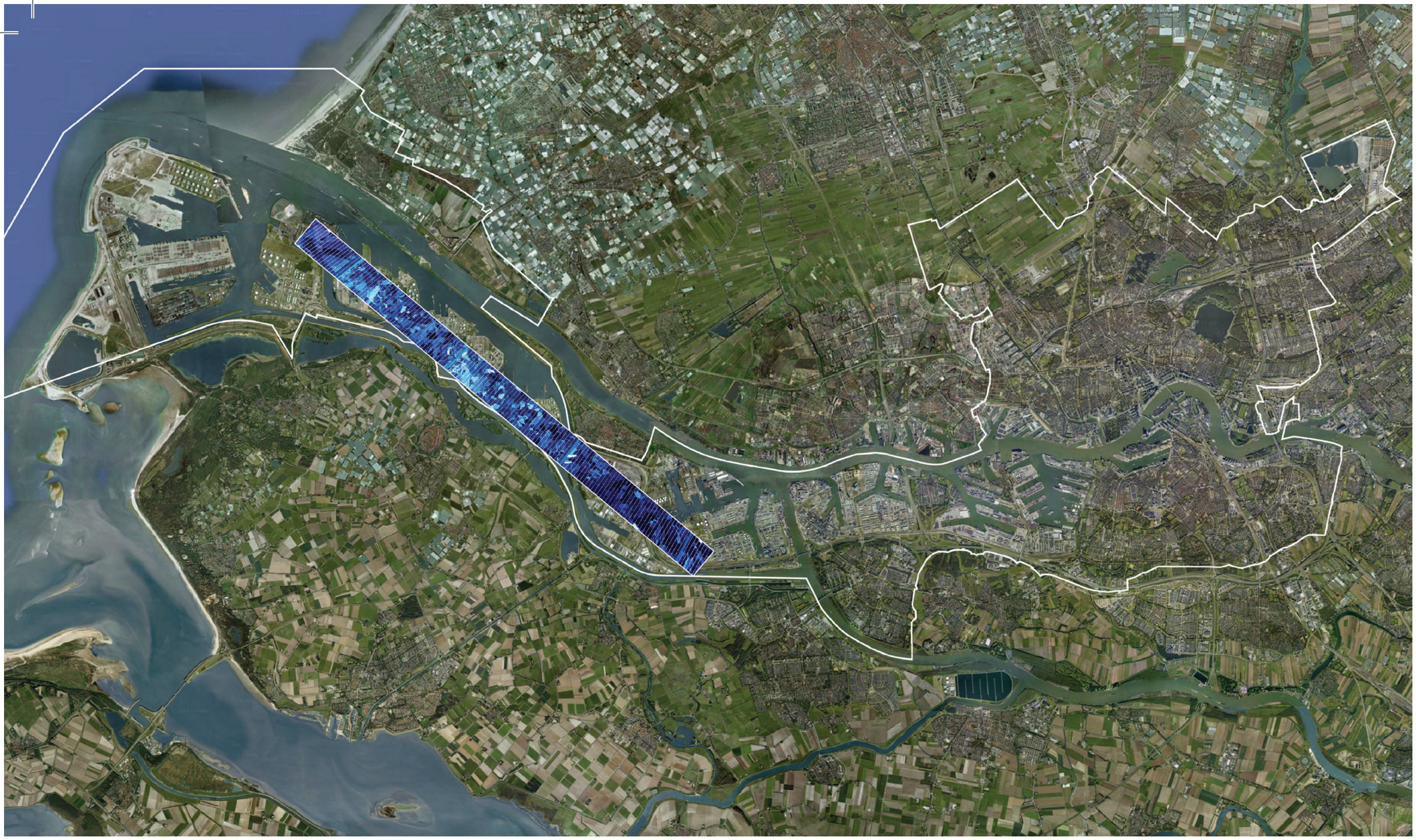
Waste energy potential
image source: author

Waste energy
potential



source: http://agentschapnl.kaartenbalie.nl/gisviewer/





Solar energy potential (1600 hectares)
image source: author

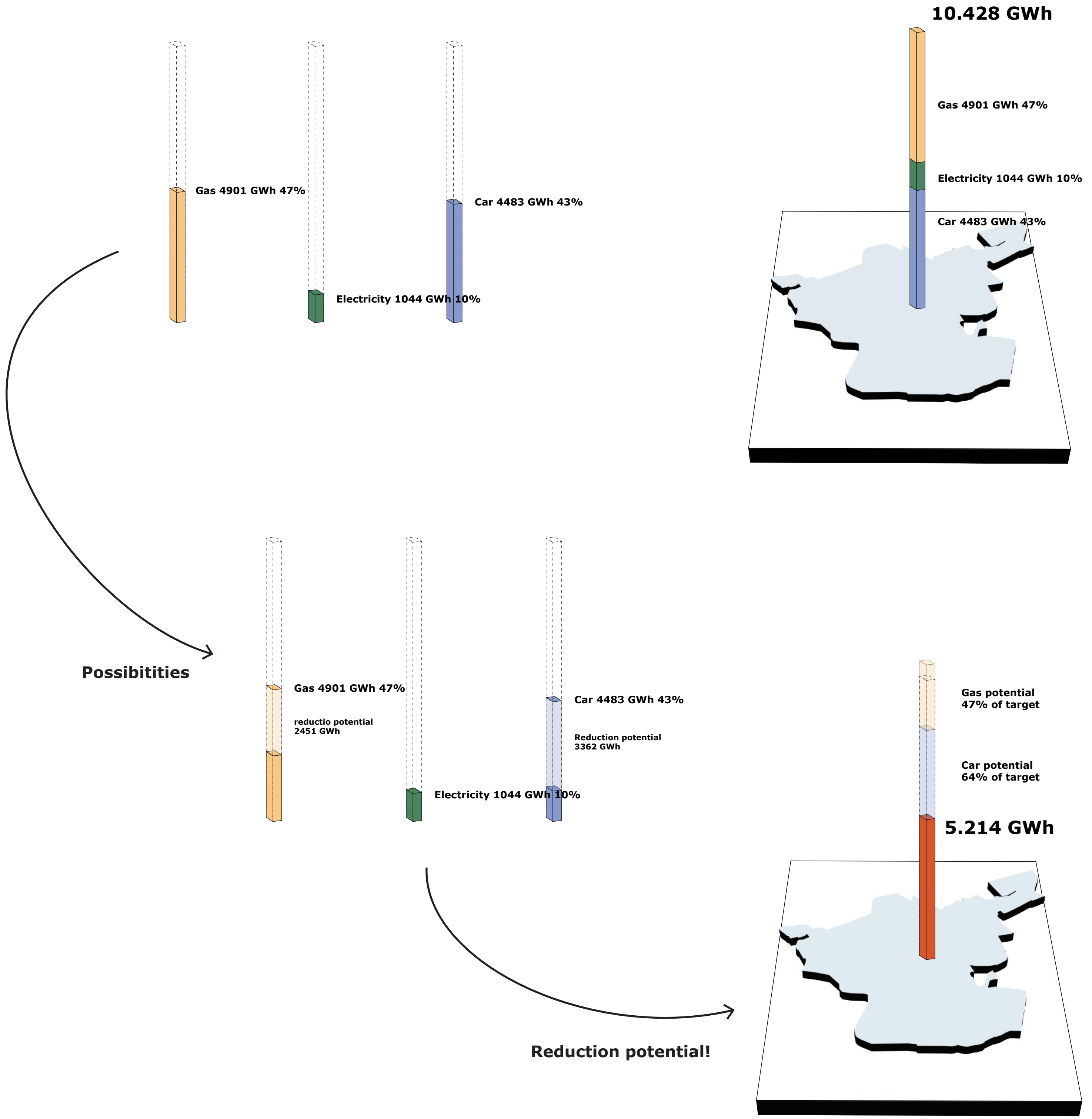
Large solar PV fields
http://greenterrafirma.com/wordpress/largest-solar-pv-facility-in-the-world-goes-live/

Small scale PV
http://www.solar-calculator.org/wp-content/uploads/solar-panels.jpg

Solar PV
Another potential energy source that can be considered is the installation of large quantities of solar PV cells in the harbour area. Solar PV forms a very viable option because they can produce great quantities of electricity. If the entire 1600 hectare of the Stadshavens is filled with solar PV cells, an annual electricity production of 1600 GWh is realized. 31 percent of the total climate ambition!

Although the yield is interesting, I think this is not a sensible thing to do. Next to the scale of the project, the rigidity of large fields of PV cells is undesired in the harbour area. The area beneath a large wind turbine is still available for industrial processes, but the space beneath a PV cell is lost. This, next to the possibility to place PV cells in very small quantities, makes them much more suited to use in other places. A small solar PV cell performs just as well as a big one, a feature that makes them ideal to put in small leftover spaces like rooftops.


Project area 1:5000
image: Google maps



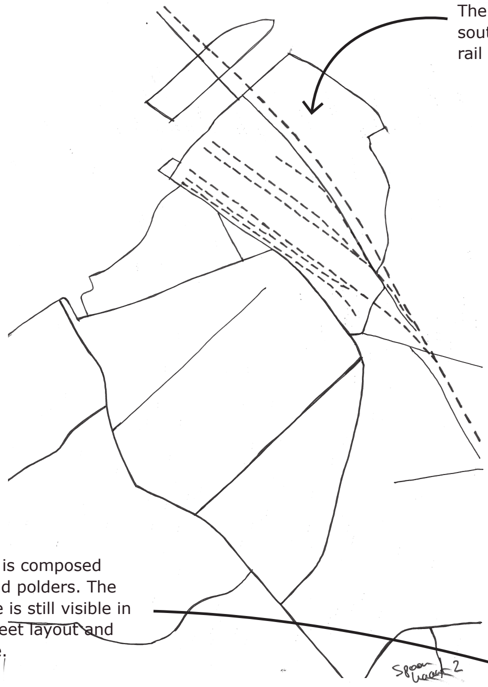
Reduction potential
image source: author

City scale

When reviewing the energy demand of Rotterdam, foremost the quantity differences stand out. Car and gas consumption form 90 percent of the total consumption and therefore have the biggest saving potential. The gas demand can be reduced by building insulation and energy cascading. Transport can be reduced by a dense living environment and car efficiency can be increased by 400 percent with the transition from petrol to electric vehicles. Next to a large carbon reduction potential, the electric car also has the benefit that it does not exhaust polluting gasses. Therefore the electric car can also be seen as a quality improvement.

On the city level, improving the living environment is the main focus of the interventions. When reviewing the pre-war part of Rotterdam South, the influence of the old harbour is visible in the distinctive urban structure. The form of the structure can be traced back to the rail infrastructure. The old rail lines produce strong and wide lines, cutting through the urban fabric with typical rounded corners. The old maps show these lines where created first when the harbour was constructed, afterward the city followed. After the war, modernistic city planning embraced the wide structure to produce a car orientated super grid which is still in use this day. Forming lively urban islands, with a peculiar inner scale and a car oriented super grid that functions completely independent from the urban islands. This results in very well connected, but dead city boulevards and very local scaled urban life within the urban islands.

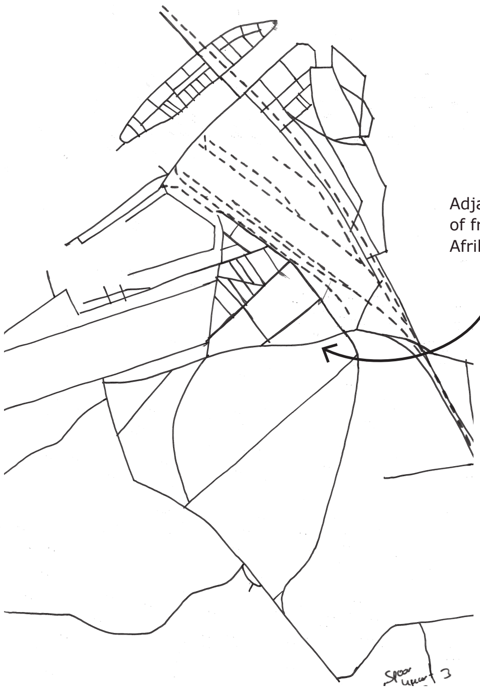
The first intervention on the south side of the Maas was the rail infrastructure.



The landscape is composed out of dikes and polders. The polder stucture is still visible in the current street layout and block structure.

1874

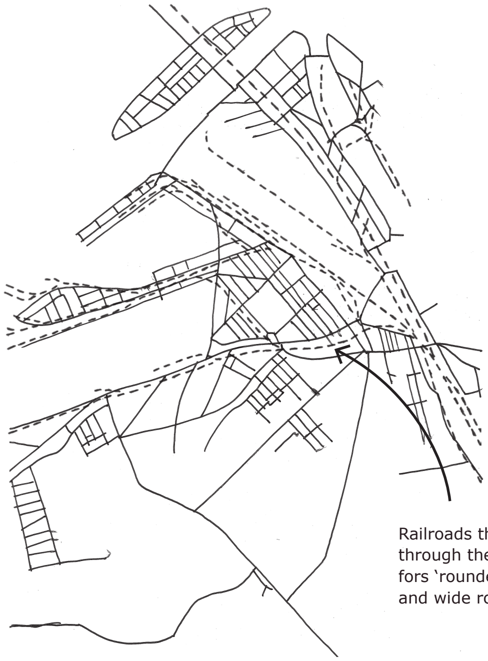
Adjacent to the harbor, but cut of from the rest of Rotterdam Afrikaanderwijk arised.



