rethinking the power of water

Master Thesis

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Re-thinking the Power of Water

integrating sustainable water management and renewable energy systems in a surface water oriented strategy to design future living quality in the Rhine-Meuse delta

Preliminary Thesis Report

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preface

This is the preliminary version of the graduation thesis report for the Masters study of Urbanism at the Faculty of Architecture, Delft University of Technology.
This graduation project has taken place in the graduation studio Delta Interventions. This studio deals with the following issue:
“*Due to a changing climate and changing insights concerning sustainable relations between cities and water-landscapes, new interventions will be needed to create a new urban delta-landscape. In addition to safety and better water-systems, in urban delta’s there is a need for stronger spatial identities and new cohesion of cities and their water-landscapes. This is a task that cannot be solved within one discipline; architects, urban designers, landscape designers and civil engineers will have to work together on different pieces of this complex assignment.*” (DeltaInterventions.com, 2009, accessed 10-5-2013)

What started off in September 2012 as a ‘plan to save the world’ – as many have addressed my initial ambitions – has resulted in an integration of disciplines that had my interest even before participating in this graduation studio.

I think that urban deltas are the urban territories that need a multidisciplinary attention to solve urgent threats at hand.
The water, that has been vital in the development of the urban deltas, still has its importance. However it is not exploited enough. This graduation project will show ways to re-think the power of water, see it more as a friend instead of a foe.

By combining the disciplines of energy management and water management together with urban development integrated solutions can be found to make a more sustainable urban delta that can face the climate changes and energy transitions of the coming century.

Caspar Lysen
Delft, October 31st, 2013.

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1 introducing the problem

introduction
problem statement

aerial view of Manhattan (source: pixelcase.com)

1.1 introduction

Ever since the Industrial Revolution, cities have become more and more attractive and have been expanding rapidly ever since. Nowadays, the majority of people worldwide live in cities. This will continue to grow. By 2030 six out of ten people and in 2050 even seven out of ten people is expected to live in cities (WHO UN-HABITAT, 2010). This will result in large urban expansion within the coming decades, where cities have to accommodate even more people in often already densely populated areas.
Although living close together in cities is relatively more energy efficient than rural living, the worldwide amount of energy used is mostly consumed in cities. This will increase in the future, when even more people will live in urban areas.

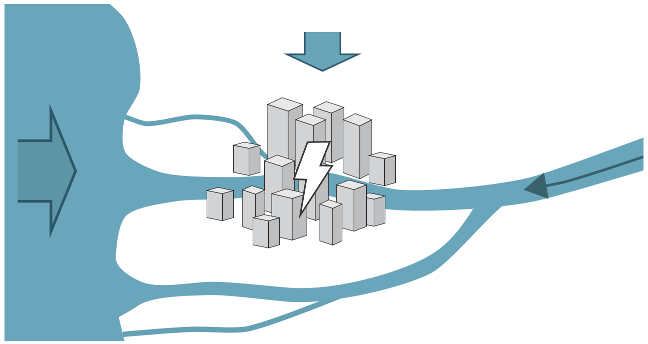
The majority of these urban areas are situated at or near waterfronts. It is predicted that half of the worlds population will live within 100 kilometers from the coast by the year 2050 (Adger *et al.*, 2005). The water is vital to the cities and the humans that live there. People have settled here centuries ago and have grown to the current urban deltas due to the favourable conditions. In delta areas settlers could benefit from reliable water sources, that could be used for drinking, but also as a mode of transport to dispose of waste. The land is favourable to growing crops because of its fertility and often flat. But on top of that, it offers a great place to start trade from (De Graaf, 2012).
Deltas are, apart from very favourable to urbanization, also a very susceptible to the threat from water. Since deltas can be defined as the place where river and sea meet, they are also experiencing the effects of both systems on the land (Meyer, 2009). This results in threats of river floods, storm surges from the seas, changes in sea level and dealing with heavy rainfall. The urbanization of the treacherous deltas can therefore be seen as a double complexity, which Meyer (2009) describes as:
“.. *they have to deal with the complexity of the delta, as the meeting of rivers and sea, and with the complexity of urban patterns, as a condition and result of economic, cultural and social life*.” (p.432)
This clearly shows that these deltas are difficult to develop, since one has to take the complexities of nature’s threat on top of complexity that human beings living together brings to the table.
Over the ages, though, man has developed measures to overcome these threats from nature that deltas have been subjected to. Building dikes and pumping water away from swampy land made safe urban expansion possible. On top of that, man was able to keep feeding and fuelling these ever growing delta populations. This results in today’s situation, where the largest cities in the world are located in delta areas and will only increase in number and size.

However, the coming century these urban deltas will face major threats when they continue to grow in the same manner. Apart from planning the rapid inflow of people into (mega)cities, climate change affects water systems and many of the currently used energy sources are depleting.

problem statement

1.2

The conditions in which we have been able to settle ourselves on this planet are changing. The energy sources that we use, are being depleted and due to climate change water systems are also changing, causing sea level rise, more floods and more droughts. This is affecting the densely populated urban areas across the world.



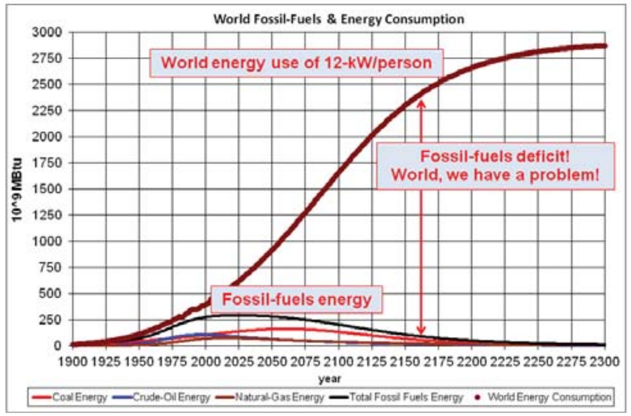
[Figure 1.1]: Graph showing the threats to life in the urban delta: energy shortage and a triple threat from the water, namely rising sea levels, increasing river discharge and more extreme precipitation levels
(source: by author)

Energy transition

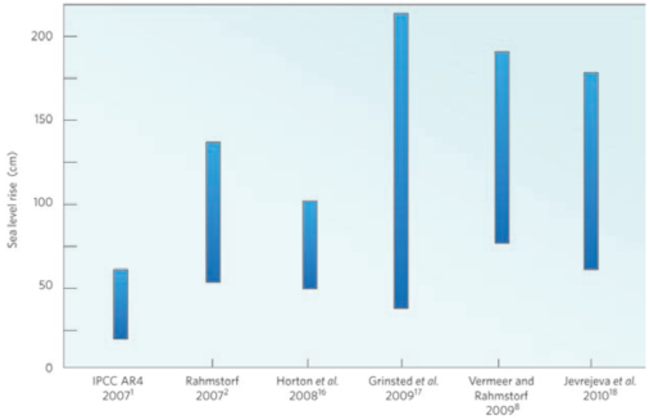
The current system needs a change to be able to afford the expansion and energy consumption we got used to over the last century. This awareness for sustainability has risen over the last decades. With the growth of the urban population comes an increasing demand for energy that cannot be met by most of the sources that are currently used. Therefore a more efficient use of sources is necessary along with a transition towards a sustainable system based on renewable sources.
Although living close together in cities is relatively more energy efficient than rural living (Owen, 2009), the worldwide amount of energy used is mostly consumed in cities. This will increase in the future, when even more people will live in urban areas. A transition to renewable energy sources is essential to meet our future energy demands, as [Fig. 1.2] shows a vast gap is showing in the graph. This is a serious concern, especially since it predicts the shortage will occur within the next twenty years.

Flood adaptation

On the other hand a triple water threat is facing urban deltas due to climate change. Due to global warming



[Figure 1.2]: Graph showing world energy deficit between the demand and the availability of fossil fuels. This clearly shows a transition towards new energy sources is eminent.
(source: Roper (2006), Future Energy, online: http://arts.bev.net/RoperLDavid, accessed Nov 7th, 2012)



[Figure 1.3]: Range of expected sea level rise in the 21st century. This graph shows that the estimates vary more than 150 cm.
(source: Rahmstorf (2010), A new view on sea level rise. In: Nature Reports [online:] http://www.nature.com/climate/ 2010/1004/full/ climate.2010.29.html, accessed October 26th, 2012)

sea levels are rising and storms become more powerful, causing more severe storm surges.
This is something that is visible in many places around the world already, often with great social and economical impact. Disasters such as in the state of Queensland (Australia) in December 2010, or New York (USA) in November 2012 are clear examples of how extreme weather could lead to enormous amounts of damage.

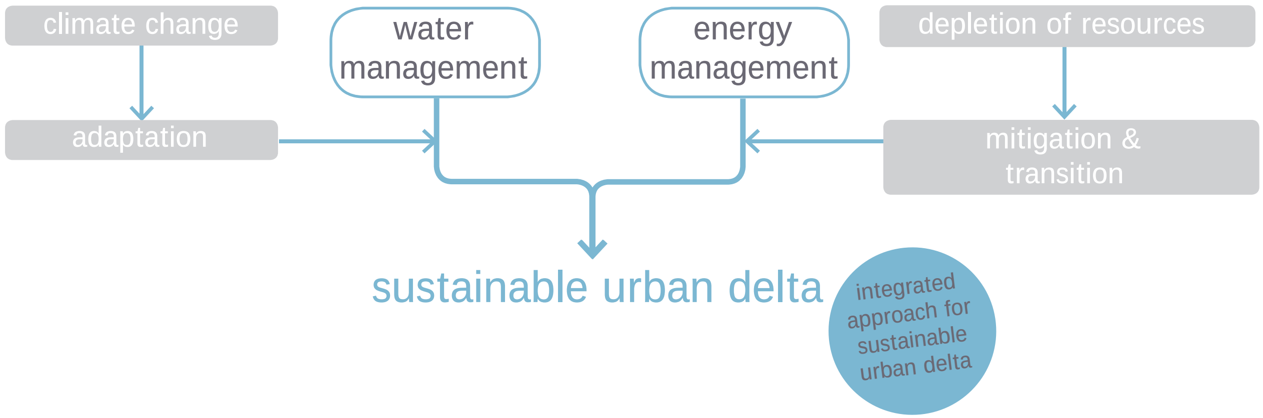
Over the past few years several studies have been done to predict the mean sea level rise. These results vary significantly [Figure 1.3] but most show a significant sea level rise.

The Delta Committee also has different scenarios for the Dutch coast, but the most likely prediction is that by the year 2100 the sea level have risen with 65 to 135 cm (Programmabureau Zuidwestelijke Delta, 2011). This is still a large margin, but it matches with the estimates in [figure 1.3]. This graph clearly shows that in any case serious water level rise will take place towards 2100 and will continue to rise afterwards.
Another characteristic of the changing climate conditions is excessive precipitation figures. Drought will occur more frequently, but also more precipitation with heavy peak loads will cause flooding
These changes will force us to adapt our water management to be able to cope with large amounts of precipitation as well as droughts. It would be a solution to have more storage capacity for fresh water. This is not only applicable to the outer dike area, but especially for precipitation also for inner dike area. Creating extra buffer capacity by means of implementing storage space is relatively easy in rural areas with much open land, but in dense urban area, the river squeezes itself through built-up area, with little space

for expansion. One solution is creating a bypass on a regional scale to relieve the city. There is still heavy debate on whether this bypassing is the right solution or perhaps even to open up the delta. Fact is, that creating more space for water in urban areas is very valuable in this matter, also because especially the water from the urban areas is important to store.

It can be said that there is a need for a new approach for urban deltas when it comes to resilience in water safety but also in energy consumption for the coming century. It will take a lot of change to the current situation, but this will be the way to anticipate to the situation in 2100 or even beyond. To make a good plan, there should be an integrated multidisciplinary solution to the challenge.

But how to combine a new strategies for surface water management with energy management in an urban delta? Today, these worlds are currently not very well integrated. Although both worlds are concerned with the future and try to work towards more sustainable solutions, their approach is different. As water management focuses on adaptation to climate change, energy management is more concerned with mitigation towards this problem and a transition to renewable energy sources. When finding long lasting and resilient solutions for urban delta redevelopment. This project should find the integrated approach for water- and energy management to evolve towards a sustainable urban delta. When we are able to manage our water better we can see it less as a foe, but treat it more like a friend and let it into our urban environment. This way, it can become possible to make this water work to our benefit when urban areas are (re) developed. Surface water can be seen as a blue swiss army knife with many functions. The versatile possibilities could create a sustainable urban environment. The sustainability in this project can be explained in two ways: environmentally friendly and long lasting.



[Figure 1.xx]: scheme showing the two disciplines that will be attempted to integrate in this graduation project (source: by author)

The urban developments should be using less energy, which be generated by using renewable local sources. The solution should last as long as possible. This means it should be able to withstand or adapt to the changing circumstances in both environment and governance. By implementing multidisciplinary solutions, they will be more widely supported. Adaptation to the changing environment means dealing with and overcoming changing economic circumstances or climatological changes that affect the area, such as water level rise.

Project location

The Dutch delta forms an excellent location for this graduation project. For centuries the Dutch have been battling the water quite successfully. They are renowned for it throughout the whole world. The country has been subsiding in the area near the coast and is below sea level; most people live in these western subsided areas below sea level. Major rivers such as the Rhine and the Meuse mount into the sea here, carrying water from large parts of Europe. At the same time, these rivers form the main reason for the economic success. The port of Rotterdam is one of the largest in the world and forms the gateway to the European main land.

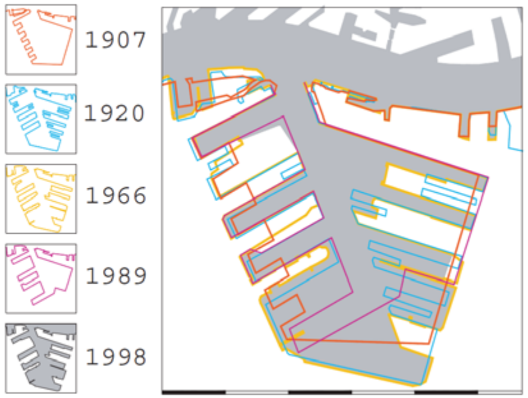
On top of that, this region is suitable, because it already has an extensive programme to become more sustainable. This is mainly combined in the Rotterdam Climate Initiative. The water threat is also addressed in this region by the Delta Committee and the municipality itself.

Another interesting characteristic of this delta lies in the planning. In Rotterdam, a vast area of city ports will be due for redevelopment within the coming cen-

tury. This is an opportunity to implement new and more integrated systems. Many city ports are currently under redevelopment, while others show a reducing industrial programme. The Waalhaven - the wedge-shaped basin in the close-up of [Figure XXX] - is, with a surface of 310 ha. the largest man-made port basin in the world (Municipality of Rotterdam, s.d.) and several concepts have been made for redevelopment.
The development of this large basin has been characterized by many transitions [Figure xxxx]. This adaptive design over the last century matches the adaptive approach of water management and the transition envisioned for implementing renewable energy systems.
With its many piers this port already has potential to become integrated with the water when it will be taken over by the city. This outer dike area would be ideal to experiment with new approaches, especially from the discipline of energy management.

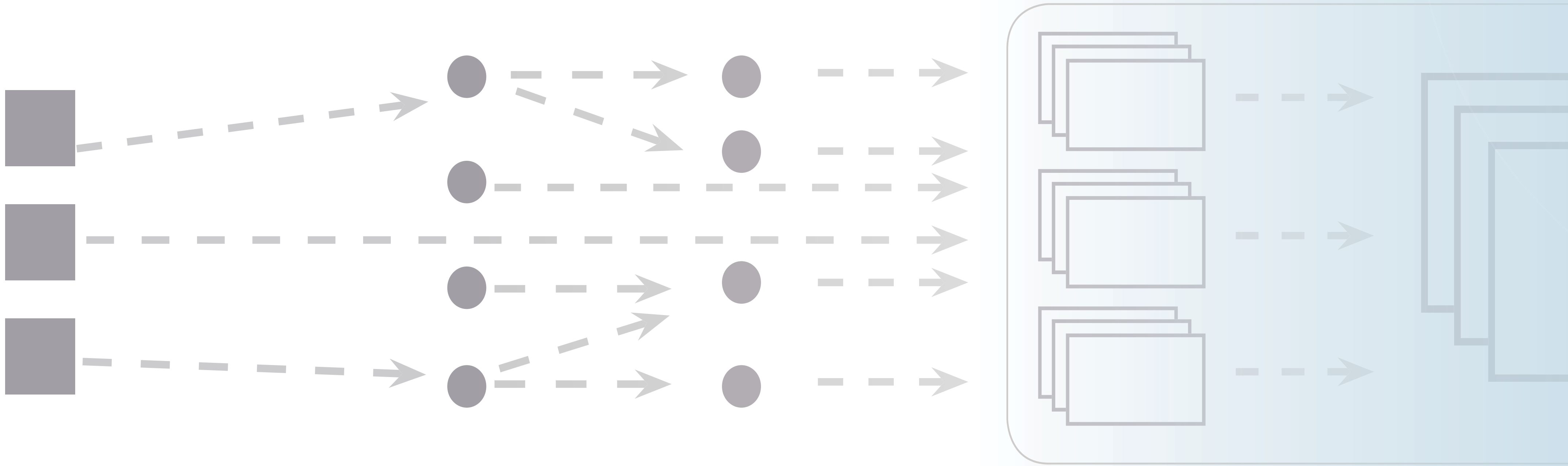
To anticipate to future threats, the potential of water should be rethought today. In this graduation project an implementation of a new energy system, integrated with the characteristics of the Rijnmond region, as a sustainable solution for sustainable and durable redevelopment of the urban delta will be researched.

[Figure 1.xxx]: project location is the Rijnmond-Drechtsteden region in the Dutch Delta. The local spatial implementations will be done in the Waalhaven; one of the city ports that will be transformed into urban area within the coming decades (source: by author, underlying map from Google Maps)



[Figure 1.xxxx]: The development of the Waalhaven in the 20th century, showing the transformations this large port basin has undergone and thusly its elasticity. (source: Kamphuis et al., 1998)

[Figure 1.xxxxx]: Aerial photo of Pier 1 in the Waalhaven, showing the pier was used as recreational area during the crisis of the 1930’s. (source: Kamphuis et al., 1998)



2 thesis setup

research questions

2.1

From the problem statement and the preferred location the following main research questions is posed for this graduation project:

How to spatially integrate flood adaptation and renewable energy systems in sustainable urban delta development?

Derived from this main question a number of sub-research questions will be answered in this project:

How to define sustainability in urban development?

How can sustainability be used for urban delta development?

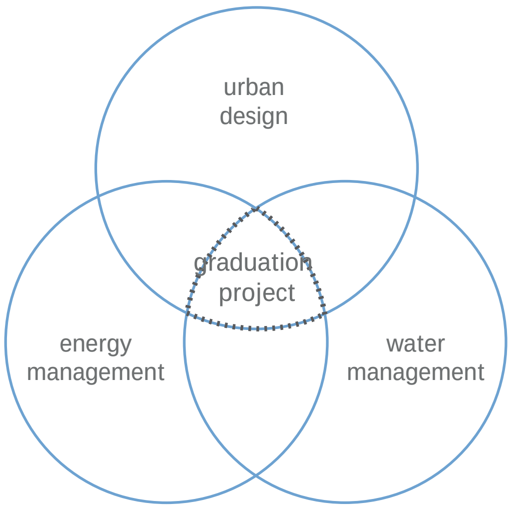
Where are the disciplines of energy management and water management best combined in spatial development?

How can these combinations play a role in a regional vision for the Rijnmond region?

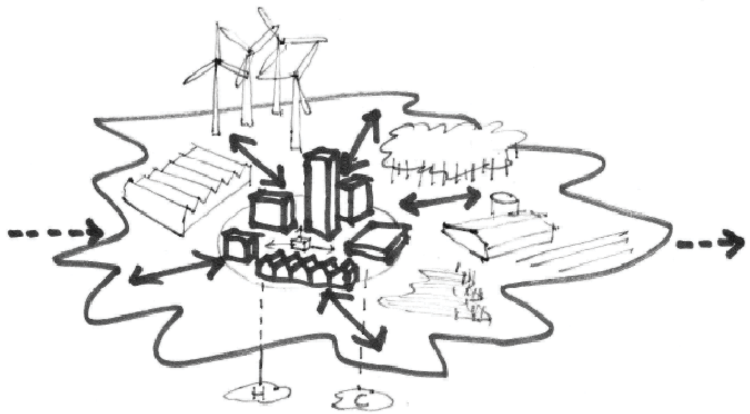
What is the potential of implementing this combination in a strategy for the city ports of Rotterdam?

How can integrated strategies be translated spatially into an urban design?

2.2 research aim



[Figure 2.1]: this graduation project tries to integrate the disciplines of energy management, water management and urban design.
(source: by author)



[Figure 2.2]: Conceptual scheme of an almost self-sustaining city, where most energy is kept inside the city's energy cycles
(source: Van den Dobbelsteen (2012), Fossil free cities: towards intelligent cities ready for the energy crisis, Lecture at University of Melbourne, March 21, 2012. Melbourne, Australia)

The main aim of this graduation project is to develop spatial solutions for an integrated approach of water management, energy management and urban development [Figure 2.1]. This should result in sustainable spatial solutions to withstand the effects of climate change and the energy transition that threaten the urban delta in the twenty-first century.

The first objective in this project is to find the optimum for gathering energy from surface water that can be implemented in the Rijnmond area.
Secondly, a regional vision on implementing this combination of water and energy should lead to the urban plan and –design, in which sustainable water management, sustainable energy management and urbanism form an integrated whole in spatial solution.

This project should aim for a strategy that makes the delta region of Rotterdam more self sustaining in energy use. This should be done by using the energy potential in the region and aim for more closed cycles (as seen in [Figure 2.2]). However, this should still match with the flood adaptation and the urban transformation.

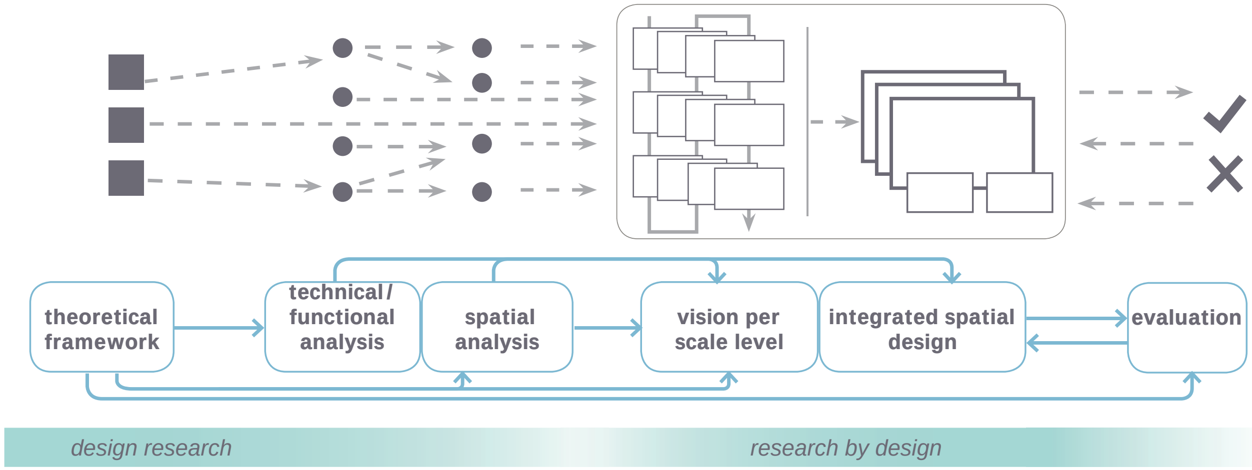
methodology & approach 2.3

2.3.1 Methodology

The main structure of this graduation project is as follows:

I – theoretical framework
II:A - technical analysis (Water&Energy)
II:B – spatial analysis (Energy&Urban dev.)
III:A – spatial vision, strategy and rules per discipline
III:B – integrated vision, strategy and design
IV – conclusion & evaluation

The theoretical framework and the analyses of the project can be characterized as design research (De Jong & Van der Voordt, 2002). In this stage knowledge is gathered to form the base of the design, that is feeding from this knowledge.
In phase III, the design research changes into study by design. "*Characteristic for this type of study is generating knowledge and understanding by studying the effects of actively and systematically varying of both design solutions and their context.*" (De Jong & Van der Voordt, 2002, p.21)
An overview of the methodology used for this graduation project is seen in [Figure 2.3].



	backcasting	forecasting		backtracking		
methods	literature review	literature interviewing studying precedents	site visit layer analysis	disciplinary layer assessment, data analysis	discipline integration, studying precedents	concluding reflecting
techniques/ products	review paper	diagrams schematics	maps drawings	maps	sketches drawings (2D, axonetric, perspectives) maps, calculations, toolbox	report poster

[Figure 2.3]: schematic representation of the structure of the graduation project linked to the methodology and techniques (source: by author)

The methodological details of each part is described:

I - Theoretical framework

Creating the theoretical framework is the start of this graduation project. It is used to gather knowledge on the subject of water management, energy management, sustainability and the design region (the urban delta in general, but also more specific the project area).

The literature in this theoretical framework consist for the greater part of literature studies. By reading books, proceedings, journals and reports, the knowledge on water management, energy management, development of the region and the array of implementable systems has been gathered. There is attention paid to the date of the pieces of literature. The most recent studies are more likely to include the latest technologies and should have included the new post-crisis perspective.

Attending lectures also contributes to the increase of knowledge on the topic. The lecturers themselves offer direct information on various related topics, but above all, they often refer to projects or literature that is very helpful in gathering the needed knowledge.

These types of research can be categorized as ‘bureauonderzoek’ (Verschuren & Doorewaard, 2007), which can be translated as ‘desk research’. This research methods mainly take place behind a desk, where data, gathered by others, is processed.

II – A: Technical analysis (W&E)

By combing the disciplines of water and energy, the technical research is executed.

By studying reports and papers and consulting Van de Ven, Tillie and Broersma (amongst others) in interviews, an overview of the many technical possibilities combining water and energy is created and subsequently assessed by focusing on potential and efficiency. Calculations are done to get an indication of the quantification of the best assessed system. Calculations are based on data found in reports and from case studies of similarly implemented systems.

II – B: Spatial analysis (E&U)

The results of the functional/technical analysis is combined with the characteristics of the project location. A comparative study of the REAP-initiative leads to adopt certain elements of these studies. Preconditions for the location are shaped by studying the municipal visions as well as visions of the City Ports and a combination with the technical research is made.

During the analysis, the progress and first envisioned solutions have been tested by presenting to the mentors of this graduation project.

III – A: spatial vision, strategy and rules per discipline

The vision and strategy are a spatial translation of the results of the research-and-analysis phase. In the third phase, a disciplinary layer assessment is applied. This is inspired by the layer method. This layer method, as originally used, distinguishes “*spatial planning tasks on the basis of the differing spatial dynamics of substratum, networks and occupation patterns*”(Van Schaick & Klaassen, 2011, p.1). However, in this project, the layers will represent a discipline: energy management, water management and urban development. Each discipline will be designed throughout different scales. The scales used are: regional, municipal, district, neighbourhood and segments of neighbourhood.

This phase is characterized as design research. The results from the analysis are put on paper. By drawing and sketching, but also digitally drawn maps and schemes a vision for a combined approach of water- and energy management is created. This leads to an adaptive strategy for the Rijnmond delta.

Creating a spatial vision requires more research. More knowledge is gathered via reports and interviews, but also from a comparative study, using reference projects. These precedents are taken from other urban delta regions. Rotterdam takes part in many alliances with delta cities all over the world, such as the DeltaAlliance, Connecting Delta Cities (CDC), C40 and Celsius Cities.

III – B: integrated vision, strategy and design

This step combines the design results per discipline per scale, creating the following products:

- Regional scale: vision
- Municipal scale: strategy
- District scale: masterplan
- Neighbourhood scale: urban design
- Segments of neighbourhood scale: urban de sign principles and visualization

The results of the two methods show four steps. Each step represents a scale level in which the three disciplines are spatially developed. Then, an integrated product is designed by using the ingredients from the three disciplines. The integrated result of one scale then feeds the individual disciplines on a lower level of scale. The results are organized in a matrix with scales on one axis and disciplines on the other [Figure METH3].

Step III-B is dominated by the method of study by design. By using sketches and collages a range of solutions of spatial integration of water and energy is created. By assessing these possibilities through empirical research (Verschuren & Doorewaard, 2007), such

as site visits and interviews, but also by more reports and precedents, a creative design process is fed. This process does not develop via a straight path, but has a more cyclical progress. This is something that is seen regularly with creative design processes (Van Doorn, 2004); sometimes a step back is required to move forward in the design process. The process described by De Jong and Hickling (1990) resembles the design process during this project (pp.23-26):
-> formulate –> generate –> compare –> choose -> execute –> explore ->

This design shows how to spatially translate the vision from larger scale into a key intervention in the strategy – namely the pier - in which energy and water are combined with urban challenges of the next decades. During this process the research by design inviolved the following research:
- Local analysis: subsoil specifications, site visit,
- Interviews with thermal network specialist for municipality of Rotterdam, Havenbedrijf Rotterdam, sustainable energy expert.
- Reference projects of rebuilding port areas: Hamburg, Copenhagen, Antwerp, Gotenburg and references in Rotterdam itself. This reference research is meant to discover smart implementations that have been executed or planned to improve living qualities and support the technical aspects of the energy- and water systems that are being implemented.

IV – conclusion & evaluation

The conclusions are drawn according to the way the research questions are posed. This includes a conclusion on theoretical, functional and spatial results.
Subsequently, the project as a whole is evaluated including the process. Both are presented in this integral thesis report at the end of the graduation project.

2.3.2 Approach

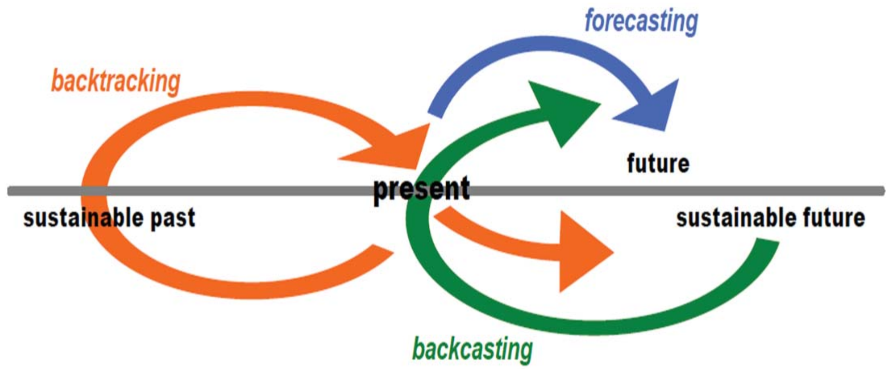
Backtracking, forecasting, backcasting

In the research to find the suitable systems from water management and renewable energy sources, an approach from literature is used. The principles of forecasting, backtracking and backcasting suit this project well. [Figure METH2] shows the principle of these three methods. In short they can be defined as follows (Van den Dobbelsteen et al., 2006):
- Forecasting is ‘ [..] *to estimate the consequences of current developments and our own intervention on long-term effects.*’(p.3)
- Backtracking is basing solutions ‘*on historical circumstances at the time there still was a sustainable equilibrium.*’(p.3)
- Backcasting is *‘involving the description of a desired future state* [...] *and translating this state back to strategies and measures we need to develop now.*’(p.3)

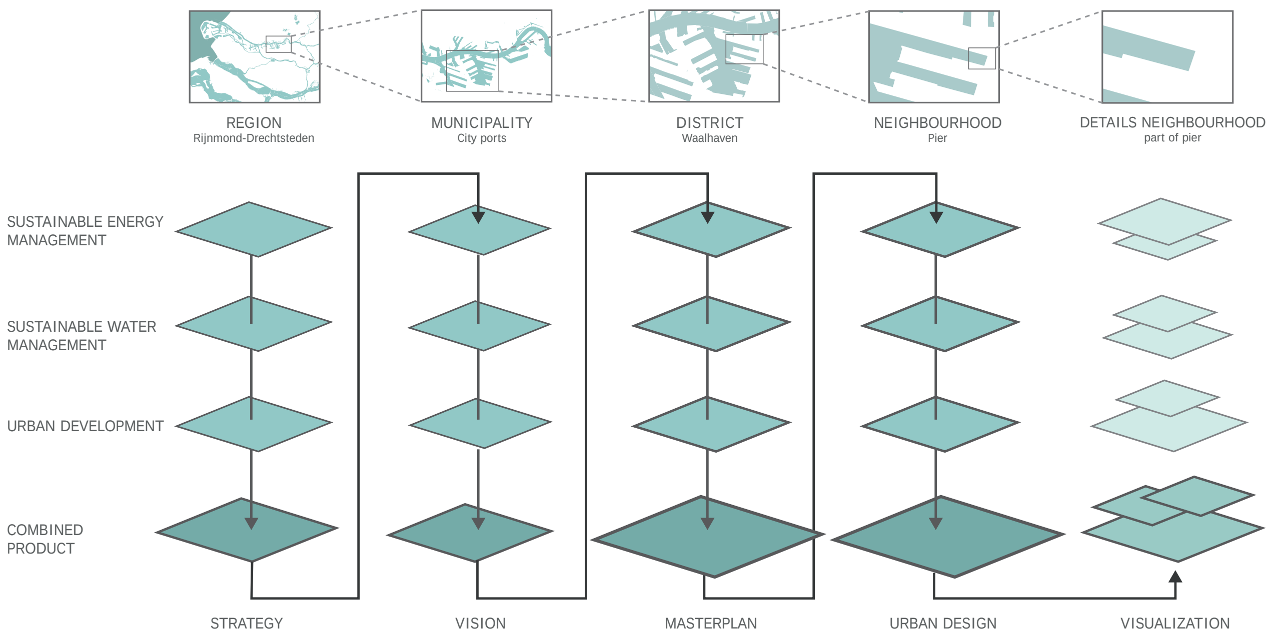
Translated to the graduation project, this means the following:
The future situation is forecasted. In fact, this is the problem statement; the forecasts might be vague, but they clearly show a challenge at hand.
The backtracking begins with researching the historical development of predominantly energy and water management, but also combined with urban development. This is elaborated in the literature studies. After establishing the historical sustainable equilibrium and understanding how these disciplines have developed until today, the conclusions can be projected onto future developments.
The next step can be interpreted as backcasting. If a certain sustainable future is desired, in which urban deltas will not suffer from the changing climate and the depleting energy sources, a vision and strategy should be developed today. This is preceded and ac-

companied by research and analysis. An urban design shows how this vision and this strategy can be translated spatially.