1899

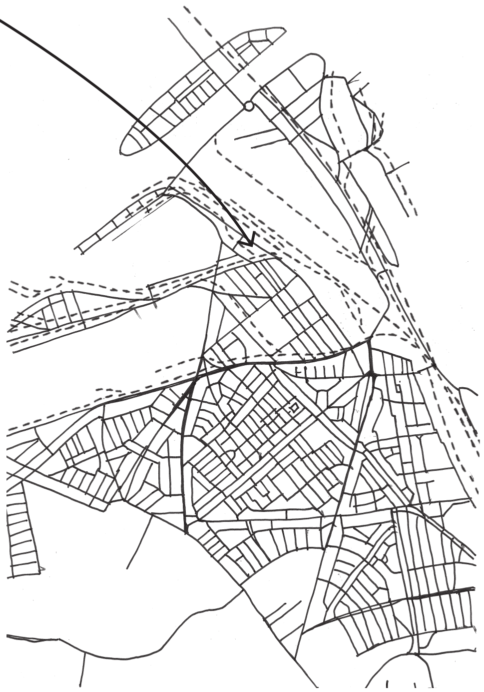
Historic development

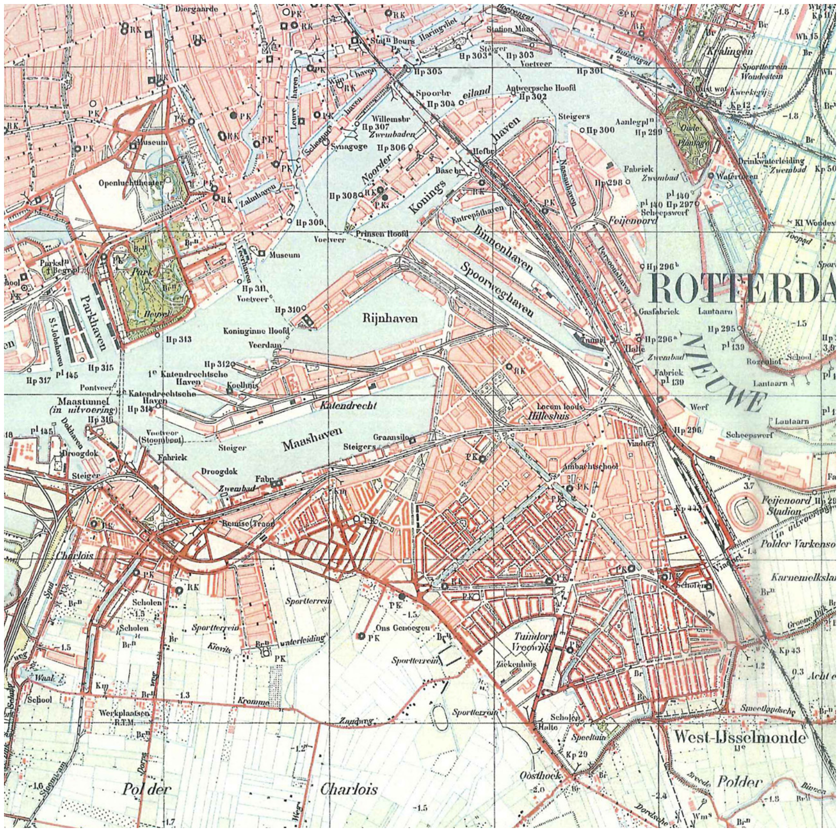
maps taken from Rotterdam - Zuid: Meijel et al, 2008



Railroads that cut through the urban area fors 'rounded' corners and wide roads.

1919



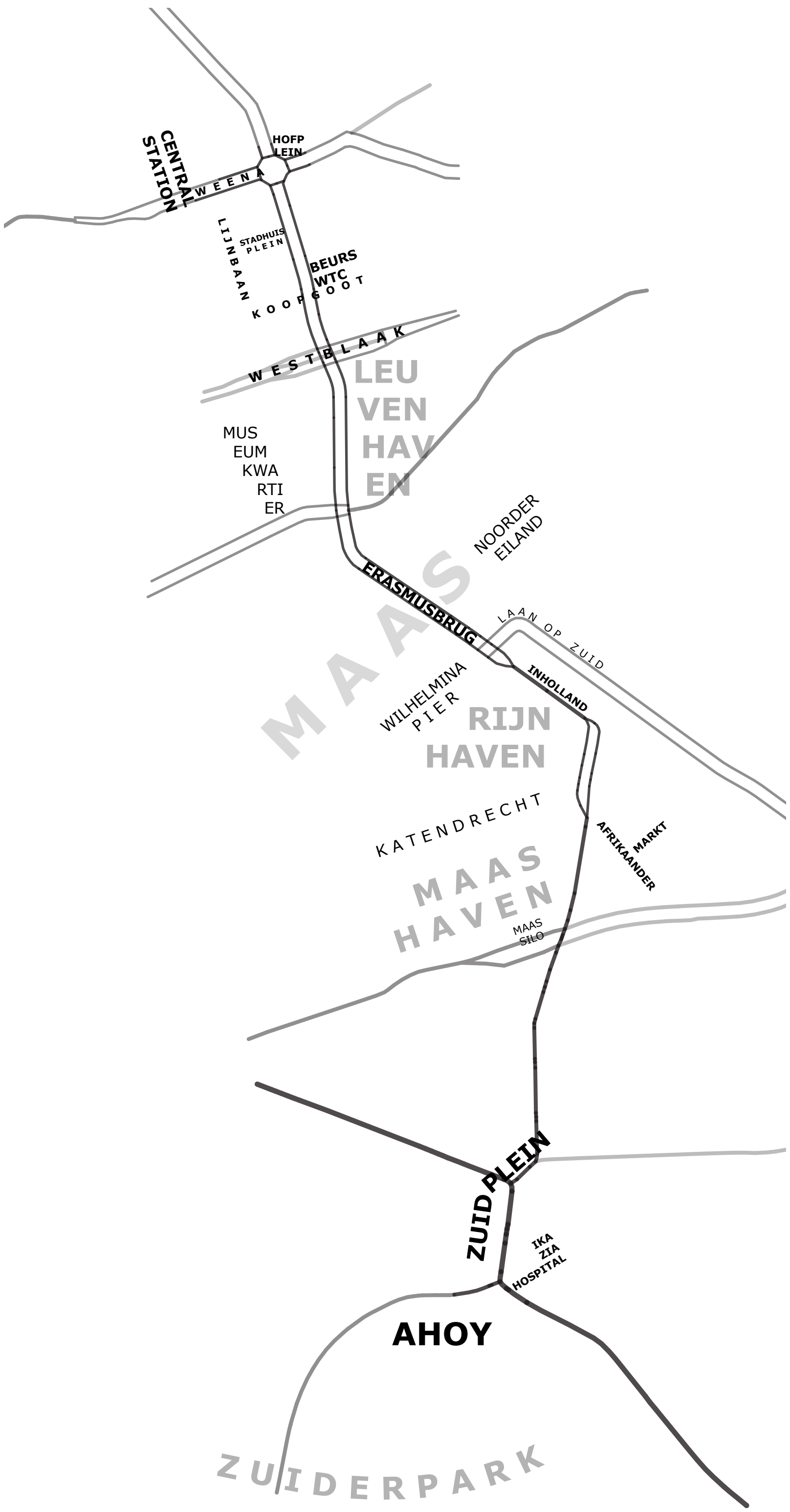


1935

Urban island structure of Rotterdam South
map taken from Rotterdam - Zuid: Meijel et al, 2008



Small scale and big lines
image source: autho



With the erection of the Erasmus Bridge, the Dordtselaan became one of the best connected axis of Rotterdam. But when taking a closer look at the important places on the axis, the axis does not fulfil its promises. After the Inholland development, the active places on the Dordtselaan die out and the axis becomes completely car dominated. Only the Afrikaander market offers an interesting place and the old harbours are beautiful, but asleep. The car dominance is not surprising based on the excellent position of the axis, from highway to highway, but very unfortunate for the people living there. Also interesting is the lack of hierarchy in amenities that is seen between the Dordtselaan and the small parallel streets. Both streets lack amenities and have the same strip use, where it may be expected that the Dordtselaan is much more active, due to its better position.

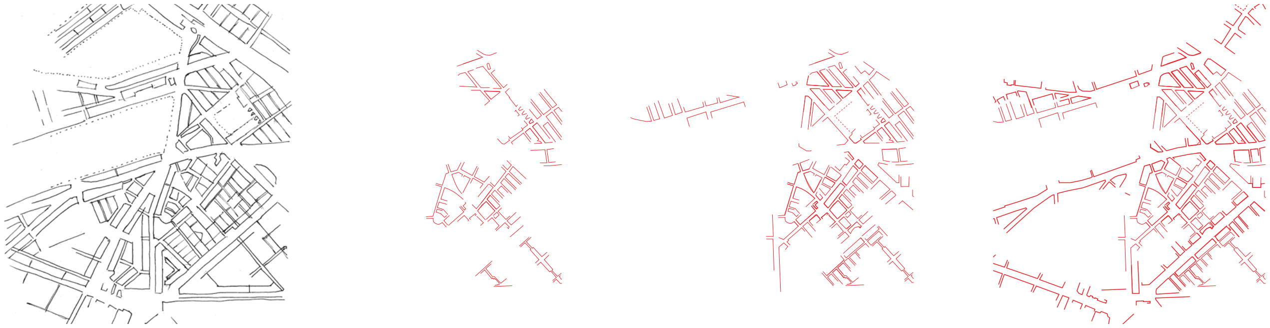
Strong axis
image source: author

Public space on the Dordtselaan
image source: author

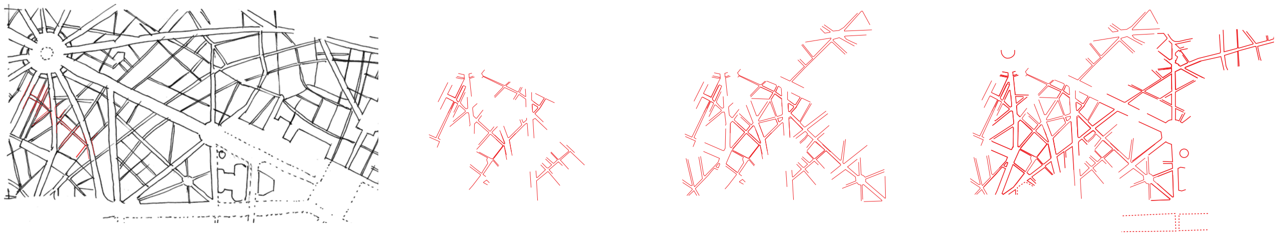
Living environment
The first step on the city scale is creating a living environment that reduces energy consumption. Therefore the project area is reviewed according to the criteria of the integrated typology.

1. Density of a 100 – 150 dwellings per hectare.
The current density of Afrikaanderwijk and Bloemhof is around 80 dwellings per hectare. This is acceptable but does not reach the minimum density of a 100 dwellings per hectare. A density of a 150 dwellings per hectare is excessive for Dutch standards, but in future refurbishments densification should be considered. New developments should at least offer the minimum density of a 100 dwelling per hectare as well. Fortunately, the urban fabric of the project area offers many densification possibilities.