Disciplinary assessment: result matrix
To organize the results from the three disciplines with the conclusions on each scale, a structuring matrix is created [Fig. METH3], visualising the disciplinary layer assessment. This matrix works as follows:
Horizontally, the products per discipline are placed, starting at the large scale en continuing to zoom in towards the right. Logically, in the vertical rows each scale is displayed, showing the each discipline per scale and the combined product. This project meanders through this matrix, elaborating on the results per level of scale; starting with the disciplines and concluded by the combined products and subsequently taking this as starting point for a smaller scale.



[Figure 2.4]: A graphic representation to clarify the principles of forecasting, backtracking and backcasting. (source: Van den Dobbelsteen et al., 2006, p.3)



[Figure METH3]: The result matrix of different layers. Horizontally the different scales, vertically the disciplines and the combined product. The storyline throughout this report will run per scale level (source: by author)

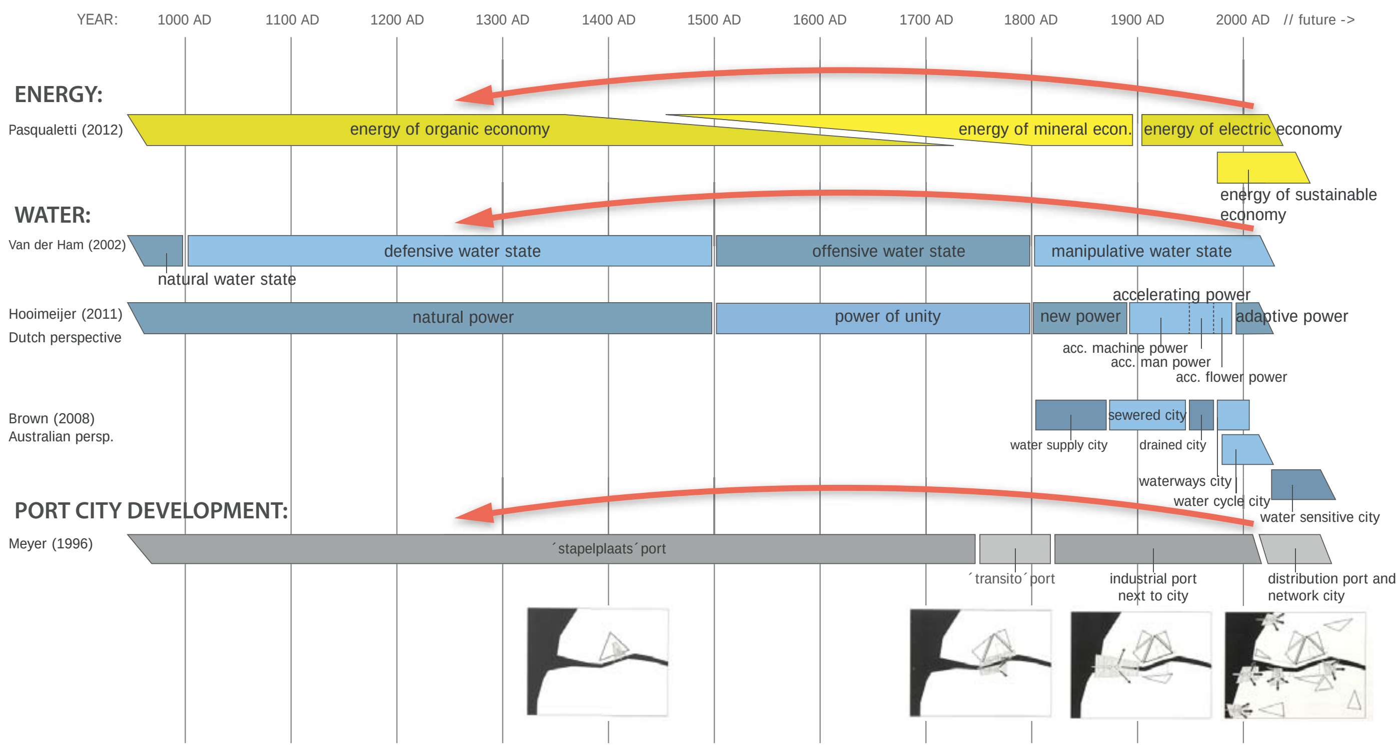
3 research & analysis

theoretical framework 3.1

Introduction

The theoretical framework for this graduation project consists of literature studies of the historical development of energy-, water management and port city development as a backtracking study.

Subsequently, the theoretical forecasting showcases future situations and sustainable approaches in the three disciplines to manage these paradigms.



[Figure 3.1]: Graphic comparison of the different theoretical studies on energy management, water manegement and urban development. The figure shows a similar trend in all disciplines: refering back to sustainable equilibriums of the past to approach the future. (source: by author)

<u>backcasting conclusions:</u>

Future energy systems should use renewable, local ly available resources to power a sustainable economy. The principles of centuries ago are suitable when we use modern technological paradigms to meet the ever growing demands.

The sustainable equilibrium can be found in partially giving space to the water and partially control it. In these controled areas, development should be more integrated with water management instead of relying on offensive power, that has strengthened sinced the Industrial Revolution.

The predicted reduction of scale and fragmentation of port and city, developing towards a network that forms a mosaic of funtions is not directly tracking back. However, this mosaic allows functions to mix and form interesting mulitple use of the public space and urban area. This can be tracked back to port activities integrated in urban area.

Historic development of water management and energy use

Different eras in energy sources

The different stages of used energy sources over time can be best categorized according to the different stages in energy landscapes, described by Pasqualetti (2012, pp.14-40).

I energy of the organic economy
II energy of the mineral economy
III energy of the electric economy
IV energy of the sustainable economy

[See also Appendix B???]

Today, we still use all of the resources mentioned in the stages above. Fossil fuels, currently the most used energy source, are depleting and therefore we are currently only at the beginning of this fourth age. One could also say that a circular process is completed and we have returned to our organic stage. This is a clear example of backtracking energy use.

Different eras in water management

Water management has always been closely related to urbanization. Meyer (2009) states: '*Throughout history, in a watery region such as the Dutch lowlands the question of water management and flood defence has been related to the question of the relation between the urban and the rural communities*'(p.433). Hooimeijer (2011) also focuses on the Dutch delta and gives a clear guideline to approach the Dutch water management history. It is divided into the following eras (using Hooimeijer's terminology):

I	before the year 1500:	Natural defensive
II	1500 – 1800:	Anticipative
III	1800 – 1890:	Offensive
IV	1890 – 1990:	Manipulative
V	1990 – present:	Adaptive manipulative

Hooimeijer also conludes: '*The Fine Dutch Tradition expressed in the new Dutch water city can return to its roots: complex urban developments that connect different challenges in the most efficient way*' (Hooimeijer, 2011, p.287). This can also be interpreted as backtracking to a time where urban design and water management were sustainably balanced.

A study by Brown et al. (2008) shows a similar division in different eras of water management. It also advocates to strive for water sensitive cities, in which adaptive and multifunctional urban design should enforce awareness of water in urban areas as well as flood resilience. Brown concludes that 'given the significant climate change and population growth challenges facing cities, there is a critical need for strategic investment in solutions that will deliver long-term sustainable outcomes.'(Brown et al., 2008, p.9)
This matches with this graduation project, where a vision and an urban design should be exemplary for a durable sustainable approach for the urban delta.

Meyer (1996) studied the historic development of port cities and defines four different eras. The main trend in this development is the separation of port and city as they increased in size, but predictions show a development into a mosaic of scattered port- and urban areas throughout the urban delta.

Backtracking historical trends

These studies on energy- and water management shows that backtracking towards the sustainable equilibrium can be seen in both disciplines. The use of local resources and being in touch with the local environment is the modern approach, just like it was back in the 1300's. In port city development also, a similar trend is visible [Figure 3.1]. The smaller scale is envisioned by Meyer (1996) for future port development, with a mosaic landscape of port and city. The approach for this project shows that all three disciplines show signs of working towards a new situation that was already seen centuries ago. Smaller scale systems with solutions adapted to the local problems at hand.

In this project, the integrated approach harnesses the traditional polder city water awareness with the small scale port development – integrated in the urban tissue. It should power the new developments with the use of locally available renewable resources from the sun, the moon and the earth. This will be spatially translated into an urban design. It should be noted that the design can use today's technological progress to be used in sustainable ways instead of using the paradigms of the 1500's.

Energy and sustainable planning

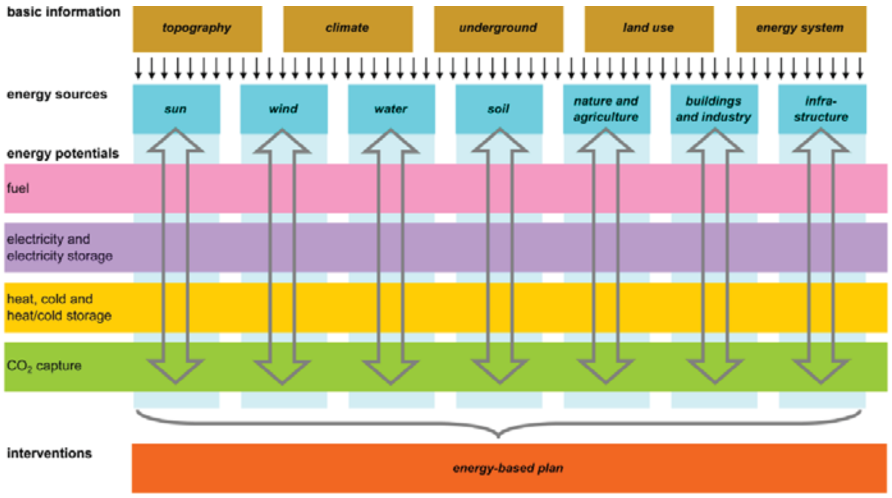
Technological advancement has given us the power to battle nature and to harvest resources from this planet in growing amounts. However, in the last decades awareness for environmental issues is raised. Gradually, the understanding that the used energy sources were not endless, started to emerge and that it would be wise to reduce our footprint. 'Limits to Growth' (Meadows et al., 1972), 'Our Common Future' (WCED, 1987) and 'Cradle to cradle' (McDonough & Braungart, 2002) are some of the main documents to indicate this trend. This mindset - along with ever evolving technology – should bring us towards a more balanced coexistence with nature.

This change, that has to take place, should occur in multiple ways. Using the Trias Energetica (Lysen, 1996) and the 'Cradle-to-Cradle' method (McDonough and Braungart, 2002) the New Stepped Strategy (Van den Dobbelsteen, 2008) was created:

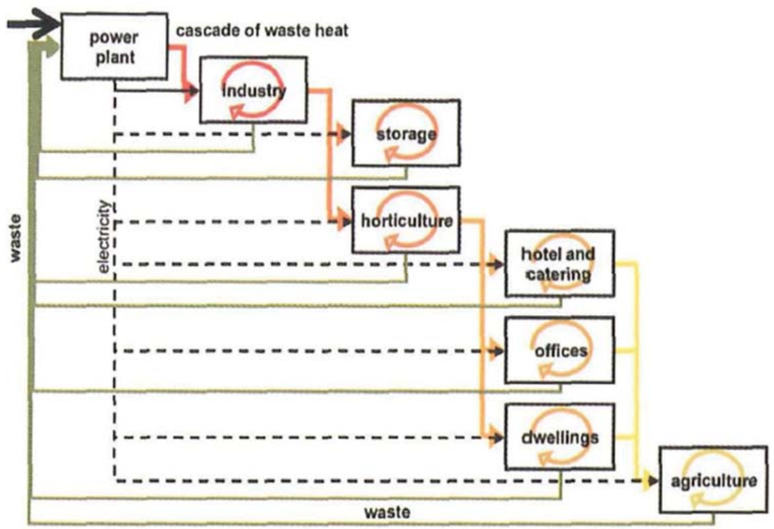
1. Reduce the demand
2. Reuse waste streams
3. A. Use renewable energy sources
   B. '*Ensure that waste can be used as food*' (Van den Dobbelsteen and Tillie, 2011, p.6)

In REAP – Rotterdam Energy Approach & Planning – by Van den Dobbelsteen and Tillie (2011) the New Stepped Strategy is applied to a principle for the city of Rotterdam. This includes the principle of energy cascading as seen in [Figure 3.3]. This principle shows that unused energy – entropy – from one user can be the exergy for another (Van den Dobbelsteen, 2010).

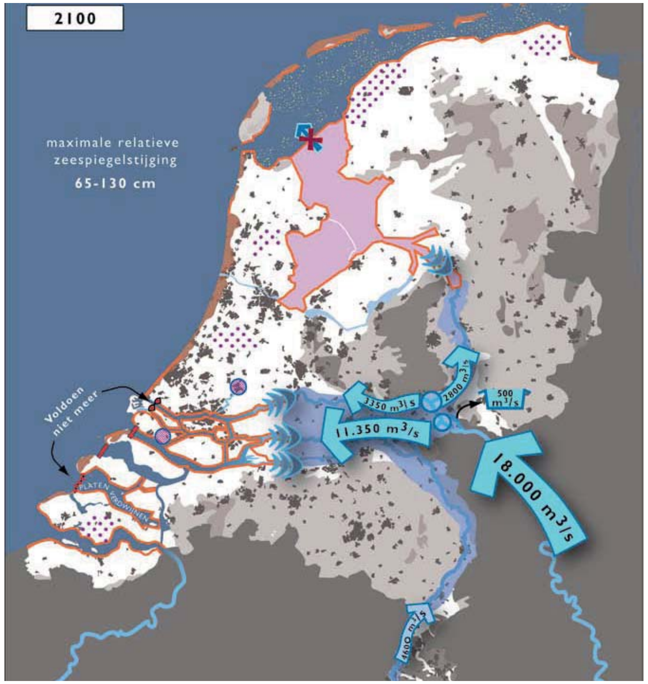
Transporting the energy from one user to another should be done across small distances, as it energy loss occurs and – mainly infrastructural - costs need to be made. Project Ground for Change (Van den Dobbelsteen et al., 2006) promotes the use of local strengths to come to sustainable energy solutions: 'there is no



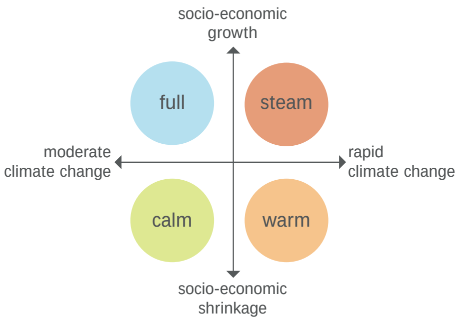
[Figure 3.2]: Energy potential mapping scheme (EPM). (source: Van den Dobbelsteen et al. (2011), Energy Potential Mapping for Energy-Producing Neighborhoods. In: SUSB Journal, Issue no. 14, 2011.



[Figure 3.3]: Principle of cascading where unused energy (entropy) cascades down to the next step where it partly serves as exergy. Source: Van den Dobbelsteen, 2010



[Figure 3.4]: The effects of the climate change on the Dutch water system predicted for the year 2100. Sea levels will rise 65 to 130 cm, creating a larger area of influence inland . Also a larger discharge from the rivers towards the sea. Part of the current deltaworks will be obsolete and dike reinforcement is emminent.
(source: Delta Committee, 2008)



[Figure 3.5]: four scenarios for the Dutch delta as predicted in the delat programme (source: by author, based on Delta Committee, 2008)

one true method or solution to attain a certain goal; every location and situation demands for different measures'(p.2). Looking for local energy potential is a complex study, considering many variables, as seen in [Fig. 3.2]

Power to the people

The New Stepped Strategy combined with harvesting from local sources, fits into Rifkin's idea on The Third Industrial Revolution (Rifkin, 2011). It describes that after the occurrence of steam power and the internal combustion engine , the third revolution in energy is occurring today; a switch towards renewable energy combined with the leap in communication due to the digital revolution. This third revolution consists of five pillars (Rifkin, 2011):

I - shifting to renewable energy
II - buildings as power plants
III - deploying storage techniques
IV - internet technology to transform the po wer grid
V - transition of transportation to electric

The European Union has already applied this to their energy politics (Energieoverheid, 2012)
This revolution also changes consumers into producers. It becomes more easily for a household to collect their own energy and become more independent. It creates the possibility to organise power on a very local level, such as a street or a neighbourhood. This is (literally) giving the power to the people (Tegenlicht, 2012). It gives individuals or small communities the chance to sort out their own energy needs, but also their own food and even their insurance.
The first four pillars are included in this project, predominantly the shift to renewables and deploying storage techniques.

Water

Water influences the energy system, as [Figure 3.2] shows. It can be a primary source - such as hydropower or tidal energy - or contribute in a secondary role, such as reducing Urban Heat Island effect (UHI-effect) and facilitate mariculture (Deltasync, 2012) and create an ideal environment for wind energy yield. These characteristics are very interesting to explore in the urban delta, where surface water makes up a significant percentage of the total area.

Today however, water is seen more as a threat that we need to control. This attitude is for good reason. In the coming century, high water levels will occur more frequently, due to rising sea levels, more extreme river discharges and more extreme precipitation. The Delta Committee (2008) predicted that by the year 2100 [Figure 3.4]:

- Sea level will rise 65 – 130 cm and will be influencing the water more upstream inland
- River discharge will increase to 18.000 cubic metres per second, of which the majority will pass through the Rijnmond-Drechtsteden region.

There are four scenarios developed to show what the Dutch urban delta will look like in the year 2100. They are predominantly determined by the development of the economy and the rapidity of climate change (Deltaprogramma Rijnmond-Drechtsteden, 2011):

- 'VOL' ('Full'): moderate climate change, socio-economic growth
- 'RUST' ('Calm'): moderate climate change, socio-economic shrinkage
- 'STOOM' ('Steam'): rapid climate change, socio-economic growth
- 'WARM' ('Warm'): rapid climate change, socio-economic shrinkage

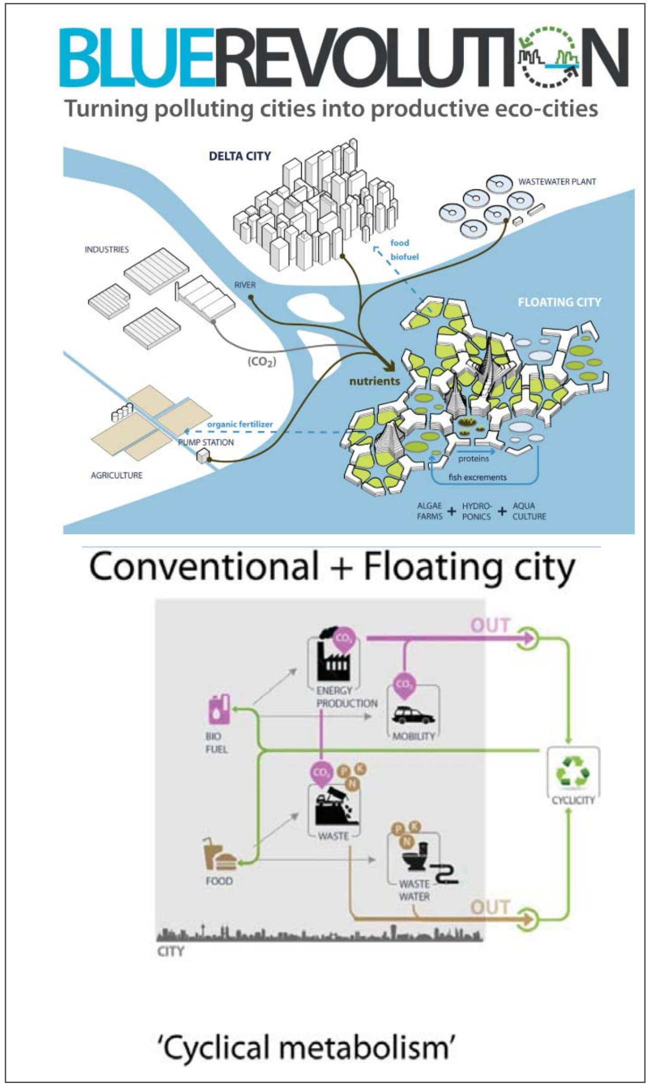
The future over a time span of a hundred years is hard to predict. For socio-economic developments this is even harder than climate change. Therefore, all four scenarios are likely to happen. However, the Delta Programme uses the 'Full'-scenario as the most likely in their strategies.

Improve overall fitness
To establish a climate proof region the 'overall fitness' of the area should be improved. This will lead to better capabilities to anticipate to climate change and become less vulnerable to threats (Homan (2005). This fitness can be improved by following these points of attention (Roggema, 2005):
- areas for natural resource
- networks strong, safe, flexible and overlapping
- safe living: define risk areas
- mix functions and provide many different elements
- landscape mosaic (spatial & functional)
- city differences (spatial & functional)
- border: define border of action, but also scope beyond border for regional context
- open infuence: define areas with open influence from external factors

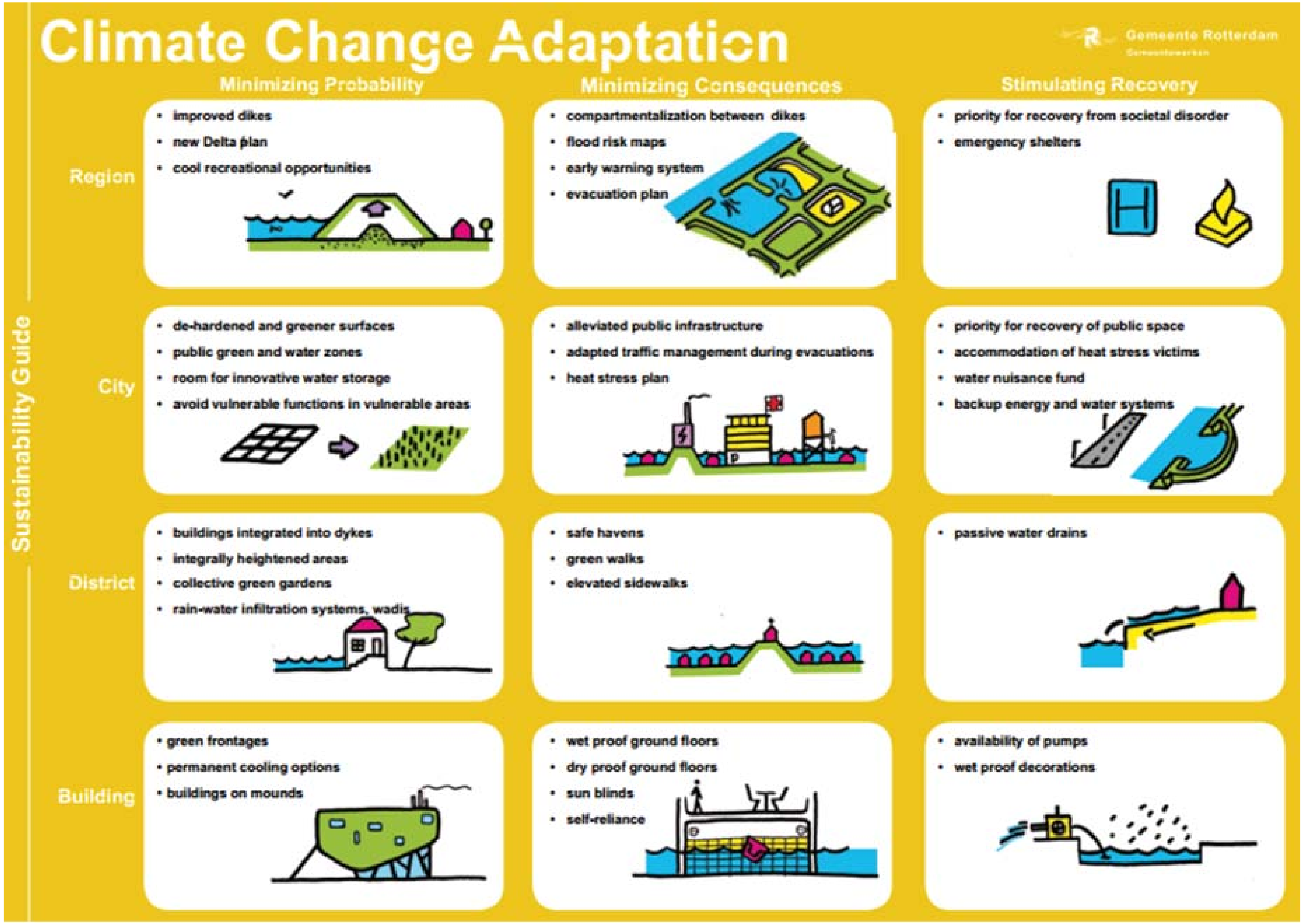
Rotterdam as one of the acting urban deltas
To understand urban deltas better, the work of Meyer is very supportive, such as 'Reinventing the Dutch delta, complexity and conflicts' (2009) and 'Delta urbanism in the Netherlands' (Meyer et al., 2010).
Delta cities worldwide have already organised themselves in different initiatives to exchange knowledge and experiences. Connecting Delta Cities (CDC), DeltaAlliance and C40 Cities are some examples of these initiatives, of which each has their own body of knowledge that could be tapped on to.
This knowledge is also published. For example the sustainability guide by the municipality of Rotterdam, in which tools for planners is published to help spatial implementation of climate change adaptation [Figure 3.7].

In the future urban development can also be taken to the large surface waters, such as the sea. Nowadays small lakes and rivers are occupied by floating buildings, but Deltasync (2012) proposes this new frontier in the concept of the Blue Revolution. This holds a long term vision in which we expand delta cities onto the water and use this area to create closed nutrient cycles for the city [Figure 3.6].

Forecasting the future
Towards the year 2100, more awareness with our environment will be creating by transition towards new energy approaches. The New Stepped Strategy forms the base of sustainable thinking. The REAP (Van den Dobbelsteen and Tillie, 2011) froms a good approach for tackling the energy transition in Rotterdam. There are many ways to extract energy from local potentialities, that can power local bottom-up initiatives to form small decentralized communities.
Since water levels will rise significantly in the coming century, more adaptive strategies to cope with this water will be needed in the urban delta, where socio-economic growth will be combined with a moderate climate change. However, preparing for the worst, the design results should be able to cope with a sea level rise of 130 cm in 2100. Extra water buffering will give more opportunities to use surface water in a way it contributes to the creation of a more self-sustaining city.



[Figure 3.6]: concept of creating floating extensions of the urban delta area onto the water to make a more environmentally friendly city, called Blue Revolution (source: De Graaf, 2012)



[Figure 3.7]: Excerpt from the Rotterdam Sustainability Guide, that can be used for planners to offer practical solutions to adapt the delta to climate change. The solutions can be executed on different scales. (source: De Jager, W. (2010) Rotterdam sustainability guide. In: Schoenmaeckers, B. & van Rijnsoever, M (2010) Change magazine: Deltas in times of climate change, 2010-2011, issue 1)

technical inventory water & energy 3.2

The goal of this project is to find spatial implementations of the integration of water management and energy management. This concentrates the research on to energy systems and their spatial effects on surface water. As a part of the backcasting, research and analysis help determining the instruments to achieve this goal with.

Understanding energy from water

Ever since the awareness of sustainable energy sources in our environment has risen, many techniques to extract this energy for our use have been developed. A wide range of possibilities can be implemented. Therefore, a categorisation is made to structure the possibilities. The energy provided by the sun and the moon and the earth´s core can be harvested as:

- Thermal energy
- Kinetic energy
- Potential energy
- electrochemical energy

Some of the applicable systems are tidal energy, wave energy, temperature and salinity differences, hydropower, geothermal energy and river flux (see appendix A for complete overview)

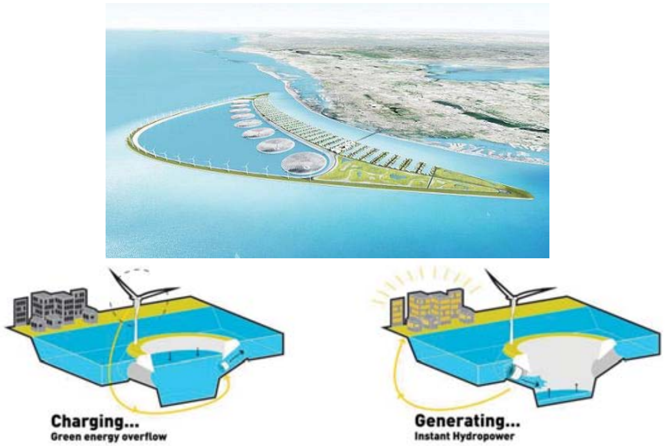
These harvestable energy potentials can be divided into three types of usage: electricity, thermal and the storage of energy [fig.3.9]. On top of that, surface water also has a secondary effect on wind energy, as a large surface of open water poses no obstruction to the wind and is therefore favourable to harvesting wind energy, but also offers space to store this energy. The storage of wind energy by height difference is applied in 'Plan Lievense' (Lievense, 2008) and more recently by Gottlieb Paludan Architects (year) [fig.3.8]. In this plan potential energy – or height energy – is combined with windpower, creating a system that could supply electricity according to the curve of the demand of the urban area.

With the aim of using these potentials regionally to meet the demands of the project area, let us focus on the Rijnmond region and its potentials.