Possibilities for densification



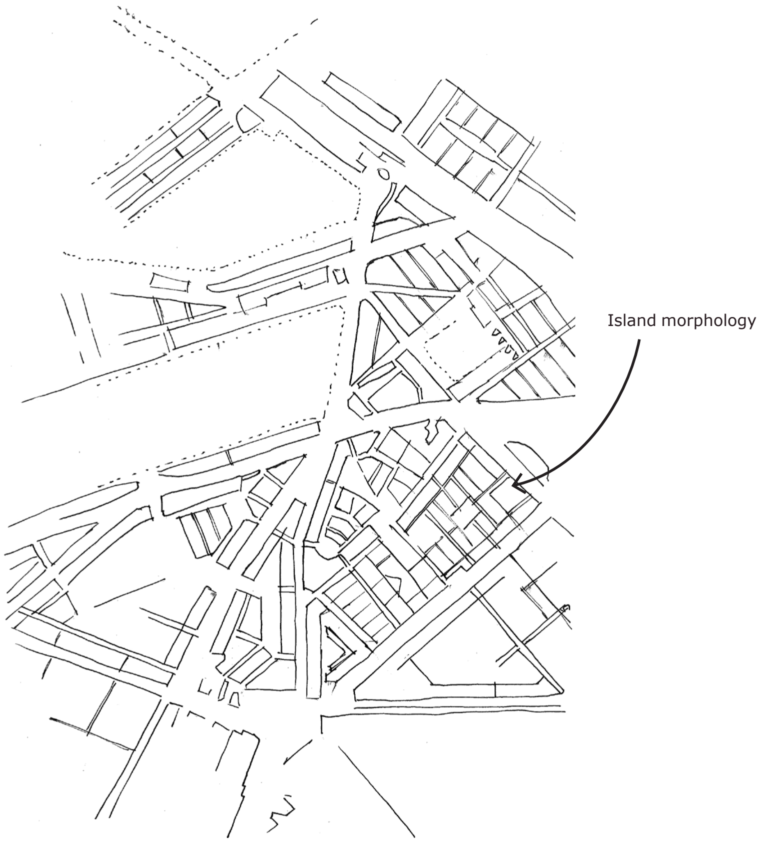
Rotterdam

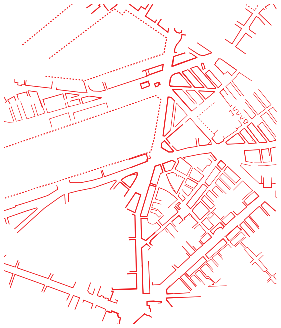


Paris

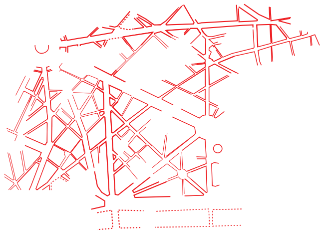
2. Grid pattern road layouts, in a semi lattice urban structure based around the traditional urban block. The grid pattern, semi lattice structure and traditional urban blocks are present, but the street pattern could be more intricate. Especially the connections between the urban islands and the super grid are sparsely. New development or refurbishments should respect the existing urban structure and improve the connection between super grid and islands.

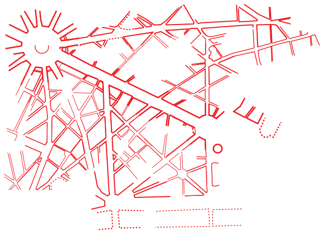
Paris and Brussels act like an interesting precedent for Rotterdam South. The super grid structure of Paris, created by the Haussmann boulevards, result in urban islands that are very similar to the islands of Rotterdam South. The islands are internally structured and confined by a super grid, but the resulting liveliness of Paris and Brussels in not found in Rotterdam. This is partly the result of incomparable densities, but also due to morphology and function differences. But the main difference between the two cities is the integration of the different levels of scale. Where in Paris even the low hierarchy streets are very well integrated with the streets of a higher hierarchy, in Rotterdam a subdivision is created. The internal structures of the islands form a very well integrated grid, but the integration of this internal grid with the super

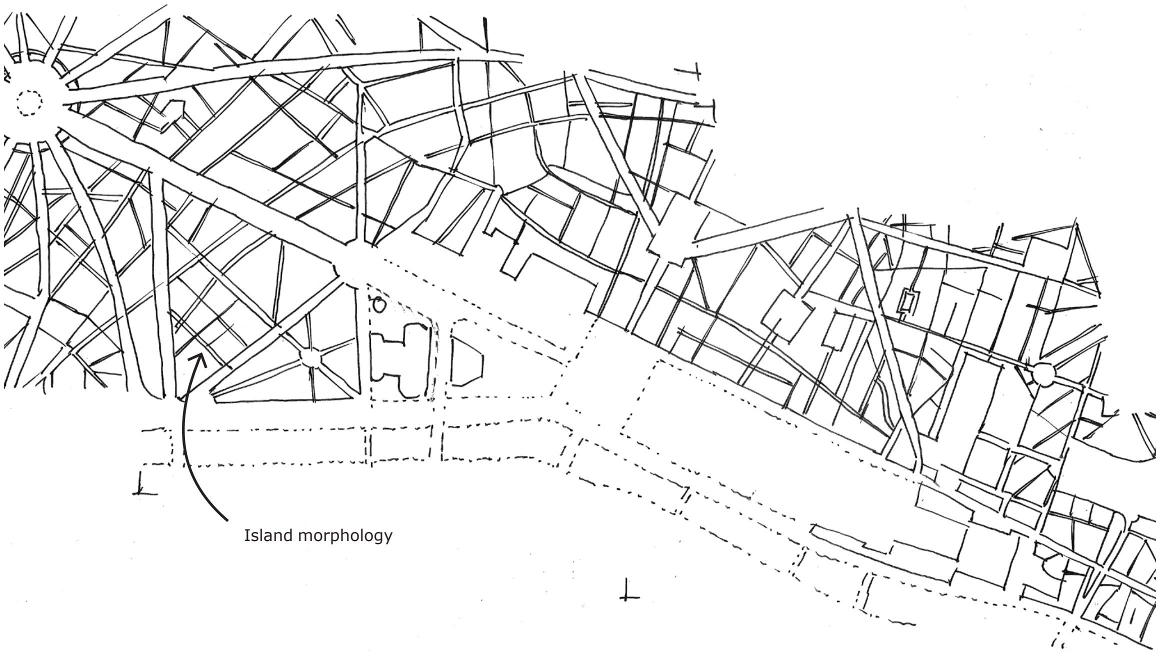




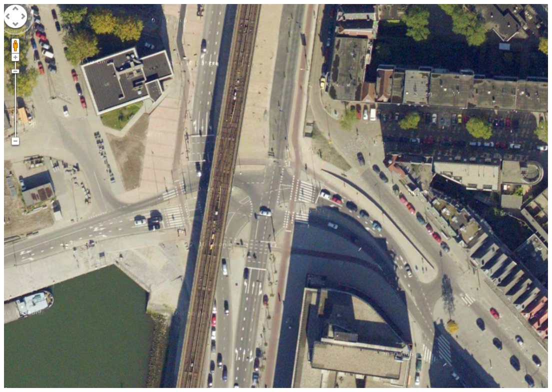
The urban nodes of Paris and Brussels, with the expressions of city life, do not occur in Rotterdam South. This is partially the result of the division between scale levels.





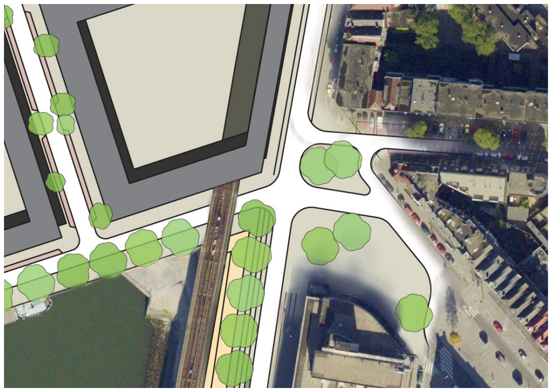


Paris I



grid is missing. As a result, the ‘city moments’ in Rotterdam are not shared between different scale levels and the street life of Paris and Brussels does not occur at the urban nodes.

Improvements can be made by restoring old connections and creating well designed nodes. The existing morphology of the connections between super grid and urban islands can easily be improved by design.



Morphology improvement urban node

image source: author / Google maps, 2012

Experience of the super grid (Dordtselaan)
pictures taken from Google maps, 2012

3. A mix between dwellings, offices and amenities with a good hierarchy.

Both a good mix and a clear hierarchy are currently absent. Program is monotonous, mostly housing, and the area misses a clear hierarchy. As discussed, Paris and Brussels can act as a precedent for hierarchy, which will also stimulate a better mix of functions. An increase in density will have positive effects on function mix as well and new development or refurbishments should offer place for diverse program. Zuidplein shopping mall forms a difficulty. This concentration of retail program competes with the retail program within the neighbourhoods and has forced out a lot of small shops. The regional function of Zuidplein does not form a problem, but ideally, a way should be found that Zuidplein stops competing with the local and city scale retail program.

4. Roads and public space designed for slow traffic to encourage walking and biking.

The roads and public spaces within the urban islands follow the criteria for slow traffic well. When leaving the long lines and entering the urban islands, the atmosphere changes. Urban life reveals itself in children playing, small shops and other activities. The super grid on the other hand, is completely car dominated and not lively at all. It does not offer public space designed for slow traffic and does not encourage walking and biking. Therefore, interventions should be made on the level of the super grid. Again Paris and Brussels act as a precedent, because their boulevard structure offers lively public space and encourages slow traffic. Further the boulevards of Barcelona can be seen as an interesting design example.

Lively city boulevards would be an interesting improvement for Rotterdam South. Boulevards filled with amenities and people, instead of cars. The existing places where activities happen are located inside the islands, very local and cut off from the higher scale roads. As a result, these activities stay isolated from the higher scales and have a ‘super local’ character. The activities are monotonous and do not show the typical Dutch gradient of local-city-regional scale. In Paris the small scale roads are

Existing quality of the super grid
image source: author

Proposed quality of the super grid
image source: author

Passeig de Sant Joan, Barcelona
image source: Google Maps, 2012

very well integrated with the super grid. They share the same city moment and therefore these moments become the places were activities happen. Often beautifully designed, the formal moments of Paris and Brussels are the places were shops, terraces and other expressions of urban life are found.

Rotterdam South should improve its super grid. It should improve the connections between the super grid and the smaller scale roads and make the big car oriented roads suitable for pedestrians. Creating attractive public space on the super grid itself. Turning the urban islands inside out and turning the super grid into beautiful city boulevards, filled with urban life.

5. A (already existing) dense public transportation network that is accessible by foot or by bike.
At the important axis a high quality (tram, metro, train) public transportation network is available. There is a metro, multiple tram lines and a train station, but when reviewing the reach bubbles, some gaps appear and the network could be intensified. Adding a tramline in the east west direction is an interesting intervention that improves connectivity. Upgrading the Rotterdam South train station should also be considered. The new tramline really improves the integration of Rotterdam South train station, with the entire public transport network. Upgrading the train station to an intercity station, will therefore connect Rotterdam South better with the Randstad network.

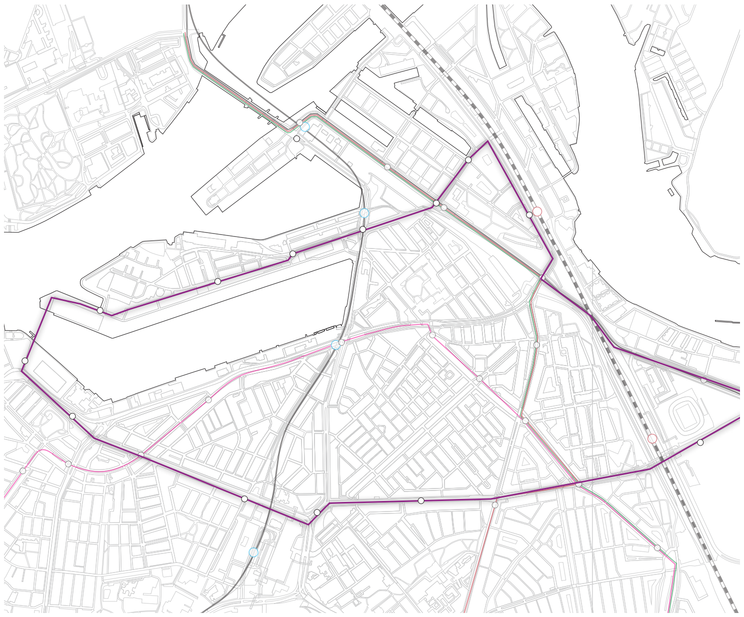
Also important is the accessibility of the metro stations. In the existing situation, the connection of some metro stations with the city fabric is bad. The stations should be much better integrated into the urban fabric and better connected to the slow traffic networks.