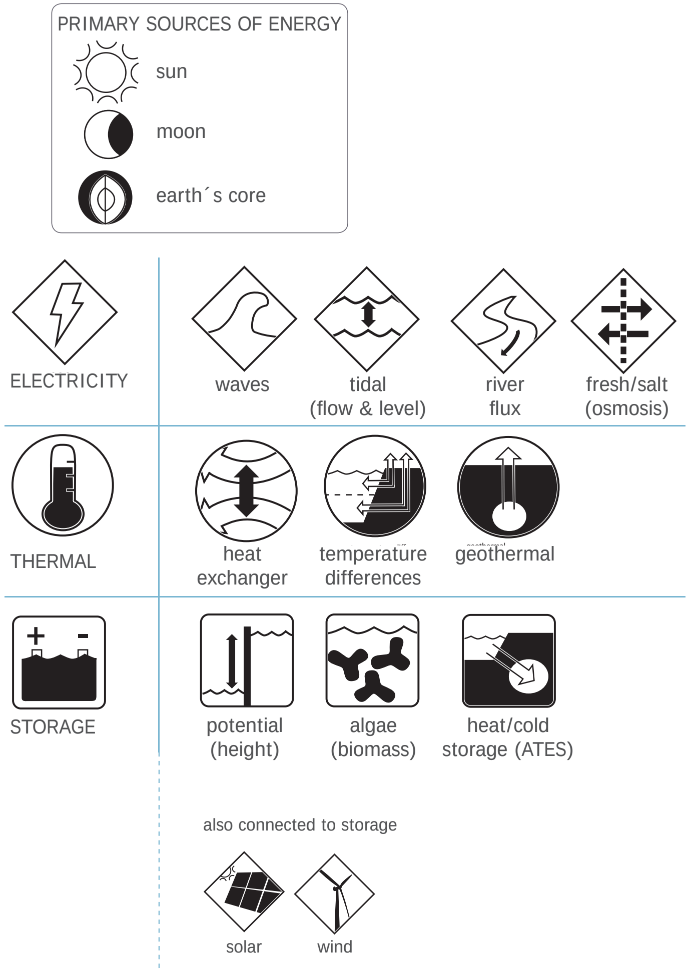
Yield potential in Rijnmond region

The potential of each system depends on the geophysical conditions of the area one is harvesting the energy from. The Dutch delta offers potential:

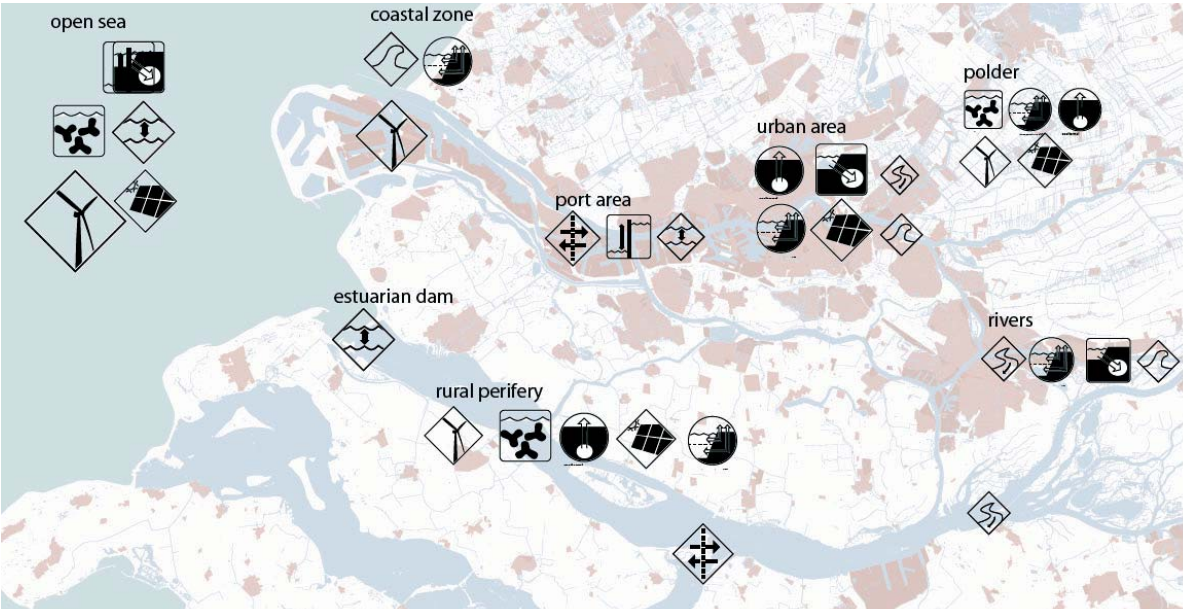
- in its estuaries with existing dams and tides for tidal energy, but also the close proximity of salt and fresh waters offers electricity through osmosis
- offshore by using the flux of the sea, the tidal differences and the waves, but also its potential for wind energy. Even thermal potential can be used for heating and cooling
- in its rivers for heating and cooling, but they run too slowly to be used for flux energy (Benner *et al.*, 2009)
- in its urban areas for heating and cooling and storing heat and cold
- in its rural polder areas, where the low-lying land is susceptive to inundation, but could therefore be a potential for heating and cooling, but also energy storage in the form of the biomass of algae. The flatness of the delta suits the rural areas for wind energy.



[Figure 3.8]: Visual of Green Island concept by Gottlieb Paludan Architects. This is a concept for an island near Tampa, FLO, USA. Energy is generated by wind and hydropower and is mainly used to provide cheaper electricity and a buffer for the peak demands. (source: Gottlieb Paludan, 2009)



[Figure 3.9]: overview of energy systems related to water, divided by their use; generating electricity, heating and cooling and energy storage (both thermal and electrical) (source: author)



[Figure 3.10]: potential renewable energy systems in the different landscapes in the project region.
(source: by author)

Implementation barriers

Of the potential implementations, the concept of the energy island 'Plan Lievense' is very expensive to build. To make this feasible, it needs to be developed on a large scale. This is very hard to do in the urban environment. A large port basin such as the Waalhaven, certainly has potential. However, in an urban environment it is undesirable to have a quay wall of about ten metres and a water level that fluctuates ten metres daily. On top of that, the cheapest and easiest way to obtain electricity to meet the peak demands is using electricity from abroad. This simply requires a cable across the sea bottom and is therefore much more cost efficient than building an energy island. Currently, The Netherlands already have a connection to Great-Britain and Norway and more connections are planned [Figure 3.12]. When generating electricity is combined with water safety, the expensive project could serve two goals – namely energy and water safety – and is therefore more feasible. In this project the possibilities of implementing this kind of islands is not included, since the combination with energy is at this point not feasible, especially in the urban areas.

Wind energy needs open space for maximum yield. On top of that, (large) turbines are experienced as nuisance in urban environment, so they should be positioned away from urban areas. This is a feasible option, because electricity can be easily transported over large

distances. Other systems need to be in non-urban areas where the conditions of the water are profitable. This is predominantly applicable to wave energy and flux energy.
Some new techniques for harvesting energy from water are not fully developed to be implemented at this point. This considers osmosis or blue energy. Also tidal energy and the energy island are still not seriously considered for implementation. It should be noted however, that predominantly the energy island and a tidal dam could also be combined with water the discipline of water management as they are also flood defence elements.

Assessment energy and water
The results of the assessment report by Deltares (2008) show the most suitable water energy systems for the Netherlands. Apart from its geographical potential, the different systems are assessed on technical and societal collectability. This means that not only the energetic potential is taken into account, but the research also shows the technical possibilities to implement the system and the acceptance by society to implement these systems. The results in [Figure 3.13] show that the most potential lies in heat and cold storage and geothermal energy.
A second report concerning the assessment of techniques of energy from water shows similar results. From this report by CE Delft (2009) can be concluded that the best techniques are:
- heat and cold from sea water
- floating housing with heat and cold from water
- energy from waves

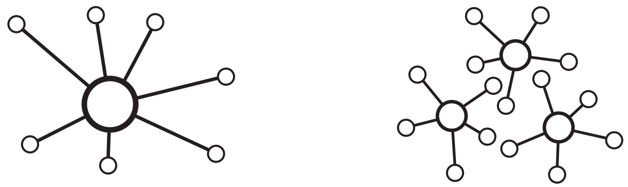
The most promising approach for a sustainable energy system would be the exploration and the implementation of thermal energy from water. The wave energy is not applicable in the urban environment. The first two options can be combined as they both consider the thermal qualities of surface water.

Thermal energy from surface water
To get more acquainted with thermal energy and its characteristics and possibilities for the urban environment, an additional study is done.
The thermal energy and water combination is concerning the surface water, but also the subterranean water and includes the systems of temperature difference, heat and cold storage and geothermal energy [Fig 3.14].

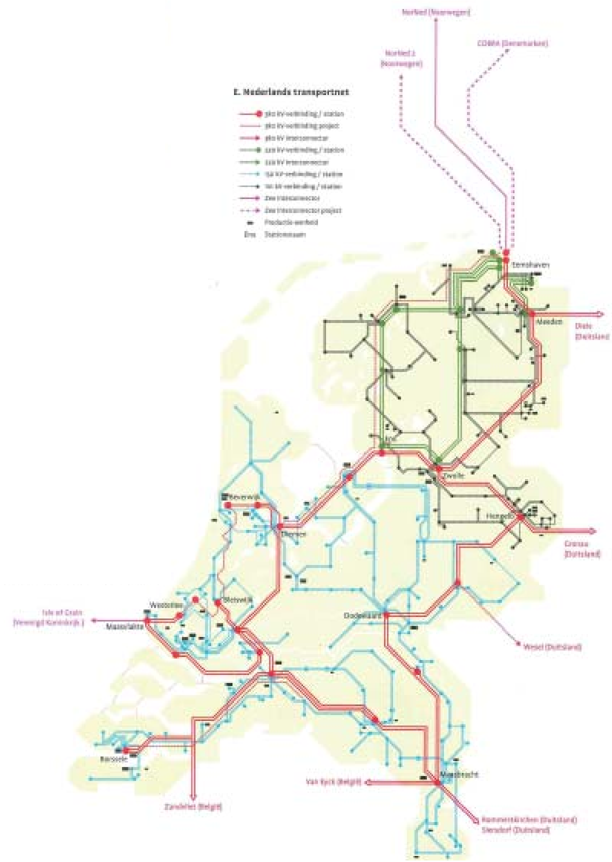
Surface water is used for cooling and heating by using the difference in temperature between the water and the indoor temperature of a building. The disadvantage of this system is that there is little temperature difference between the source and the desired temperature. Therefore, it has only a small effect. Nevertheless, the thermal capacities of surface water are nearly endless, when this is taken from a river. Here, the flow provides new source material constantly.

Surface water as a cooler seems perhaps more logical than its heating capacity, but it is actually an immense solar energy collector. For example, during summertime, the total heat (and cold) demand in The Netherlands can allegedly be collected from sunrays in the Dutch surface waters in just eleven days (Techniplan, 2010). This means an enormous heat potential form surface water, although it is a low temperature heat.

A large temperature difference can be found by using geothermal energy; the heat from the earth's core. From a depth of about two kilometres water is pump-



[Figure 3.11]: centralized(l) and decentralized(r) networks are representing the two systems for energy distribution, top-down versus bottom-up, regional versus local (source: by author)

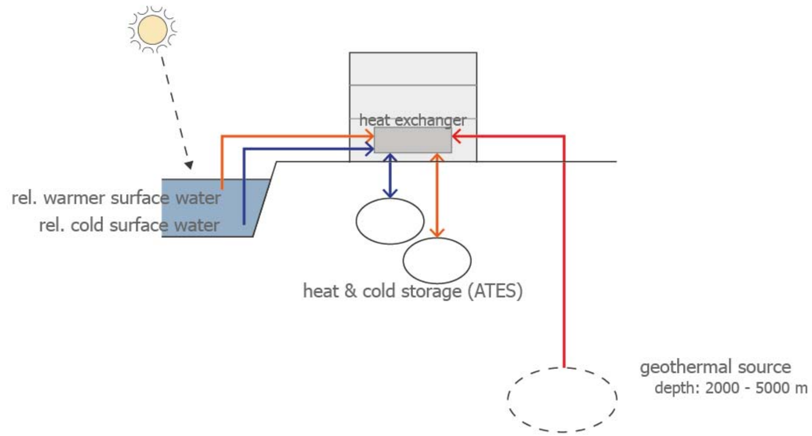


[Figure 3.12]: Dutch Electricity network with connections to Great-Britain and Scandinavia.
(source: Tennet TSO (2012). In: Leenaerts, H.(Eds.)(2012), Bosatlas van de energie. Groningen: Noordhoff Atlasproducties, p.79).

PJ / year	fresh/salt gradiënt	river flux	tidal flux or diffe-rence	waves	aquatic biomass	heat/cold storage	geother-mal	difference in tempe-rature	total energy yield
total potential	green	red	orange	orange	green	green	green	green	green
technically collectable	orange	green	orange	green	orange	green	green	orange	green
societally collectable	green	green	orange	green	orange	green	green	orange	green

	total potential	technically collectable	societally collectable
high potential	20% (or more) of the electricity use or 100% (or more) of the heat demand	relatively simple technology and already tested and proven with avarage result	hardly any disadvantages or con-flicts, perhaps even advantages
average potential	5-20% (or more) of the electricity use or 50-100% (or more) of the heat demand	in principle simple technology, however, not proven yet or limited gain	advantages and disadvantages, conflict with other users or no clear balance yet
least potential	5% (or less) of the electricity use, or 50% (or less) of the heat demand	technique still in concept phase, or bad gain	entirely or most ly onacceptable, or strongly conflicting

[Figure 3.13]: assessment table of different energy systems with water, showing the most potential can be found with heat and cold storage, geothermal energy and wave energy. (source: Deltares, 2008)



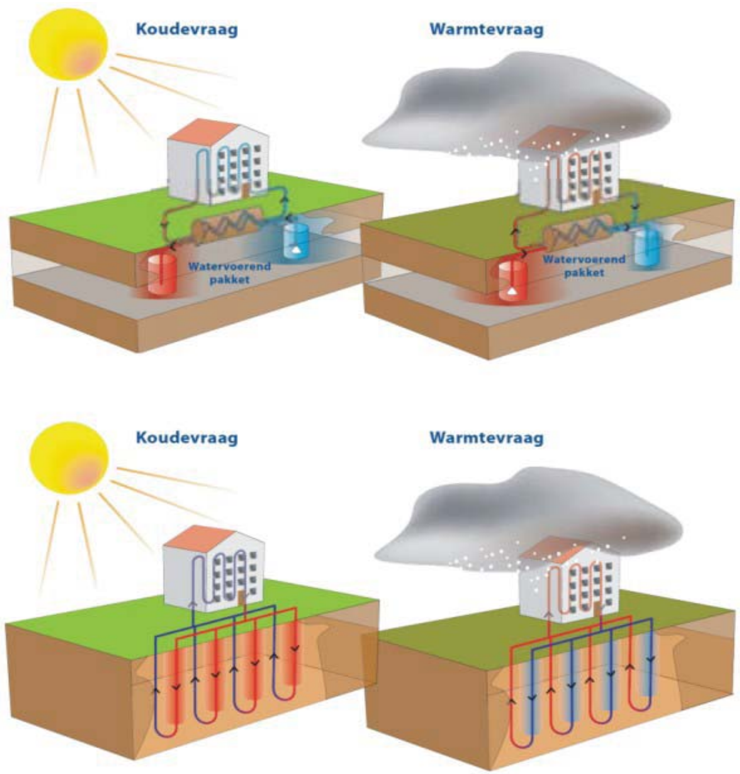
[Figure 3.14]: schematic overview of the three possibilities of thermal energy combined with water: solar power and cooling from surface water, heat and cold storage and a geothermal well. (source: by author)

ed up with temperatures between 60 and 150 degrees Celsius (Van t Slot, 2011) and is therefore mostly suitable for high-temperature heat demand, such as hospitals and industrial activities. However, geothermal wells provide no cooling option and they can deplete in a couple of decades. It then takes between one and three centuries to recharge. This makes the yield limited.

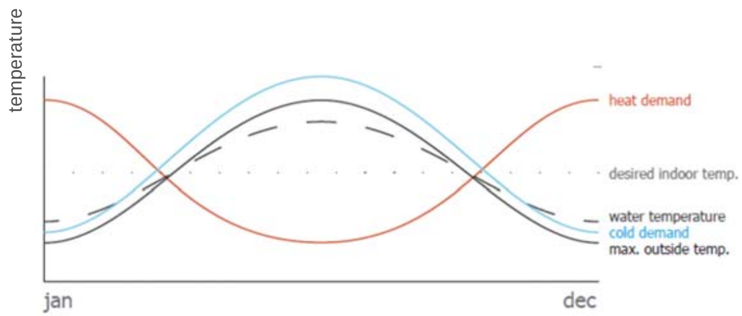
Heat and cold storage is another way to increase the difference between the source temperature and the desired temperature. It is best known in the form of Aquifer Thermal Energy Storage, or ATES. It works with the principle of transporting heat from above the surface to aquifers underground via water. This means both heat and cold can be stored to be used when it is needed. This system only stores gathered energy and therefore needs another producing source, such as indoor and outdoor air temperatures, or water. As seen in [Figure 3.15] the most common way is to use in underground aquifer stored heat and cold to create the desired indoor climate. Then, the used water has changed temperature and is stored again in the underground. During the summer, the cold source is depleted as the warm source is charged; in the winter this process is reversed to meet the heat demand. Besides ATES, there is also a closed system possible, where the stored water is not pumped into an aquifer, but heat is transferred to the surrounding soil around many pipes. This closed option is suitable for single household storage, but less suitable for the larger projects as the capacity of a closed system is smaller than an open system.

The water temperature difference is compared to the heat and cold demand schematically over a year in [Figure 3.16a]. This shows the demand is opposite to the availability of heat and cold. To achieve the desired temperature, the surplus of heat in the summer and the surplus of cold in the winter should be used half a year later [Figure 3.16b]. Storing this heat in for instance aquifers would make it possible to transfer the heat and cold from the surface water in time.

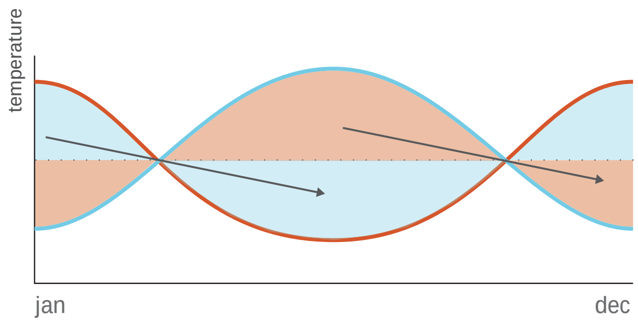
Conclusion
The most efficient usage of energy from urban surface water can be found in its thermal capacity. The electric alternatives are more efficient on larger a scale in rural or marine areas, where they are less of a nuisance, but still without a significant energy loss due to transportation. In combination with heat and cold storage, the subtraction of heat and cold from surface water can provide a substantial part of the heat and cold demand. Where other types of harvesting energy from water are far less efficient, thermal energy systems work especially well in urban areas of the delta. Also, the solar energy captured by the river water in the hinterland flows towards the ocean and often passes through delta cities. Therefore surface water should not only be seen as a coolant, but also as a heater.
Due to the limited temperature difference of the surface water and the desired temperature at that moment, the heat and cold can be used most efficient when it is stored and used half a year later when there is a significant demand for it.



[Figure 3.15]: Schematic representation of on open system (top) and a closed system (bottom) for thermal storage. The system is shown in summer (left) and winter (right) conditions. The open systems have more capacity and are therefore used for larger projects, whereas closed systems are often used for small projects. (source: Eneco, [online:] www.vrijekavelsplantagedesniep.nl)



[Figure 3.16a]: Schematic graph of the different temperatures of water and air, compared to the demand during a year. (source: by author)



[Figure 3.16b]: the difference in supply and demand should be solved by collecting the surplus and using it half a year later during shortage (source: by author)

3.3 spatio-technical analysis

After establishing thermal energy combined with storage as the favourable combination of energy and water, this result is applied to the project area: the urban environment of the Rijnmond region. This will be done according to the scale levels that are used in the design, starting with the regional scale, via municipal scale to Waalhaven scale to pier level.

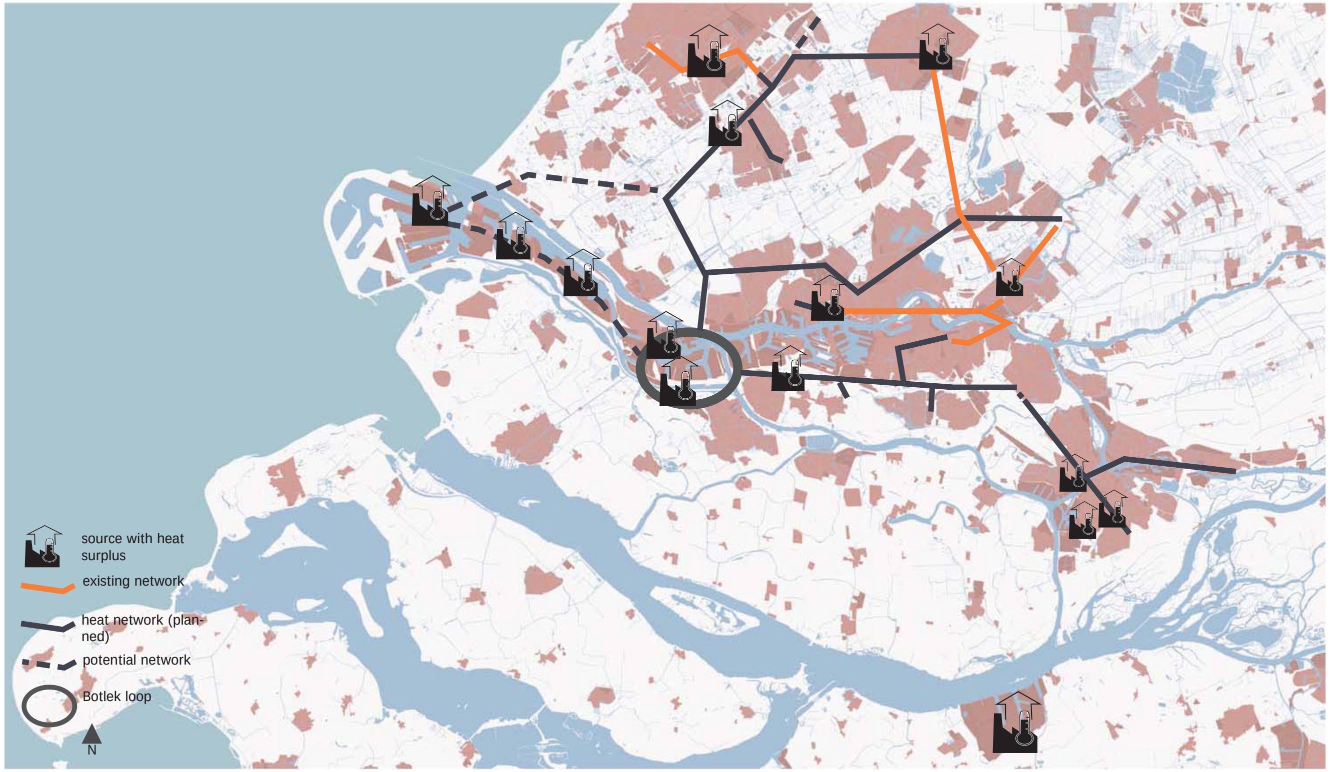
Region: thermal energy network development

Currently, several developments are already taking place in the region, such as geothermal heating for greenhouses, but also individual heat and cold storage and a district heat network fuelled by excess heat from waste incinerators and industrial activities in the Port of Rotterdam.

Currently the region has several district heat projects and is still expanding [Fig 3.17]. However, in future, the current production of heat will be reduced as these heat producing activities in the Port of Rotterdam will disappear. It is expected that by the year 2050 at least two of the five major excess heat producing industries will have disappeared to be replaced by cleaner industries (Tillie, 2013a).

Alternatives need to be developed to anticipate to this future decrease in heat supply. Two strategies have been are proposed by the author [Fig 3.18]:

- Take over parts of the district heat network with sustainable alternatives



[Figure 3.17]: District heat networks and projects in the South wing of the Randstad. Excess heat from port industry is used elsewhere in the region. Also in urban areas heat suppliers are in place.(by author, based on: Tillie, s.d.; Province of Zuid-Holland, in: Bosatlas van de Energie, 2012)

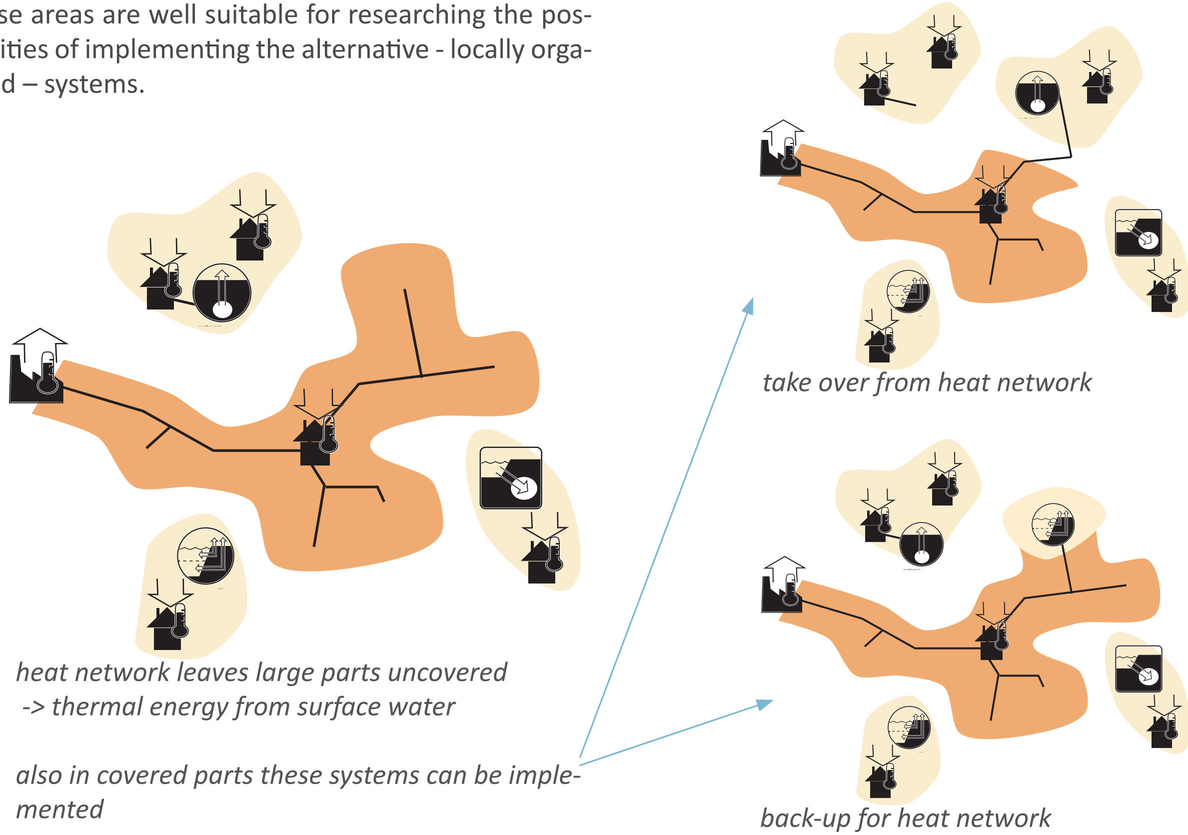
- Create sustainable back-up sources for parts of the district heat network

These alternatives can be geothermal wells, biomass incinerators or heat from surface water combined with Aquifer Thermal Energy Storage (ATES). Of course, these alternatives could also be implemented in urban areas that are not serviced by the district heating network. The alternative can by chosen by assessing which type has the greatest potential for that particular area.

The region has also geothermal potential as autonomous source. As [Figure 3.22] shows, higher temperatures can be retrieved from 2000m and 5000m. The highest temperatures can be found in the greenhouse area, an evident heat-demanding region.

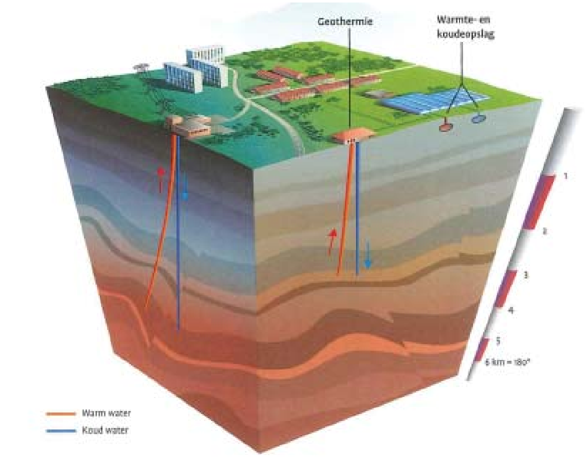
City: The Rotterdam district heat network

The current Rotterdam district heat network is the most extensive network in the region and is depending on heat suppliers that will disappear in the upcoming decades. Therefore the focus of the project lies with the municipality of Rotterdam. The current district heat network of the city [Fig 3.19]is scattered across the city, but mainly covers the city centre and the north-eastern suburbs.
One of the conditions of successfully implementing a district heating system into a neighbourhoods is to have a density of at least 30 dwellings per hectare. In neighbourhoods with lower densities it is simply too expensive to construct all the infrastructure and the extensive pipe network creates a larger heat loss during transportation. In the heating vision of the municipality or Rotterdam [Figure 3.20] these suitable areas are visible in large parts of the city. The focus areas for the municipality are situated outside the concession areas and located in the northern suburbs. These areas are well suitable for researching the possibilities of implementing the alternative - locally organised – systems.



[Figure 3.18]: schematic drawing of combining the district heating network with locally organized sustainable alternatives (source: by author)

[Figure 3.19]: current district heating network of Rotterdam (source: Tillie, 2013)

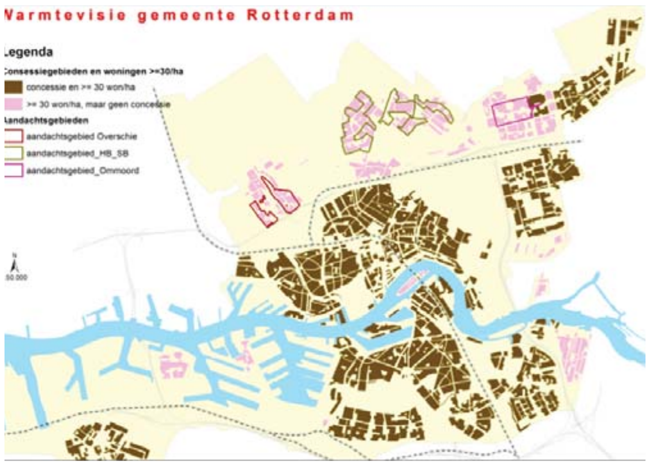


[Figure 3.21]: Principle of collecting geothermal energy (deep wells) and ATES (relatively close to surface). source: IF Technology/TNO

Subsoil potential

The region is already used for underground thermal storage, but hidden deep lies a heat source.

The geothermal potential is very favourable for this region. The most potential areas are located underneath the greenhouse area. This link has indeniable potential. The total potential for the Waalhaven is not as high as the Westland. Still, underneath the Waalhaven 9 - 15 GJ/m2 can be collected [Figure 3.22]. Because these wells can deplete, one has to take into account that thrity years of use will require the well to recharge for 100-300 years. Therefore, a continuous potential over a period of 300 years is calculated: 300 - 500 GJ/ha/yr.



[Figure 3.20]: district heating vision of municipality of Rotterdam, showing areas with suitable densities within and ouside the concession areas and the focus areas in the northern suburbs in the non-consession areas. (source: Tillie, 2013)

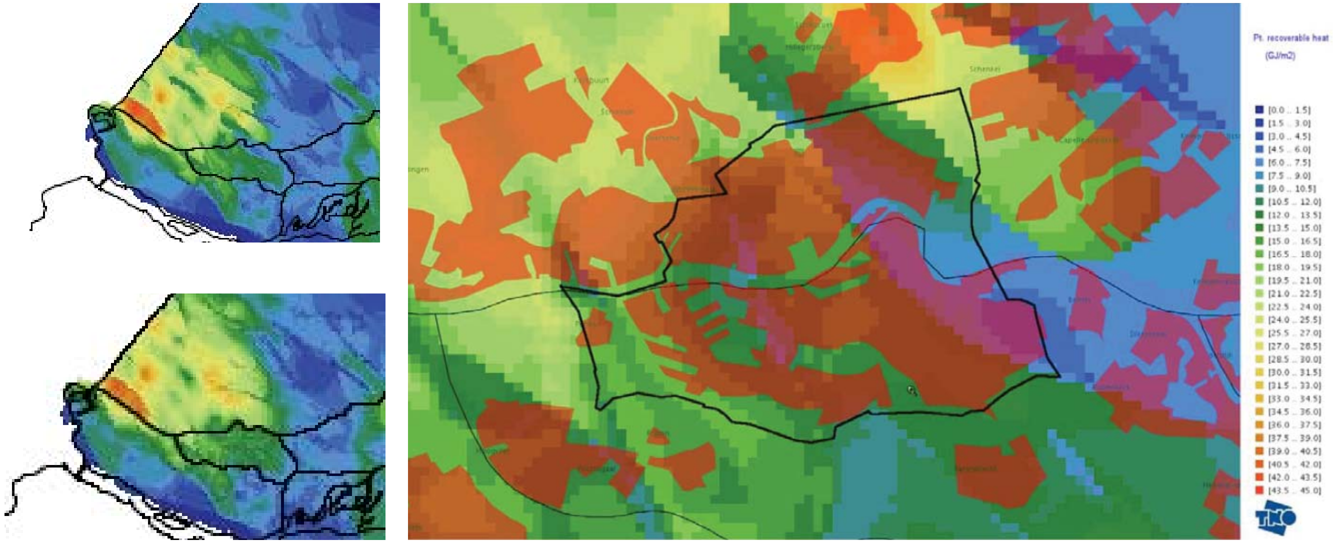


Figure 3.22: The diagrams show a potential for collecting geothermal energy in the region. A more focused image on the right shows us that the geothermal potential underneath the Waalhaven is 9-15 GJ/m2 (source: Broersma *et al.*, 2010)

Municipal scale: Sustainable solutions: REAP

The Rotterdam Energy Approach and Planning (REAP) offers a range of possible systems to make a transition to a sustainable urban thermal network. It offers guidelines that help determine how to apply thermal energy systems in the urban area, apart from the district heat network that works on regional scale. The approach to work with local sources also advocates these small scale thermal systems to add on to the regional network. REAP is a well-thought guideline for this project; apart from working on different scale levels, it not only addresses the subject of thermal systems, but it also looks at the other factors involved in this complex process.