Public transport

image source: author

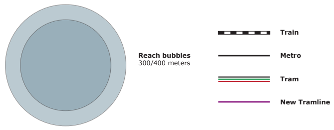
Existing

Reach



Extension

Reach



Social statistics

data source: Crimson Architectural Historians, 2007

Rotterdam

Inhabitants	588.718
Households (hh)	253.250
Average Income/hh	€ 18.200,- (Dutch average is € 20.200,-)
Unemployed	12 %
hh under poverty line	16% (Dutch average is 9%)
Average CITO score	533,2

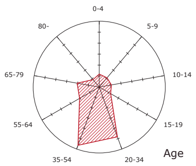
Housing stock

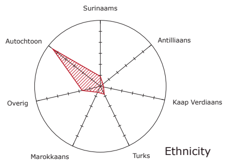
Ownership

koop	27%
huur corporatie	52%
huur particulier	21%

Construction period

before 1946	34%
1946-1968	2%
1969-1993	31%
1994-	11%





Afrikaanderwijk

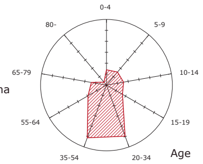
Inhabitants	9.419
Households (hh)	3.220
Density	79,6 dwellings/ha
Average Income/hh	€ 14.300,-
Unemployed	24 %
hh under poverty line	27%
Average CITO score	530,6

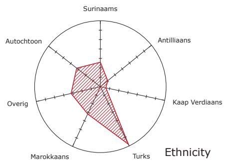
Housing stock

koop	8%
huur corporatie	85%
huur particulier	7%

Construction period

before 1946	52%
1946-1968	2%
1969-1993	32%
1994-	13%





Bloemhof

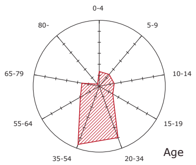
Inhabitants	13.222
Households (hh)	4.940
Density	81 dwellings/ha
Average Income/hh	€ 14.300,-
Unemployed	22 %
hh under poverty line	27%
Average CITO score	529,0

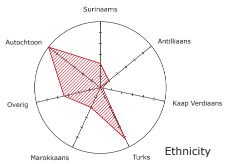
Housing stock

koop	16%
huur corporatie	60%
huur particulier	23%

Construction period

before 1946	80%
1946-1968	0%
1969-1993	8%
1994-	11%





Hillesluis*

Inhabitants	11.346
Households (hh)	3.960
Density	57 dwellings/ha
Average Income/hh	€ 14.600,-
Unemployed	22 %
hh under poverty line	26%
Average CITO score	529,6

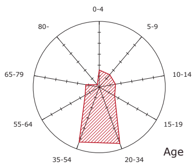
Housing stock

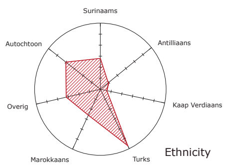
koop	17%
huur corporatie	56%
huur particulier	27%

Construction period

before 1946	78%
1946-1968	0%
1969-1993	11%
1994-	11%

* The data is for the entire Hillesluis area.

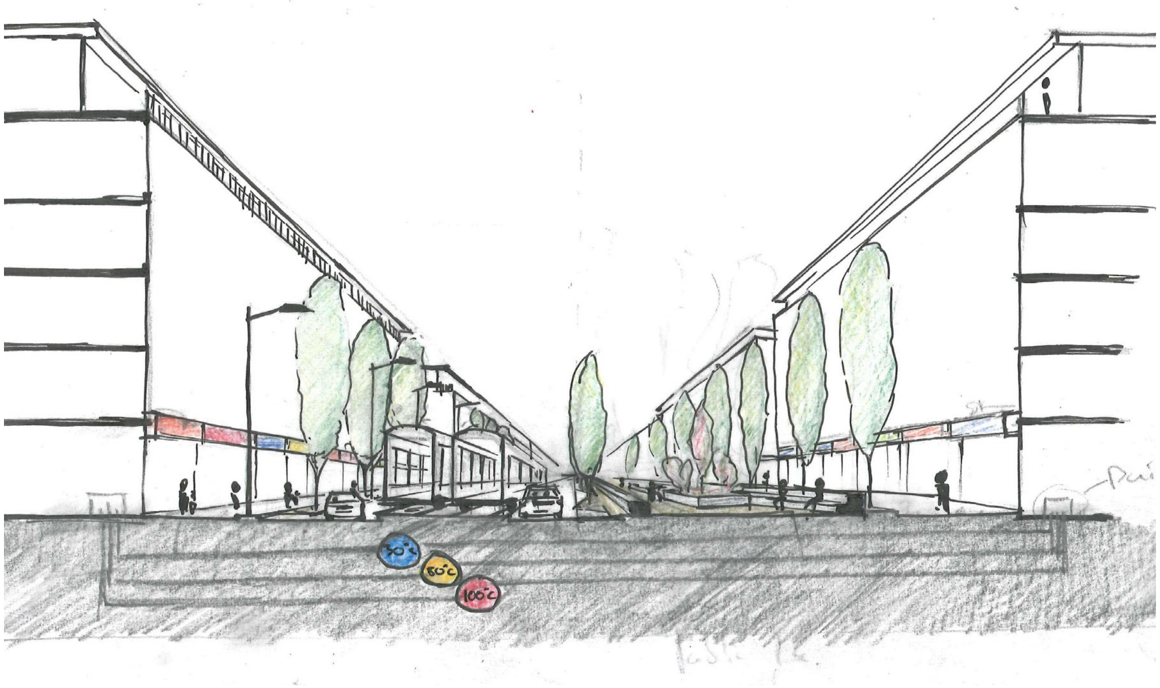




6. Attractiveness

Attractiveness can be sought in quality housing, urban morphology and public space, but also in social-economic factors. The previous steps show how to improve the urban part, but this is not enough to ensure attractiveness. Social factors should be improved to make the area a real success. Functions like schools, hospitals and amenities should be top notch, to improve liveability and attract dwellers. The existing social-economic markers are poor and safety ratings are low (Projectteam dS+V, 2011). The area is market as a priority area, which insures large stimulation programs and hopefully these social strategies are maintained to improve the soft conditions of the area.

Further good urban design and architecture should create a spatially attractive living environment: green, beautiful and human scaled.



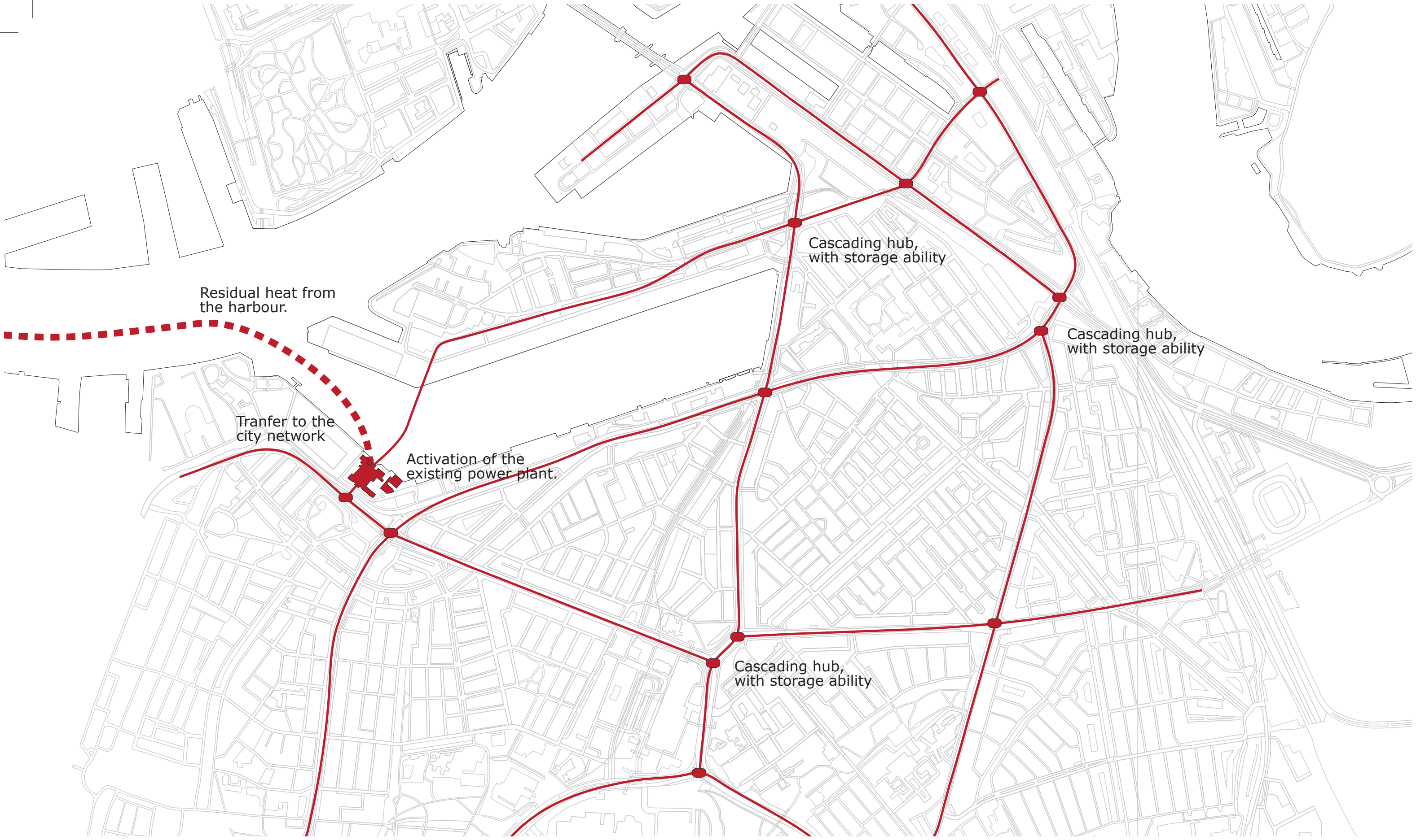
Make city boulevards
data source: author

Efficiency

The next step is making the attractive, dense area as efficient as possible. First the buildings scale should be optimized. New buildings should meet the highest climate standards and existing buildings should be refurbished. Also smart combinations and other technical climate measures should be considered.

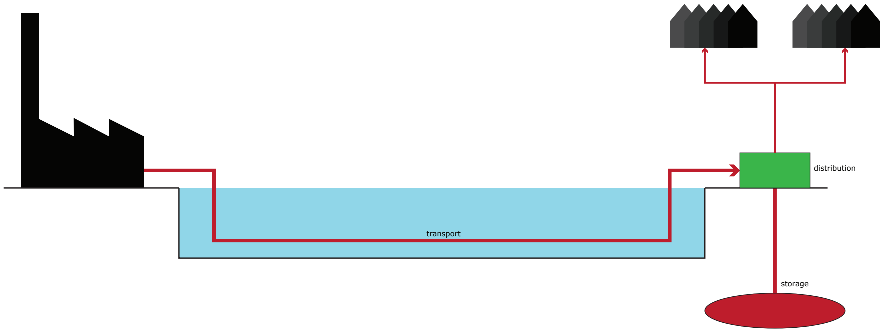
On the city scale energy cascading is an interesting measure. As shown on the municipal scale, the harbour can supply great amounts of residual heat energy and district heating should deliver this energy to the buildings. The super grid structure of Rotterdam South forms the ideal structure for implementing this cascading network. The streets are wide and well connected to the urban fabric. The implementation of a smart grid for heating offers the opportunity to also improve the streets themselves. The construction of a district heating network involves the subterranean installation of huge pipes, hence breaking open streets. An excellent opportunity to simultaneously update street profiles. Creating the city boulevards desired from the living environment perspective and implementing the tram line at the same time. This way the nuisance of the operation is minimized and next to the raise of efficiency, the attractiveness of the city is improved as well.

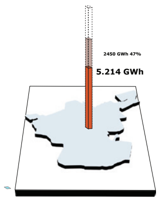
Cascading has big potential to reduce the gas consumption of households. Exact figures are hard to predict and will be dependent on what can be realized. But the assumption is made that the building refurbishments and cascading measures together can produce a gas consumption reduction of fifty percent for the whole of Rotterdam.



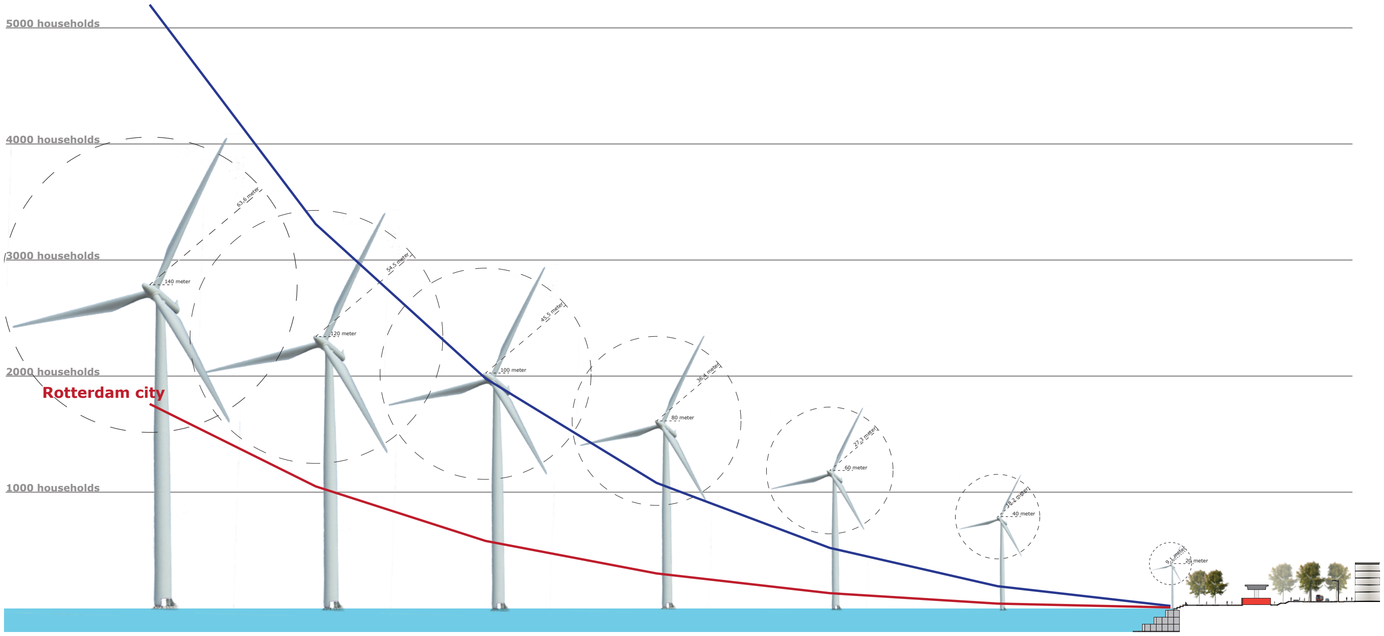
Cascading network
image source: author

Waste energy
potential





Wind turbine revenue
image source: author



Production

1. Geothermal

Rotterdam has great geothermal potential and the MUSIC project by dS+V is currently researching these potentials. For the most part this is a technical intervention and therefore left out of this study, but a geothermal well can easily be integrated with the cascading network.

2. Wind

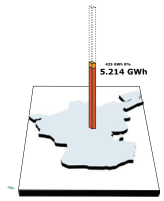
The construction of wind turbines within city limits is debatable. There is space available in the Maashaven and wind turbines could be placed there, but in my opinion this is undesired. Both the scale of the turbines and the return they generate, give reasons to reject them. The realizable return is limited, because of the limited size the turbines, when placed in the Maashaven. Also the wind conditions within the city of Rotterdam are not as good as in the harbour area. Therefore, in my opinion, it is better to place them outside the dense area, where they can function much better and do not influence the attractiveness of the city.

3. Solar

Solar PV panels have great potential within the city limits of Rotterdam, because they can be placed in small quantities. PV panels are ideal to put in unused spaces like rooftops. Construction can be done by homeowners themselves and does not require big, central planned interventions. Only (economic) stimulation could be considered.

According to Spacematrix, Afrikaanderwijk has a GSI of 0.35 which means that 35 percent of the neighbourhood is build. The area of Afrikaanderwijk is approximately 40 hectares, which results in 14 hectares of roof area. Not all the roof surface is suited for placing PV cells, but let's assume that a third of the total roof area can be filled with PV panels. This results in a total PV surface of 4,67 hectare, which can produce 4,67 GWh annually.

Afrikaanderwijk consists of 3220 households, per household an annual energy production of 1450 kWh can be realized with solar PV panels. Translating this to the 300.000 households of Rotterdam, accumulates to an energy potential of 300.000 x 1450 kWh = 435 GWh per year. 8.3 percent of the climate goal.



space syntax analysis
taken from U-LAB, TU Delft

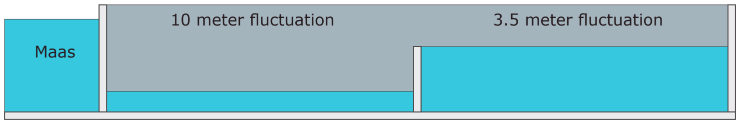
Rhythm

To counter intermittency, the Maashaven can act as an energy storage facility: an energy lake. The morphology and scale of the Maashaven are very well suited for this type of intervention and this is therefore not a new idea, but still a rather interesting one. The intervention could simultaneously be used to improve the area and create a new, energy-lean living environment. It offers an opportunity to densify the area, restore old connections and offer new attractive urban typologies. Because the water level will constantly fluctuate, a very interesting and unique environment is created. The maximum fluctuation of 10 meters will create a spectacular sight and can become a real attraction and advertisement of the Rotterdam Climate Initiative. A real eye catcher, making full use of the unique potential of the harbour basin.

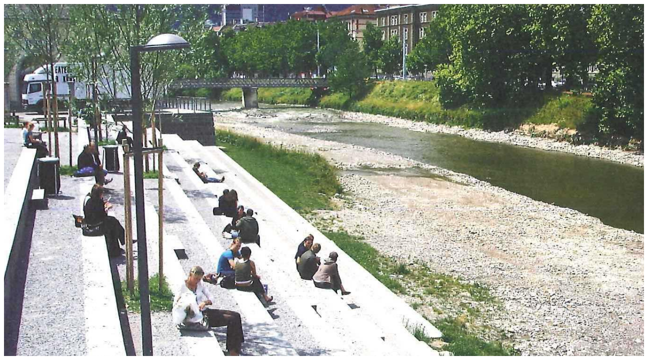
Intervention steps:

1. By damming the harbour basin the energy lake is created.
2. In the lake, connections can be restored to improve the connectivity of the area. The study of U-LAB (2011) shows the expected results. The new tramline can go over the new dam. A sluice is created that connects the Maashaven with the Rijnhaven.
3. Along the connections, islands filled with dense housing are created. The islands break the big scale of the harbour and offer diverse scales of water, suited for different types of use.
4. The quays need to be strengthened and are simultaneously designed as attractive public spaces that make the fluctuating water level approachable.

Energy lake
image source: author

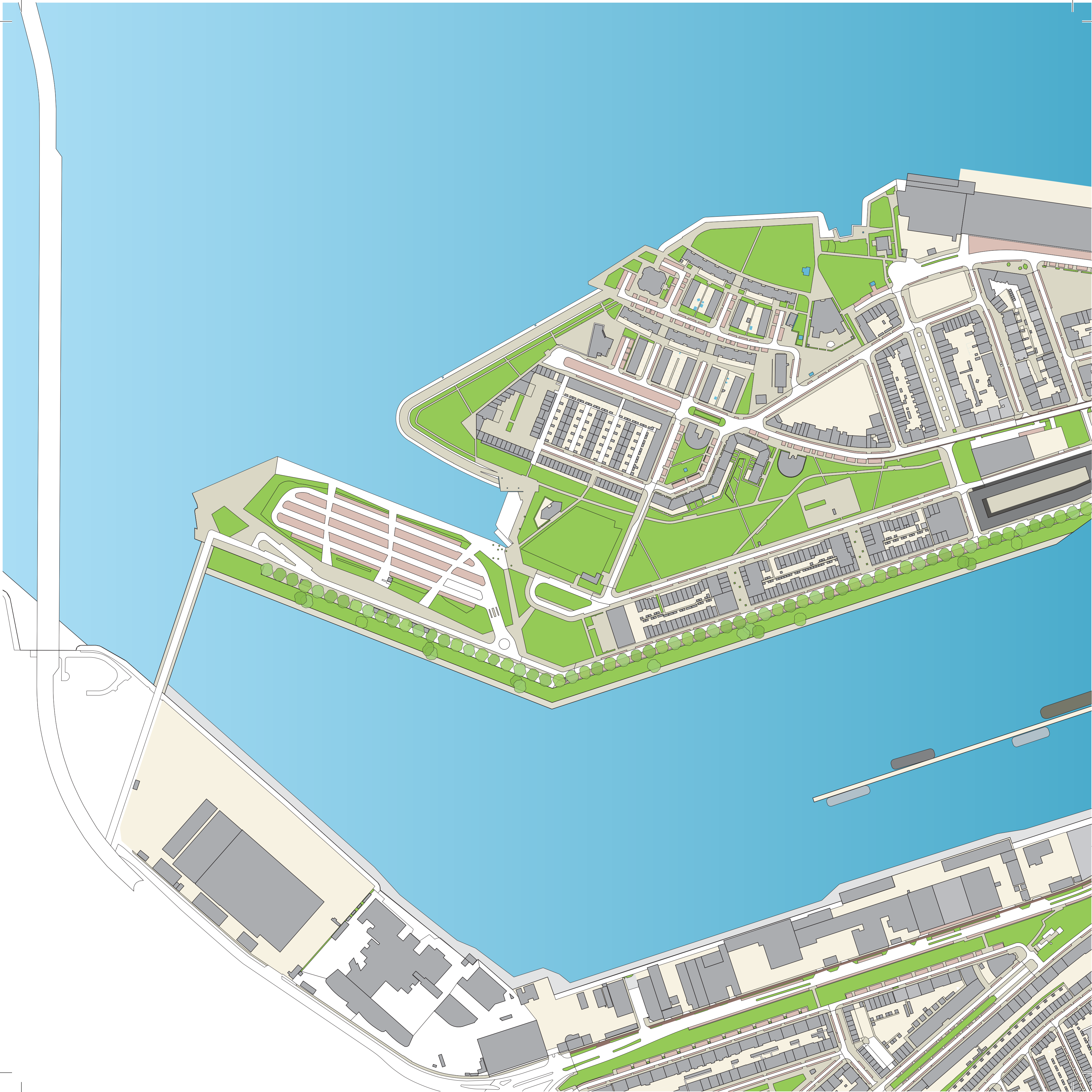


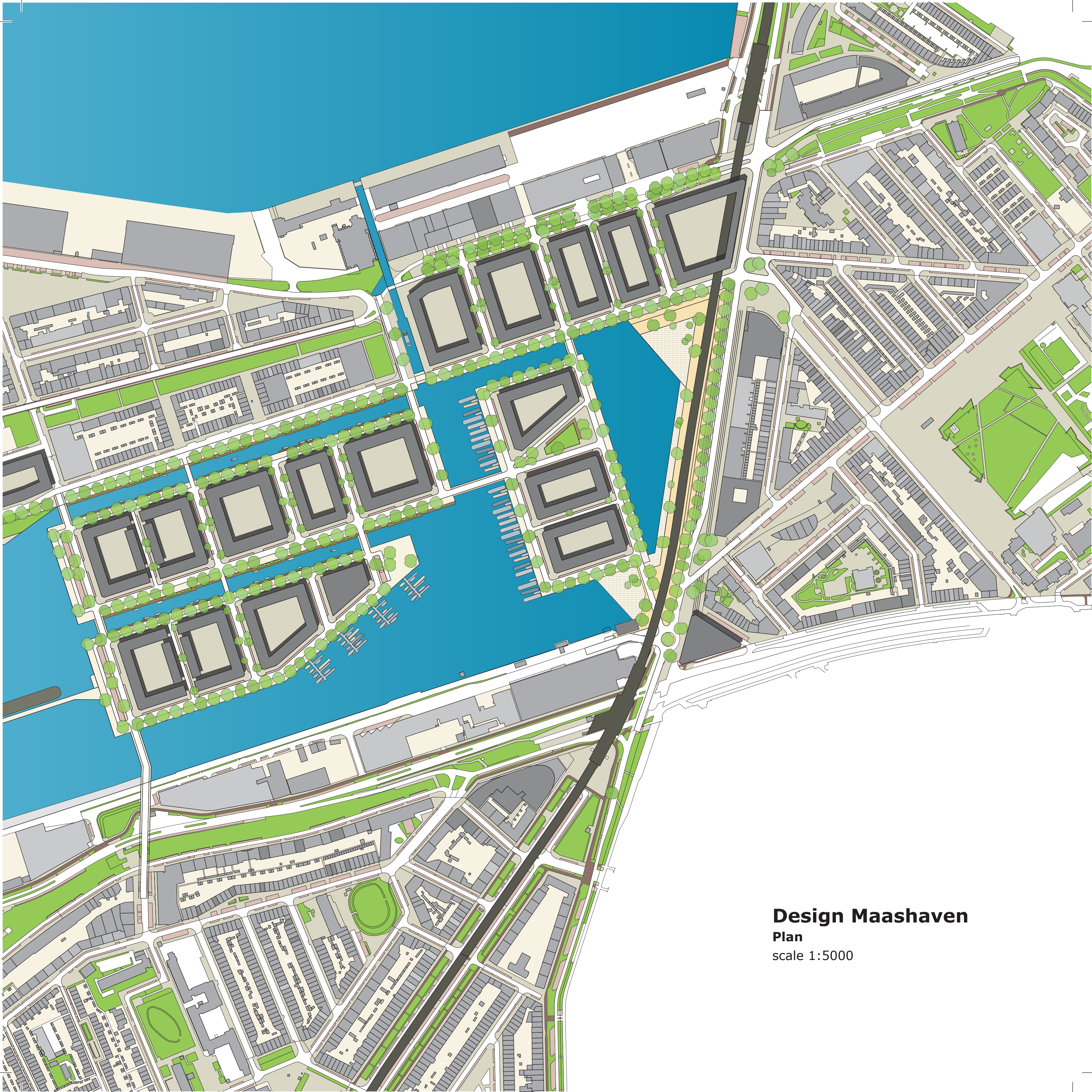
Dike with turbine | Dike | **Lake principle**