As mentioned before REAP works with the principle of the New Stepped Strategy (NSS), a combination of the Trias Energetica and the 'Cradle-to-Cradle' principle. This means considering the three steps when transitioning towards sustainable urban development:

- Reduce demand: efficient building materials and installations, energy efficient orientation, efficient distribution
- Exchange and reuse energy: cascading, exchanging
- Use sustainable sources: geothermal wells, solar collectors, biomass incineration/gassing. This should also be combined with the storage of thermal energy, for example heat&cold storage or transform into hydrogen.

The exchange and reuse of thermal energy is the most contemporary part of the approach. On top of that, it also most related to urbanism as it is about the interaction between several buildings. The reduction of the demand asks for a more architectural elaboration and the use of sustainable sources is a more technical challenge. Therefore, this project will focus on the application of exchanging and reusing energy.

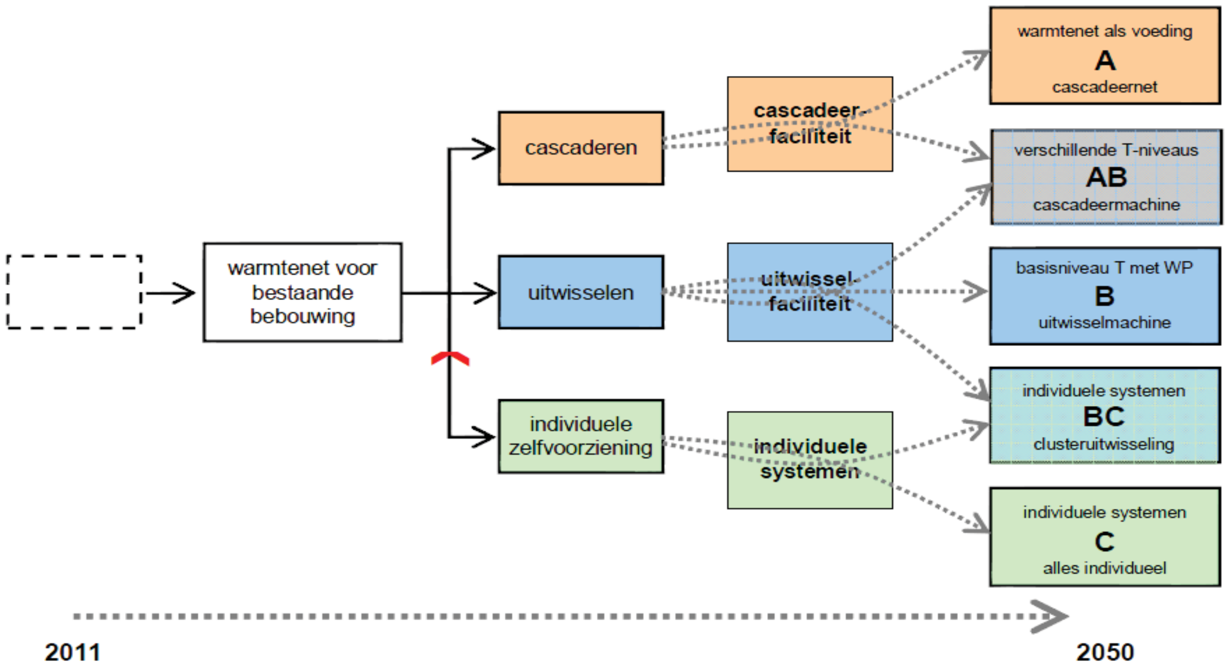


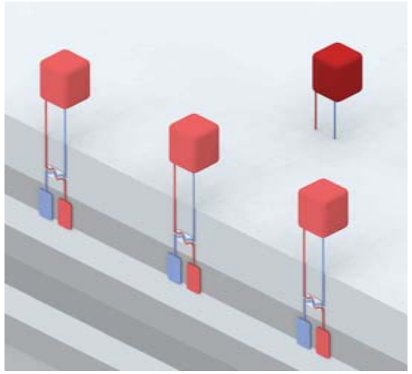
Figure x11: : The different strategies for heating of existing buildings, according to the REAP2 (source: Van den Dobbelsteen et al., 2011)

Local scale: Various energy strategies

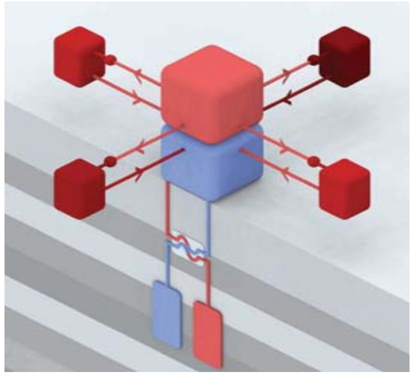
In REAP2 (Van den Dobbelsteen *et al.*, 2011) the authors focus on the different strategies to heat neighbourhoods. This can be approached by the traditional heat district network or by more inventive individual systems, cascading networks and exchange networks or a combination of these systems. Each system is described on the right page of this spread.

Before assessing the systems, it is important to know that there are different demands for heat and cold possible. For instance, older buildings have a lower heat efficiency and therefore require warmer hot water supply than a building that is being built today (Van den Dobbelsteen *et al.*, 2011). Subsequently, today's standard newly built dwellings need more heat than passive houses. Also, different programme has different heat and cold demands. A swimming pool will require a lot of heat, whereas a supermarket would require a lot of cold.

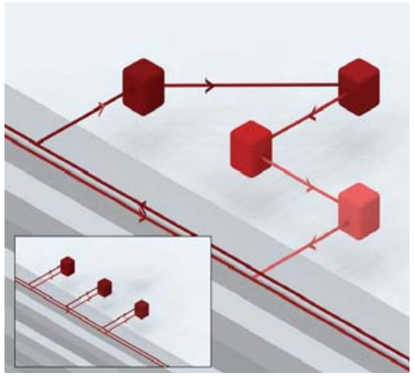
This means for example for a cascading network a high temperature pipeline runs from a swimming pool via monumental buildings, old offices and contemporary dwellings to passive houses. Then it is pumped back to the supply station to recharge. Also, the large heat demand typology - i.e. the swimming pool - can be linked with programme with a high cold demand - such as supermarket - and exchange their surpluses.



Individual systems: every cluster of buildings or individual building provides itself with their own energy. This system provides the greatest flexibility since there is no interdependency. However, every individual system has to find its place in the urban environment, taking care of its own heat supply. Because each individual unit has to construct their own hardware, it is an expensive option.



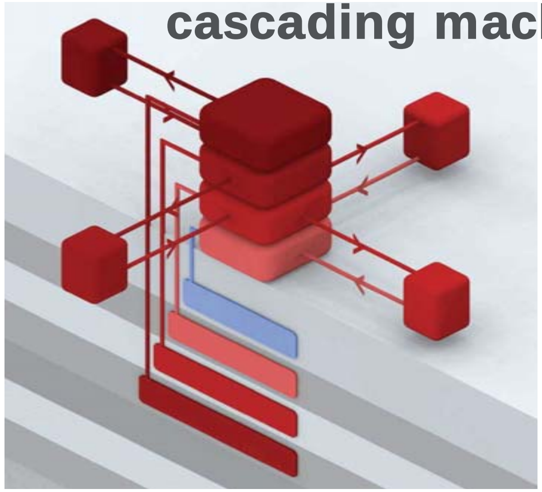
Exchange systems have less interdependency than cascading systems. A central exchange module connects a heat demanding source with a cold demanding source. The system delivers the same temperature to both users, which then needs to be heated or cooled individually.
The interdependency of both users can only exist as long as both parties keep their position. When one party leaves or changes its heat demand, the other party will be affected by this.



Cascading systems are very interdependent systems. The system is connected to a high temperature source. This could be the district heat network, but also a geothermal source or a biomass incinerator. Hot water flows from a hot water user and becomes less hot. This can subsequently be used by lower heat demanding users and so on. This system can contribute to a more cohesive community, as all the users are vital to keep this system running. Here also lies its great disadvantage. Since the users are connected serially, the change of just one user can make the whole system inefficient, if not inoperable. Therefore, although it can contribute to more social cohesion in the neighbourhood, it is also vital to have the users strung closely together.

It is also an option not to change the current district heat network and produce the heat from a renewable source. The centralized structure will remain along with the existing infrastructure, which makes it a more easily executable transition.

cascading machine



There is also a hybrid possibility; a combination of a cascading system and an exchange system. This concept, called the cascading machine, works with a central exchange mechanism, where multiple temperatures can be distributed. The return stream from a user is cascading to a lower temperature distribution to supply users at that temperature level. This system can be connected to the district heat network, but can also operate autonomously. Because the system offers a range of temperatures on which a user can be connected, the system is very flexible. It is therefore not as dictating to urban planning as a cascading system. The downside of the system is that every user or user group needs a separate connection to the central supply station. This results in an extensive pipe network.

Determining system in Waalhaven

For a port area that will face a transition within the coming decades, a sustainable energy system needs to be determined. Factors that play a role in this process are:

- The transition will take place gradually. This means there will be a gradual shift in heat demand. The thermal energy system needs to be capable to adapt to these changes
- The transition means old buildings will be gradually replaced by new buildings with better energy efficiency. Together with the envisioned mix of functions, there will also be a mix of different heat demands. Also, as time progresses, technological advance will lead to more energy efficient buildings.
- The pier structure makes a spatial division in the landscape. Each pier could be one heat distribution system.

The most suitable system for this area in transition would be the cascading machine that services one pier. This allows users to change relatively freely, without affecting other users. At the same time the whole pier as a community is supplied from one central system. This makes it visible and understandable, creating more awareness on energy use.

The system would collect its heat and cold from the surrounding surface water, storing heat in the summer and cold in the winter, to be used half a year later. In the intermediate seasons – spring and autumn – the surface water has intermediate temperatures, that can still meet cooling and heating demands. In these periods, the storage wells could be bypassed and the demand is directly gathered from the surface water.

Floating programme will not be connected to the cascading machine. Although the system is suited to deal with changing programme, the position of floating buildings is not always fixed and in fact a quality to this typology. Also it has excellent access to surface water. Therefore it can easily supply its own demands with a small system.

Implementation aspects energy system in Waalhaven

Next, the chosen energy system is linked to the spatial characteristics of the Waalhaven and the pier. The energy demand and the energy potential are compared in the Waalhaven.

Water temperature

The surface water heats up faster in shallow waters, however, this water is not suitable for collecting cold, especially not during summer, when cold collection is in progress. For cold, deep waters are needed. The Waalhaven has deep port basins, especially the central areas[Fig. X14]. These are ideal for extracting cold. The heat can be extracted from the shallow parts. However, these are situated in the south, whereas the piers are located north; a distance needs to be covered, or the water depth in the northern basins needs to be reduced.

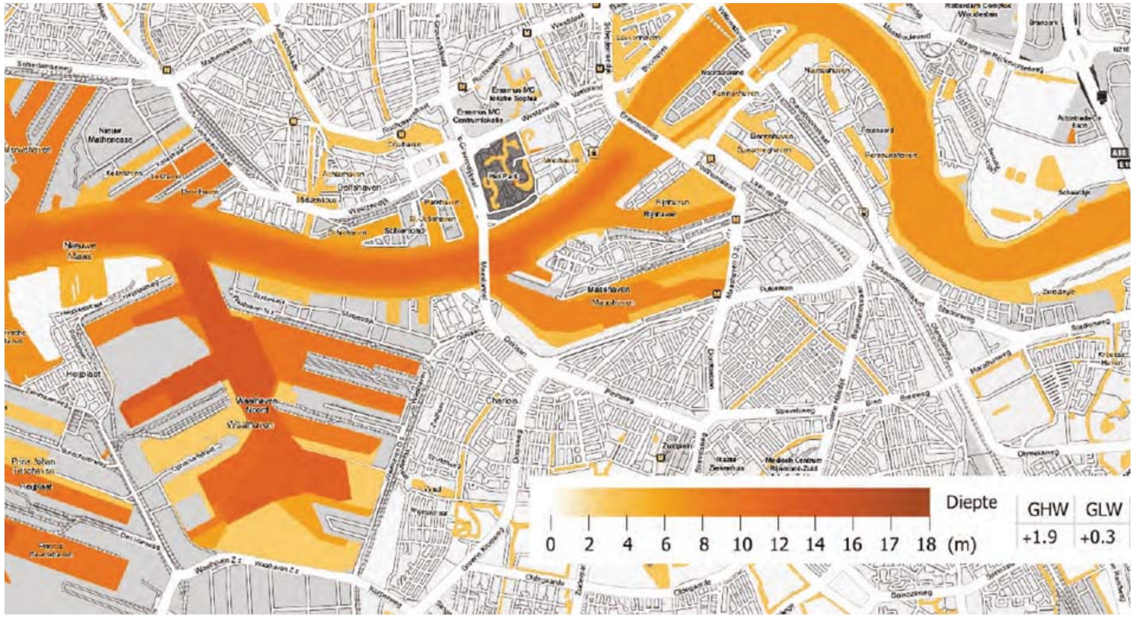


Figure X14: Map of water depths in Waalhaven and surrounding basins, showing shallow areas in the south and a deep trench at the entrance of the Waalhaven (source: Municipality of Rotterdam, 2011)

When heating up surface water, the quality can become poor, dangerously unhealthy even. To prevent this, flow and oxygen is needed. The tide could provide the flow; oxygen can be provided by vegetation.

Categorization of temperature systems

Old existing buildings need high temperatures to be heated during summer. Together with high heat demand functions, such as swimming pools and hospitals, they will be connected to a 90 degrees Celsius pipeline, as this demand cannot be met by the surface water.

Dwellings that are built today have a heat demand of 100 to 50 kWh/m2/yr. Today, newly built office buildings can have a heat demand as low as 50 kWh/m2/yr (Wisse, 2013). Both can be supplied with a pipeline that supplies a medium temperature of 45 degrees Celsius. Passive housing will be possible on a short term, which requires only 15 kWh/m2/yr (DHV et al., 2007; Lysen, 2013c). These buildings require a low temperature supply of 30 degrees Celsius. This is still a small amount of buildings, but other energy efficient houses will be able to meet their demands with this low temperature connection. Buildings in the future will be built much more energy efficient. The assumption is made that towards 2050 more buildings will be able to meet their thermal needs with a connection to the 30 degree pipeline.

It also needs to be noted that this heat demand only covers for the heating of space, not warm tap water. This demand will be supplied by each individual building.