Zurich quays
image source: Topos, 2011

Maashaven
image source: author

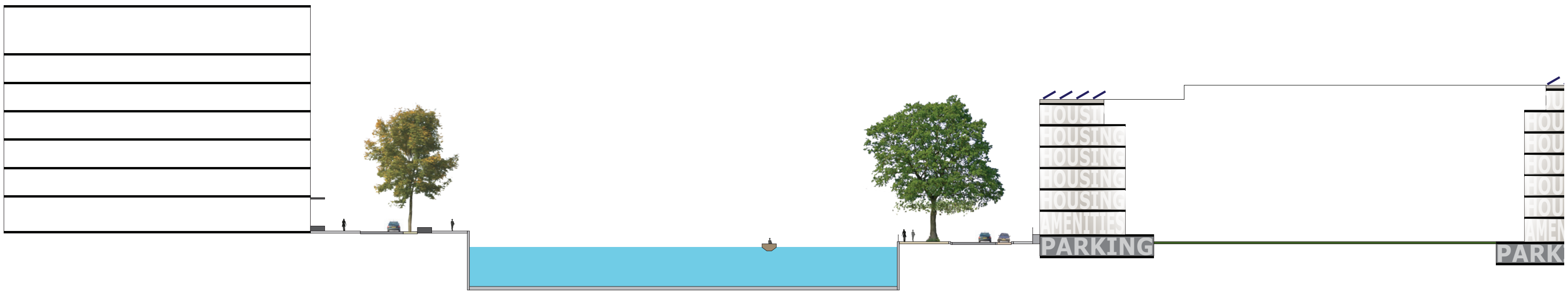




Design Maashaven

Plan

scale 1:5000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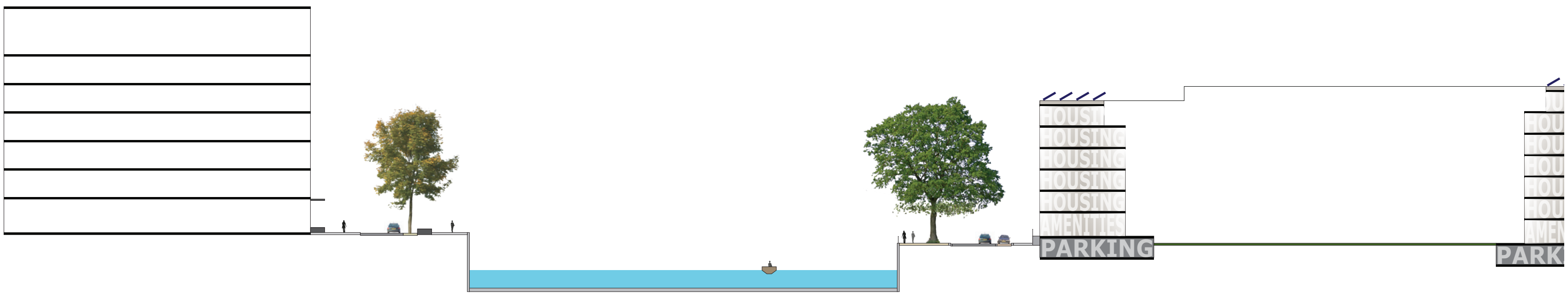
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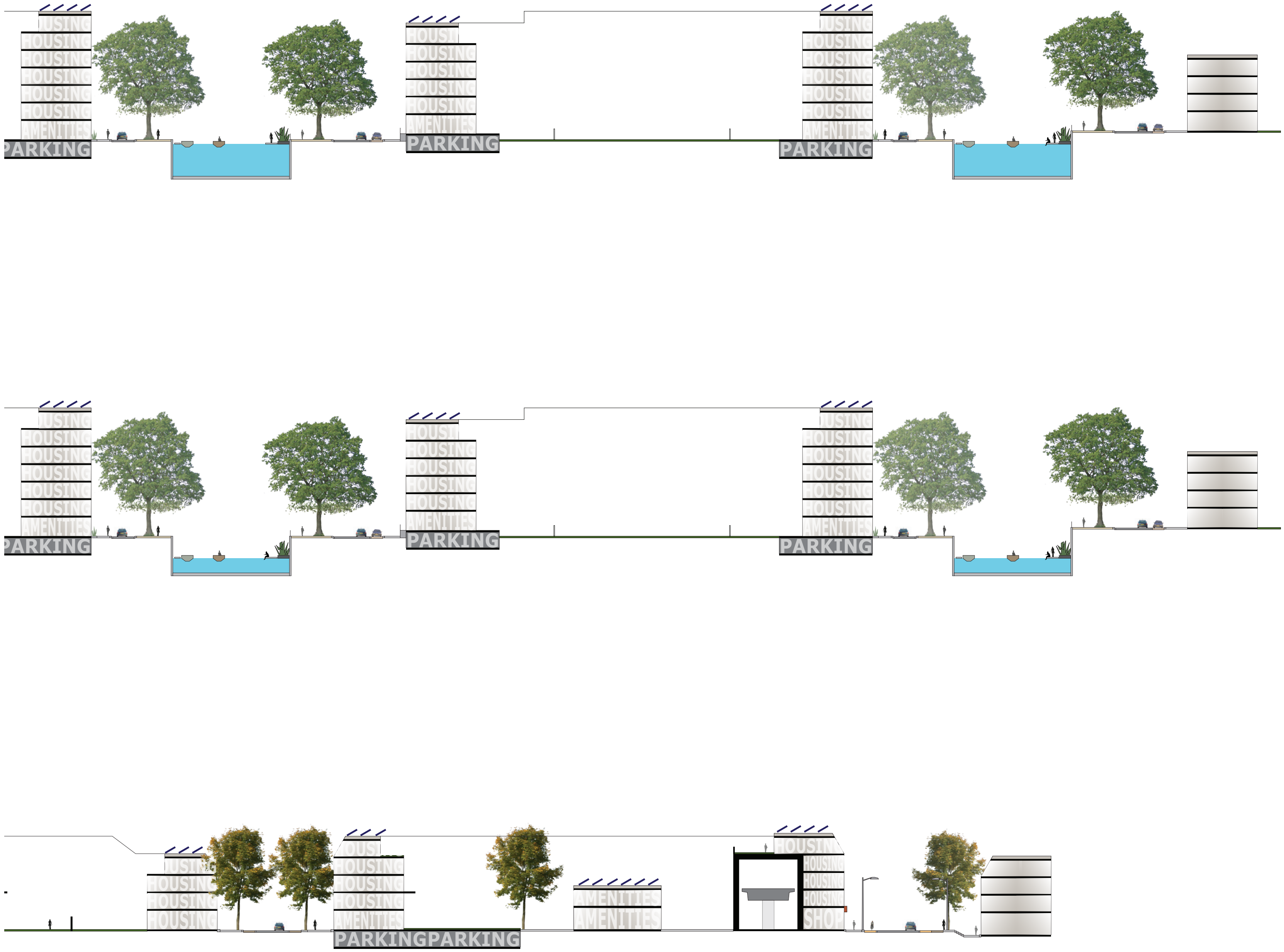
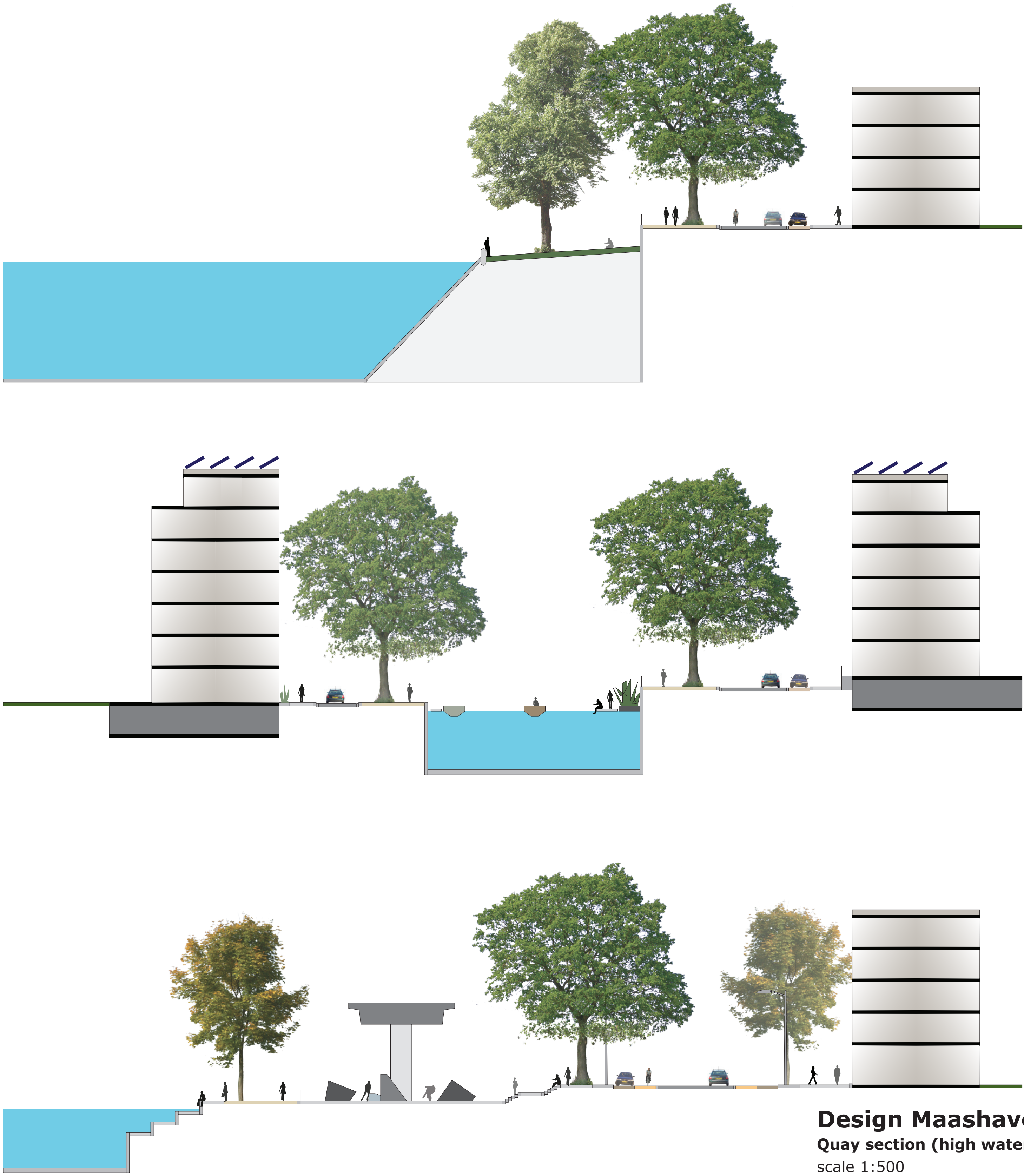


Design Maashaven

Sections

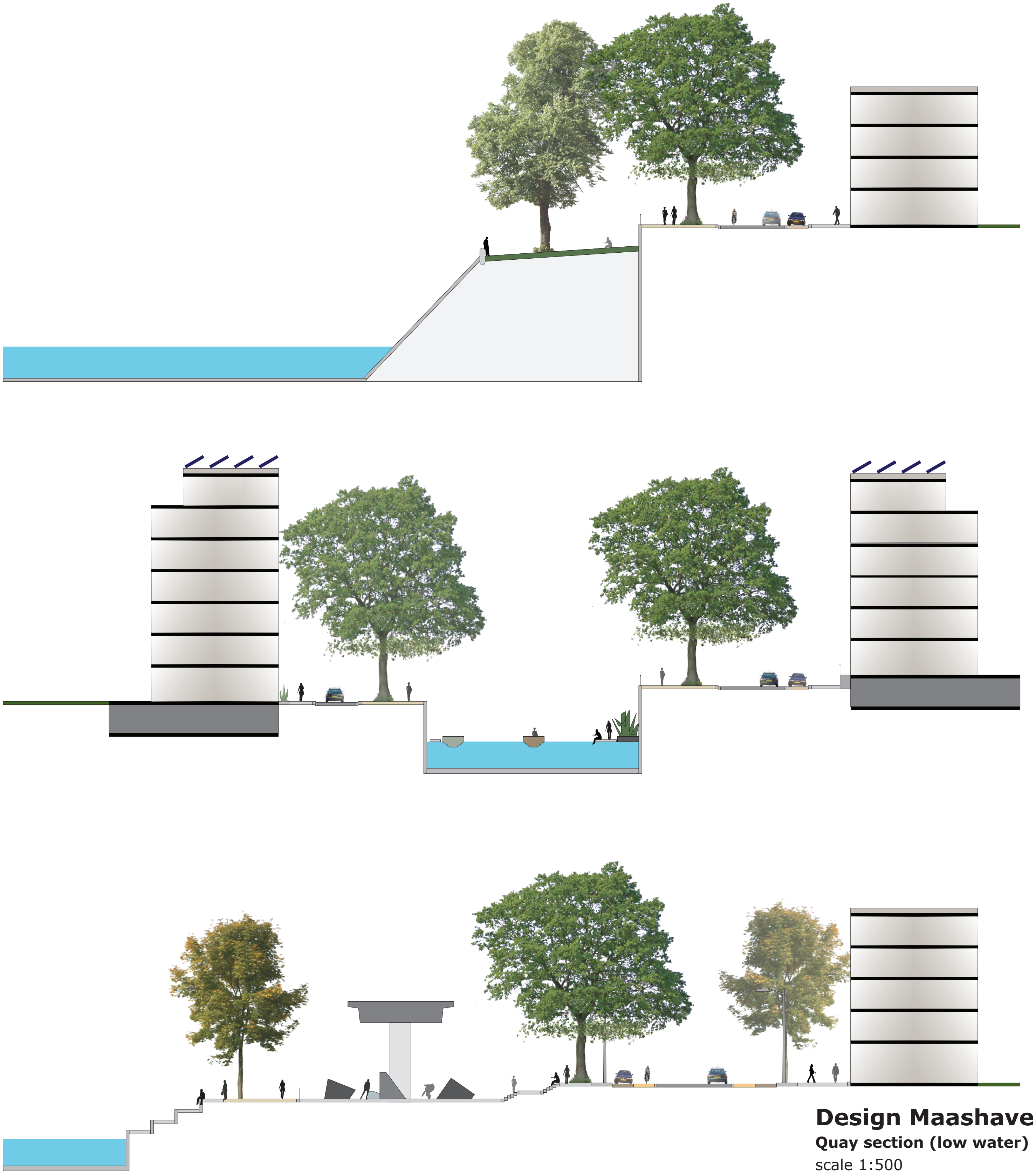
scale 1:1000



Design Maashaven

Quay section (high water)

scale 1:500



Design Maashaven

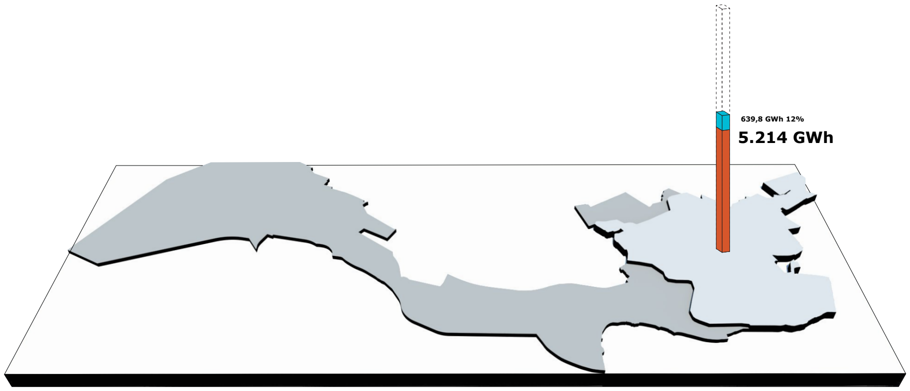
Quay section (low water)

scale 1:500

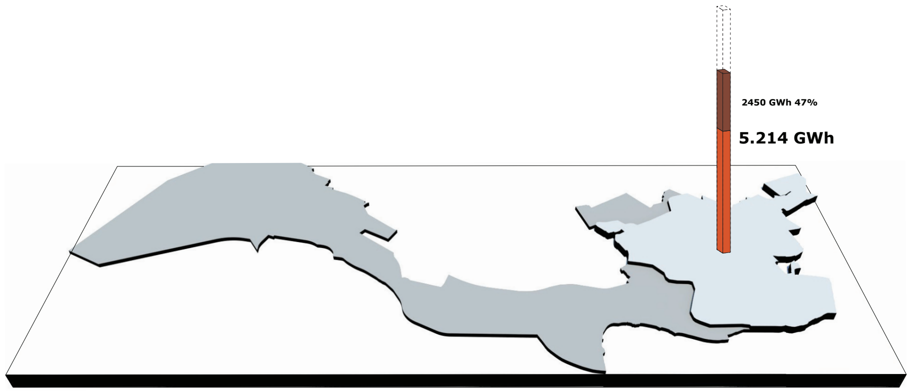
Impressions
image source: author

Energy potentials

image source: author

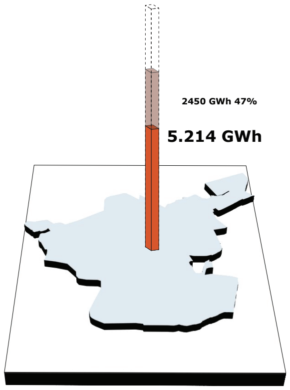


Wind energy

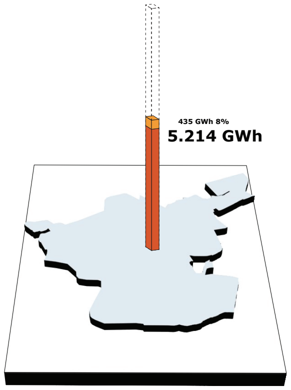


Waste energy

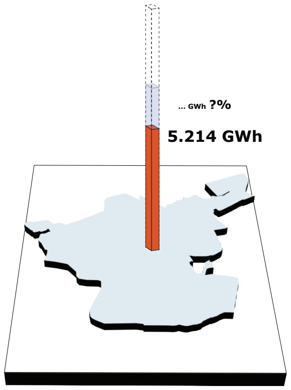
Solar energy



Waste energy



Solar energy



Transport energy

Total energy potential
image source: author

Theoretic potential

Realistic potential

Conclusions and reflection

After a year of research on energy transition, I am still very optimistic about the transition challenge. Interventions are exiting, constantly developing and very promising. We only have to act and turn them into reality!

Rotterdam Climate initiative

Rotterdam took an ambitious stand with the Rotterdam Climate Initiative. When reviewing the theoretical possibilities, the fifty percent carbon reduction can be realized, but with some very drastic measures. Turning the initiative into reality is a whole different story. 56 wind turbines can easily be realized, but building 1600 hectares of PV panels becomes harder. Just as filling all the available roof space with solar panels, or connecting 300.000 households to district heating. This seems for many reasons unrealizable, or will transform the city of Rotterdam into one big construction site, for years to come.

The challenge is enormous and the first step should be realizing a strategy is necessary. A strategy that is honest about the impact the transition has on daily processes and the unpopular, but necessary interventions acknowledges. We need consensus that we truly want to act and reach the climate goals. We need to realize that renewable energy is not as undemanding as fossil energy and that we have been spoiled with the unlimited, inexpensive fossil resources of the past century. Moreover, we need to face the consequences of the transition challenge. Yes, energy prices will rise. Yes, very large wind turbines will be everywhere. And yes, we need to change our behaviour if we really want to reduce energy consumption. If we come to an agreement and really stand behind our ambitions, then we can act according to them. The question is not if we can reduce our carbon emissions, but if we really want to reduce them.

When looking realistically at Rotterdam's transition possibilities, it is questionable if Rotterdam can reach its climate goals in time and on its own. A lot of interesting potentials are there, but if they will produce enough return is uncertain. Realizable renewable production sources are limited and even the easiest one, 56 wind turbines, can expect a lot of resistance from the inhabitants. The waste heat potential is enormous, but very hard to realize. Hooking up existing households to a cascading net will become a big challenge and maybe not very realistic. Moreover, the waste energy producers are mostly petrochemical plants. Fossil related and when the transition becomes a success, obsolete in a few decades.

Reduction seems to hold the greatest promise. Often small scaled and user related, reduction is the true decentral way of contributing to carbon reduction. Building refurbishments will take time, but will eventually occur and improve building efficiency. Further reduction is dependent on behaviour. It is very interesting to see which incentives will eventually stimulate positive behaviour and when this positive behaviour will take place. In my opinion, the behavioural changes will be provoked by economic drivers. Awareness campaigns did not change our fossil energy consuming behaviour, but rising gasoline prices and added environmental taxes for car use, are causing small energy efficient cars to become more popular. A perfect example that economic incentives are the catalyst of behavioural changes. I think that with the rice of energy prices, behaviour patterns will change as well. But if the rise of energy prices will be accepted by the public, is to be seen…

Project area

From the integrated typology perspective, the project area is doing quite well. The urban characteristics of the project area follow the principles of the integrated living environment: interconnected streets, traditional urban blocks and an already available high quality public transport network. Strong important features and already available in the area. Improvements could be made by enhancing the quality of the super grid, making it walkable and better connected to the inwards facing neighborhoods. Further, the soft characteristics of the area need improvement. The area needs to become an attractive living environment and therefore requires an attractive living climate.

From an efficiency point of view, the area can perform better. Because of the construction period, energy efficiency has never been of great importance. Refurbishments, big and small, should improve the efficiency of the project area. This can be done by small scale interventions like building isolation and double glazing, or area interventions as district heating and energy cascading.

Looking at the energy consumption of the area, the area already performs relatively well. Households consume significantly less energy than the Dutch household average. The exact factors responsible for the low energy consumption are hard to determine and form an interesting topic for further research. It could be that urban characteristics, following the dense city criteria, play a role in the low consumption rates, but if this role is significant, I do not dare to claim. Low income rates could also explain the low energy consumption.

Raised questions

- *What are strategies for an existing urban area to make the transition to a more sustainable and less carbon emissive energy system and how can this transition be beneficial for the deprived neighbourhoods within the urban area?*

A dense living environment according to the integrated typology, as described in this thesis, could be a good and realistic strategy for an existing urban area. The advantages of a dense city are numerous. Not only can a dense city, based around apartments and the traditional urban block become really efficient. It can also offer the environment in which people can live energy-lean lifestyles, while retaining access to wealth. It might sound strange that a sustainable living environment is the complete opposite of a green living environment, but the possibilities and benefits of a dense urban living environment are incomparable to any other typology. The limitation of personal wealth (small apartment, limited private space, not much room for stuff) makes this living environment very sustainable. The unlimited possibility for shared wealth (amenities and jobs), is the reason why this typology has the most potential. When we cannot afford to own a car, this typology still offers access to jobs, amenities and wealth.

The dense city should be a well considered choice. Not every (urban) area is suited for transformation into a 'polder Manhattan'. But if these areas are realized in an attractive way, I truly believe the market will turn them into a success. Unless we find a fountain of unlimited energy, energy will become scarce and more expensive. Therefore we need areas that can function well on a limited amount of energy and still offer wealth and quality of life. A high dense and mixed urban area offers this living environment. When energy prices will rice and energy poverty becomes a real issue, a certain market will arise that desires to live in dense urban areas. When reviewing the urban areas in the Netherlands that already have the integrated characteristics, they can be considered as very popular. So why not build/transform more areas in such environments?

- *What are methods to make the energy transition technically possible?*

The technical systems described in this thesis are already available and do not form a big obstacle.

Accepting and implementing them, is much more an issue. Renewable technical interventions are not as easy and comfortable as existing fossil resources and we need to accept this. Also, I believe that behaviour holds the key to energy transition. Therefore it becomes far more interesting to create the right incentives, than to optimize the technical aspects till perfection. Awareness campaign did not produce the desired effects, maybe economic drivers or a well designed living environment will.

- *What are strategies to integrate the technical transition methods into an integral and accepted urban design?*

Eventually, this was not the right question to ask. A good integral urban design does not need a lot of technical transition methods. It produces the desired results by influencing the lifestyle of its inhabitants and technical methods are only needed to increase efficiency. Moreover, the urban design should come before the technical transition methods. First a good living environment should be created, and then technical transition methods can be considered. Most of the efficiency measures are on the building scale and stay unnoticed. Large scale energy production systems (wind turbines) perform better outside an urban area and do not require integration. The only exception is district heating. This requires large interventions and planning, and should be considered at the start of an urban design.

- *What are strategies to make the energy transition beneficial for the deprived neighbourhoods within the project area?*

Again, this is not the right question one to ask. A high dense, energy transition proof urban area, is per definition beneficial for any deprived neighbourhood. The inhabitants of a deprived neighbourhood often have a low income and energy poverty forms a risk for these groups. An energy transition proof neighbourhood, in other words a neighbourhood that can function on a limited amount of energy, will offer these groups the environment in which they can live normally, even if energy prices rice.

To conclude

Traffic reduction is on a city scale one of the best changes to realize a big carbon reduction. The electric car holds great efficiency promises and the living environment can strongly reduce travelled miles. But traffic reduction is also the subject that receives the least amount of attention, at least in the reports

I reviewed. I believe municipalities should act on this. They should make public transport better, stimulate electric personal transport and create living environments that can function without cars. Municipalities are the ideal stakeholder to enforce this traffic transition!

Also, the conclusion that traditional Jane Jacobs like cities are the objective of a carbon reduction strategy is very promising. Not futuristic, modernistic or environmental typologies are the objective, but a traditional dense and attractive city. A great opportunity for urbanism to show its value.

Reflection

- *The relationship between research and design.*

The best example of the relationship between research and design is seen in the clear design principles resulting from the research. The generic principles resulting from the research phase can be used in any urban design or analysis. The principles, a dense city based around the traditional urban block, produce the desired effects and are an interesting conclusion in the technical field of energy transition. Not technical principles should be the start of an energy-lean city, but traditional urban structures, resulting in an attractive living environment should be the base of a sustainable city. This environment offers the context in which people and technical principles can perform optimal. In the theory part of this thesis, these principles are state is such a way that they can be applied in a design case. This is done in the second part of this thesis.

- *The relationship between the theme of the studio and the subject/case study chosen.*

The Urban Regeneration studio focuses on analysis and design, to improve existing urban areas, based on theoretical principles. In this thesis, generic principles for an energy-lean city are researched and applied on the Rotterdam (South) region.

The location, the methodology and the objectives, follow the studio principles. Rotterdam South is an existing urban area, the interventions are based on theoretical principles and the objective of the thesis, reducing carbon emission, will improve the area.

- *The relationship between the methodical line of approach of the studio and the method chosen by the student in this framework*

The thesis has a clear division between a theoretic literature study and a case study. The literature review underpins the case study theoretically and results in generic urban principles. In the case study the generic principles are used to guide the analysis and design interventions. Producing tangible results, which is a very welcome variation in the abstract and technical field of energy.

- *The relationship between the project and the wider social context*

The value of the project for the wider social context is rooted in the importance of the energy topic. Energy transition is a very hot topic and the Rotterdam Climate Initiative proofs this. Moreover, the topic is in its starting phase. We are just starting to realize what it will mean for our cities, when we need to reduce our energy demand. A lot of measures have already started, but some big challenges still lie ahead. Both users and technical systems can expect changes in the near future. This thesis has touched upon the changes related to urban areas.

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Appendixes

Consumption

Average national household consumption

Gas	1550 m3[1]
Electricity	3480 kWh[1]
Car	1[2] (53.8 GJ/yr)[3]

Consumption Afrikaanderwijk[2] (3690 households, 2009)

Typology	Gas (m3)	Electricity (kWh)	Car (quantity)
Apartment	1000	2350	0.5
Terraced house	1150	2550	0.5
Corner house	1100	2850	0.5
Average	1083	2583	0.5

Consumption Bloemhof[2] (6275 households, 2009)

Typology	Gas (m3)	Electricity (kWh)	Car (quantity)
Apartment	1100	2200	0.5
Terraced house	1350	2700	0.5
Corner house	1450	2750	0.5
Average	1300	2550	0.5

1 Taken from www.nuon.nl/energie-besparen/e-manager/gemiddeld-energieverbruik.jsp, Accessed on 1-07-2012
2 Taken from statline.cbs.nl/statweb/, Accessed on 1-07-2012
3 Taken from Broersma, et. al. 2011. Duurzame Energiebeelden voor de Veenkoloniën. TU Delft/ Wageningen UR. page 20.

Spatial translation

Spatial yield energy production[1]

Waste burning	0.1851 GWh/ha/yr
Wind turbines	0.1142 GWh/ha/yr
Solar CSP	9.9912 GWh/ha/yr
Solar PV	1.7003 GWh/ha/yr
Biomass	0.0159 GWh/ha/yr

Energy demand

	Gas (GWh/yr)	Electricity (GWh/yr)	Car (GWh/yr)	Total (GWh/yr)
Afrikaanderwijk	42.1207	9.5312	27.5724	79.2243
Bloemhof	85.9800	16.0013	46.8881	148.8694

Spatial footprint energy demand

	Afrikaanderwijk (ha)	Bloemhof (ha)	Total (ha)
Waste burning	428	804	1232
Wind turbines	694	1304	1998
Solar CSP	8	15	23
Solar PV	47	87	134
Biomass	4983	9363	14346

1 H+N+S 2008. *Kleine Energieatlas, Ruimtebeslag van Elektriciteitsopwekking*, Utrecht.

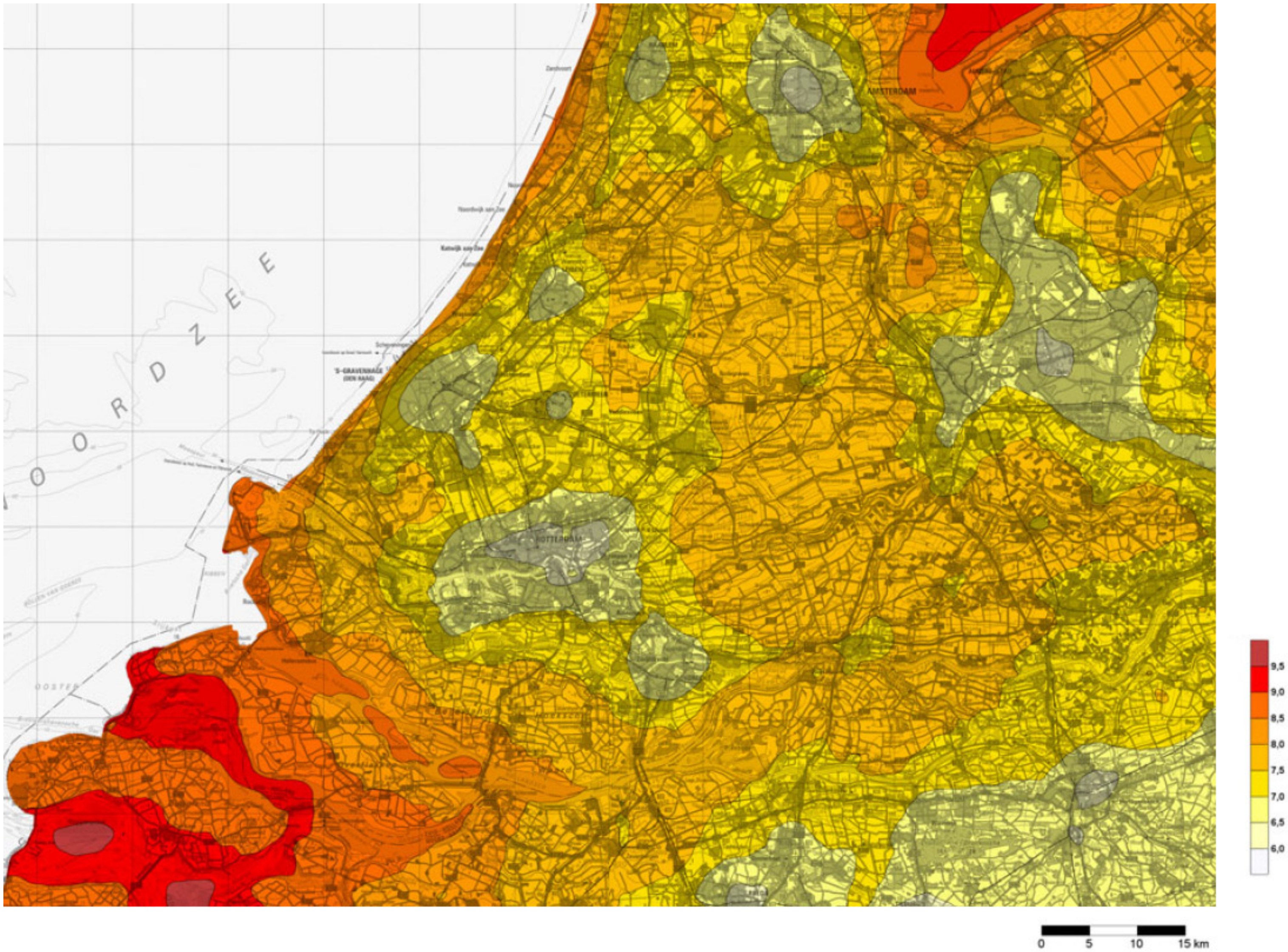
Total energy demand Rotterdam

Households	300.000
Gas	1550 m3[1]
Electricity	3480 kWh[1]
Car	1[2] (53.8 GJ/yr)[3]
Total demand of	10428.42 GWh/yr

Spatial footprint energy demand

	Rotterdam (ha)
Waste burning	56329
Wind turbines	91316
Solar CSP	1044
Solar PV	6133
Biomass	656840

1 Taken from www.nuon.nl/energie-besparen/e-manager/gemiddeld-energieverbruik.jsp, Accessed on 1-07-2012
2 Taken from statline.cbs.nl/statweb/, Accessed on 1-07-2012
3 Taken from Broersma, et. al. 2011. Duurzame Energiebeelden voor de Veenkoloniën. TU Delft/ Wageningen UR. page 20.


NOORDZEE
AMSTERDAM
'S-GRAVENHAGE
(DEN HAAG)
ROTTERDAM
9,5
9,0
8,5
8,0
7,5
7,0
6,5
6,0
0
5
10
15 km

Yield wind turbines

Formula used to calculate the power of a wind turbine:

$$P = \frac{p \times A \times U_0^3}{2}$$

P stands for Watt (W)
p stands for the density of dry air at sea level.
U_0 stands for the average wind speed at axis height.
A is the area of the turbine's rotor blades defined by radius r.

To correct the average wind speed at axis height the following formula is used:

$$U_{(z)} = U_{100} + C \times (z-100)$$

With:
U = wind speed in m/s
z = height
C = a constant of 0,023

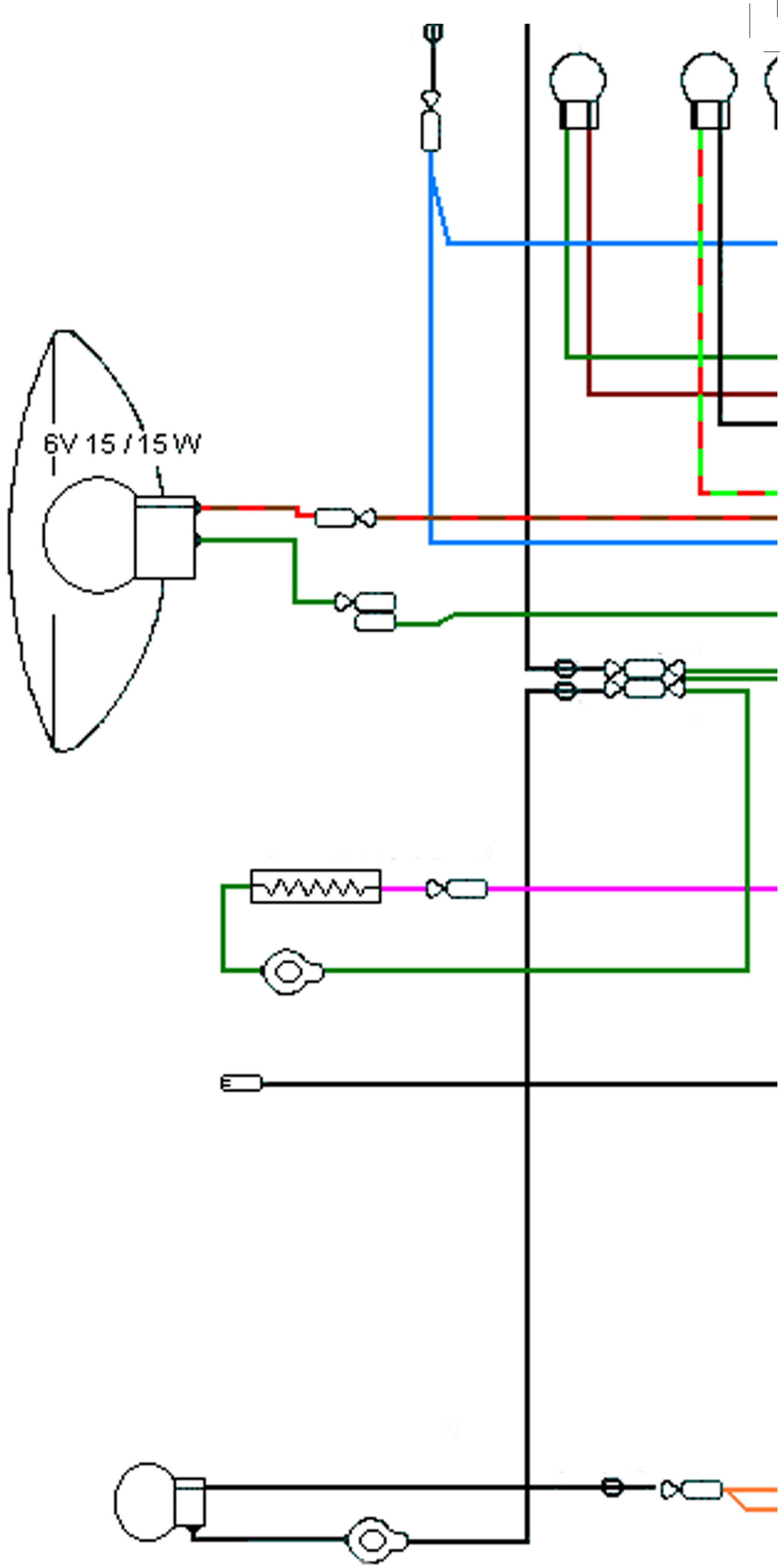
Windspeeds are taken from the map[1] on the left page.

Vollast uren: 2200

1 SenterNovem 2005. De Windkaart van Nederland op 100 m hoogte. Arnhem

Wind turbine Enercon E-126.
Height 140 meters.

Windspeed (m/s)	Yield/unit (GWh/yr)	Amount	Total revenue (GWh/yr)
6,5	7,39	9	66,51
7	8,99	11	98,89
7,5	10,8	12	129,6
8	12,84	8	102,72
8,5	15,13	16	242,08
Total		56	639,8


6V 15 / 15 W