Thermal energy system for Waalhaven pier

The system that has been developed works as follows:

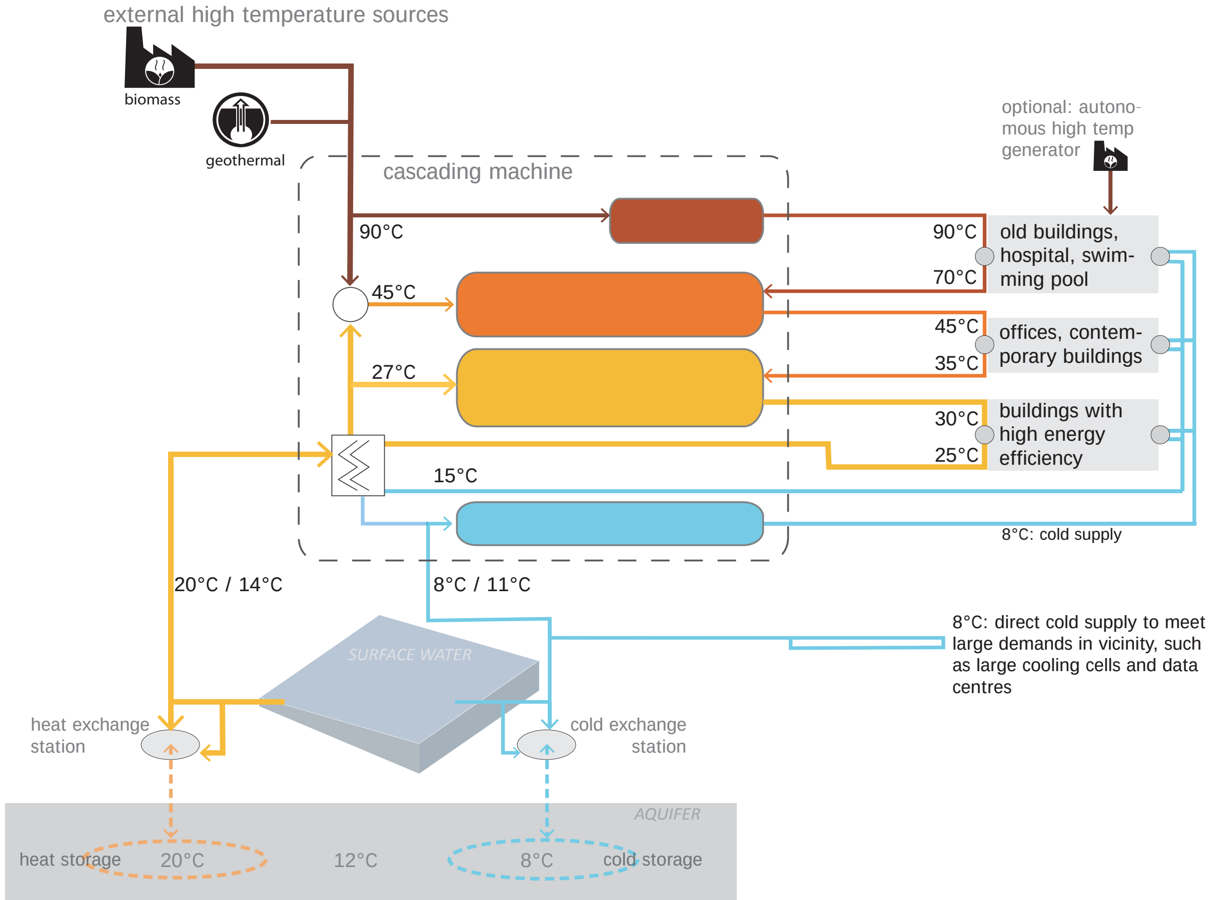


Figure AA: principle of chosen system, the cascading machine, fed by return streams, heat and cold from surface water and high temperature suppliers. Network will have three levels of temperature. (source: by author

The system that has been developed is seen in [Figure AA]. It is in principle the cascading machine, but with extra supply from the thermal energy from the surrounding water. The system consists of the following elements:

- a central distribution building
- a cold exchanger and distribution station, collecting cold water and storing it underground
- a heat exchanger and distribution station, collecting warm water and storing it underground
- distribution pipes across the pier in three different warm temperatures (90'C, 50'C & 30'C) and cold temperature (8'C)
- an external high temperature supplier: excess industrial heat, biomass plant or geothermal source

The system works as follows throughout the seasons:

Summer [Figure AAA-a]:
The large cold demand is met by pumping cold water from the ATES and the deep parts of the Waalhaven via heat exchangers to the distribution station.
The demand for warm water is minimal, but there is plenty available. The warm water from the shallow water is therefore mostly stored by ATES via heat exchanger.

Spring and autumn [Figure AAA-b]:
There is an average heat and cold demand. This can mostly be subtracted from the surface water and via exchanger directly supplied to the distribution system. This means the ATES's do not need to be depleted during these seasons.

Winter [Figure AAA-c]:
The large heat demand is met by pumping warm water from the ATES and the deep parts of the Waalhaven via heat exchangers to the distribution station. Here an additional external supply is delivered to the system to meet the high temperature demand.
The demand for cold water is minimal, but there is plenty available. The cold water from the shallow water is therefore mostly stored by ATES via the exchanger.

The developed system is different from the cascading machine presented in REAP2. With the help of currently accessible high temperature sources, all the different heat demands can be met. This can be supplied by the existing district heat network, but also from a geothermal source. Until around 2050 the pipeline of district heat network could be fed from the current suppliers, but they will have partially disappeared by then. The emergence of for instance a biomass plant could take over this supply on a regional scale, but perhaps even on a small local scale, such as a geothermal source. The demand for high temperatures will decrease as the more efficient future buildings will not be needing the high temperature water. When this happens, the system might function autonomously on the heat and cold it can retrieve from the port basin.

Heat and cold demand versus pier potential
To implement a system into the Waalhaven, one distribution network is focused on. This project will elaborate on the spatial and functional implementation on pier 1, which is the first pier south of Stieltjesdijk.
To determine the possibilities of programme on the pier, one has to deal with many variables, that are listed briefly:

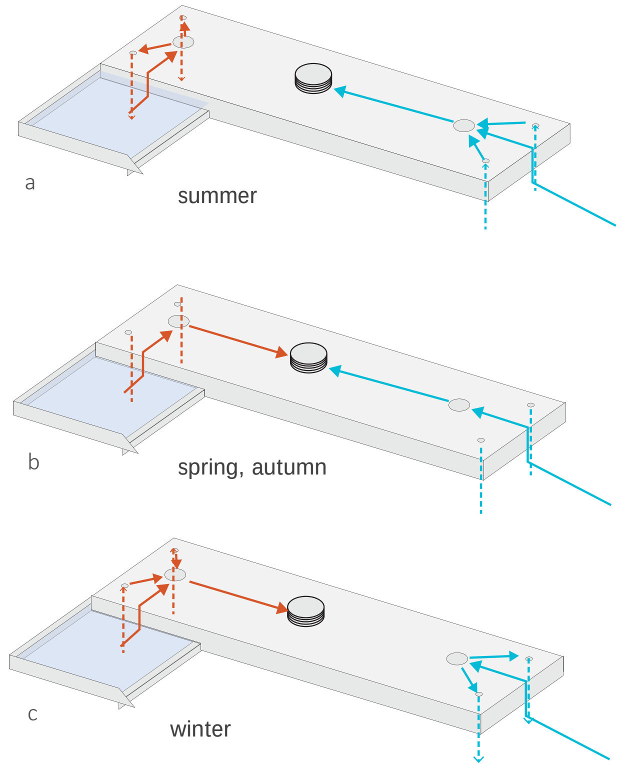


Figure a-c]: 3 types of season makes the heat and cold collection work in three different ways (by author)

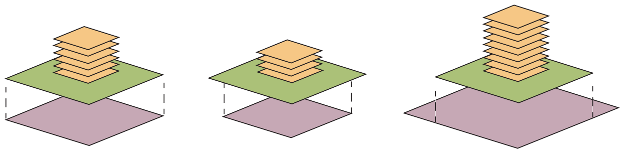


Figure XXX2: diagrams of building energy footprint (green) exceeding the limits of the underground storage footprint(purple). This will cause interference with other wells if they are placed too close to each other. (source: by author)

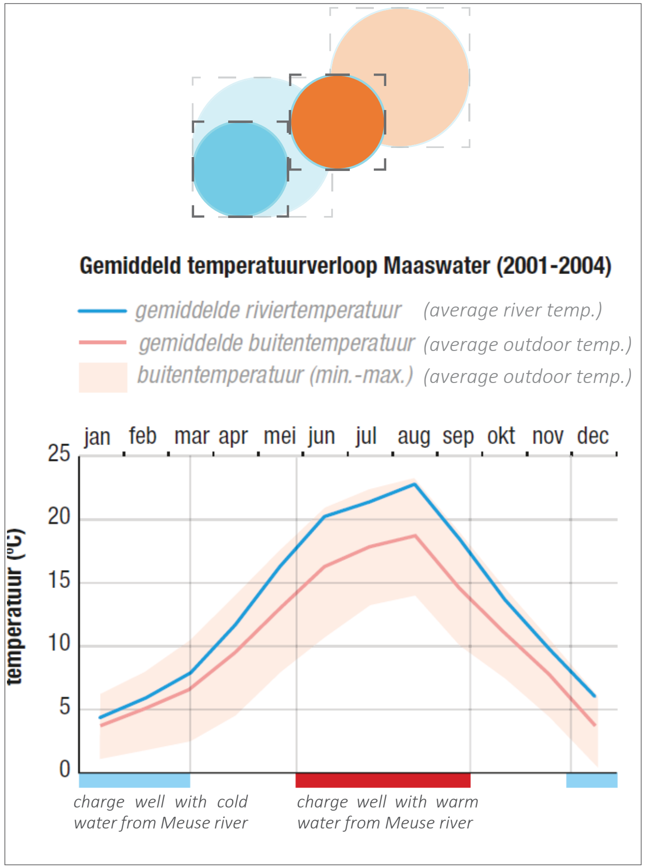


Figure MT]: reduced footprint by direct cooling from surface water. (by author & s.n., 2007)

- Due to new technology and better insulation techniques, more energy efficient buildings will emerge, which leads to a reduced heat and cold demand in future.
- The diversity of programme with different types of heat demand – different temperatures - makes it difficult to calculate the exact values for a certain programme
- To store the demand that is needed after making an assumption for the demand in 2050, the footprint of the well cannot be larger than the footprint of the programme. In other words, the FSI should not supersede the footprint of the well [FigXXX2].

Many variables

Determining the potential and the size of the ATES is relatively complex, since there are many variables involved. The surface that it is occupying is related to ground water speed, the thickness of the aquifer, the number of aquifers on top of each other, the unbalance between the heat and cold well. This unbalance is caused by the difference in heat and cold use, which is due to the heat and cold demand of the built programme. When this programme is also changing, the (un)balance between heat and cold demand will shift, which makes it even more difficult to determine the size of the footprint.

Reducing underground storage footprint

The unbalance - and therefore the footprint - can be reduced by compensating the surplus or shortage. This is done by using the surface water of the port basins. The possibility to use the surface water in the intermediate season – spring and autumn – directly for heating and cooling buildings without depleting the ATES, has a reducing effect on the footprint. A case study of the Maastoren, recently built three kilometres upstream from the project location, shows that implementing this system could drasticly reduce the storage footprint (s.n, 2007; Blankesteijn & Gerritsen, 2009). Using the additional surface water in heat and cold storage also helps to minimize the footprint as it restore an unbalance.

Evaluation of thermal system

The downside of the system that has been created to be locally implemented, is the complexity of it. Apart form the fact that it needs much piping, it could also be cascading more simply. However, this will limit the freedom of placement and change of programme. This is one of the characteristics that has signified the Waalhaven over the last century (Figure 1.???) and should be preserved.

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Water management in the Rijnmond region

Urban deltas formed by success of their port activity and connection to the water. Therefore the urban waterfront is often characterized by a structure of piers and port basins; blue fingers stretch inland, forming an interwoven structure of land and water.

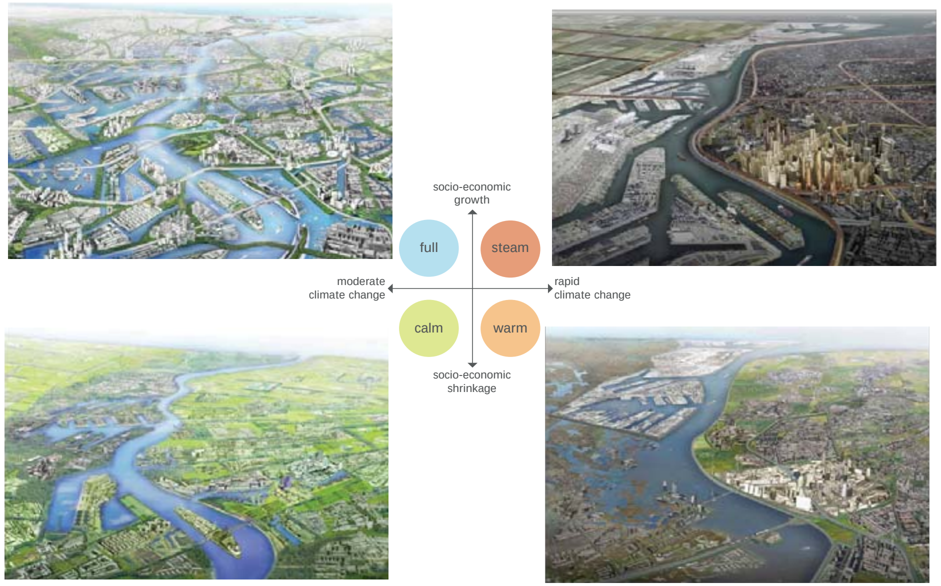
Water threat in Rijnmond-Drechtsteden region

The four scenarios developed for the Dutch urban delta in the year 2100 (Deltaprogramma Rijnmond-Drechtsteden, 2011) will have their effect on the spatial conditions of the urban delta as seen in [Figure SSSS].

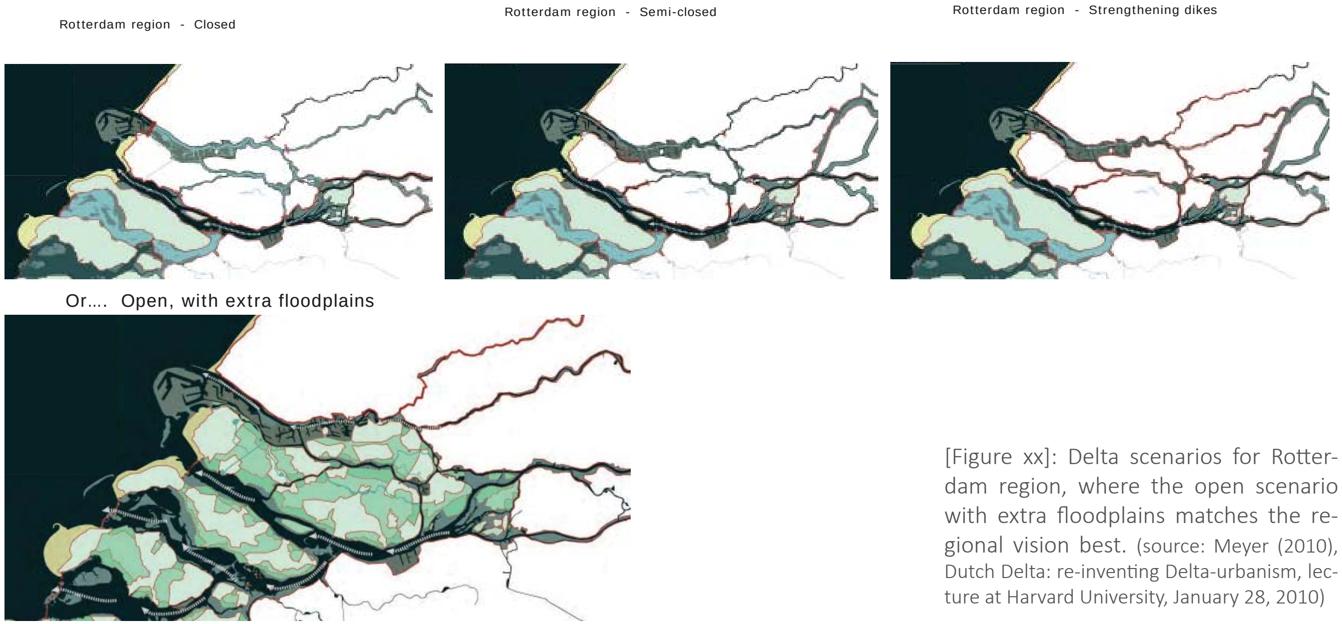
The only certainty at this point is that more extreme water levels will occur. The two main strategies to battle this threat is to either follow the robust path and increase the reinforcements to withstand every scenario, or try to coexist more with the water, giving it more space and adapt ourselves to the changes made by nature. There are also strategies that include both elements, as the following Delta scenarios for the south-western Dutch Delta by Meyer (2010):

- Closed [Figure Ta]
- Semi-closed [Figure Tb]
- Strengthening dikes [Figure Tc]
- Open and extra floodplains [Figure Td]

These strategies need to be implemented on this level of scale to execute a well-functioning solution. This also means it will have an impact on the landscape and socio-economic activities in a large region and will affect the decision making on local level.



[Figure SSSS]: Four delta scenarios for the Rijnmond-Drechtsteden region have been spatially translated by Studio Vermeulen (source: Deltaprogramma Rijnmond Drechtsteden, 2011)



[Figure xx]: Delta scenarios for Rotterdam region, where the open scenario with extra floodplains matches the regional vision best. (source: Meyer (2010), Dutch Delta: re-inventing Delta-urbanism, lecture at Harvard University, January 28, 2010)

City port scale
On municipal scale integral visions on water in the urban delta are created in Waterplan 2 (Municipality of Rotterdam et al., 2012) In this second Waterplan, the municipality of Rotterdam indicates the following points of attention concern this project:
The city of Rotterdam should be an attractive city and its character as water city and city on the Meuse river should be advertised more.

The flood defences need to be strengthened to battle the higher water levels in the future

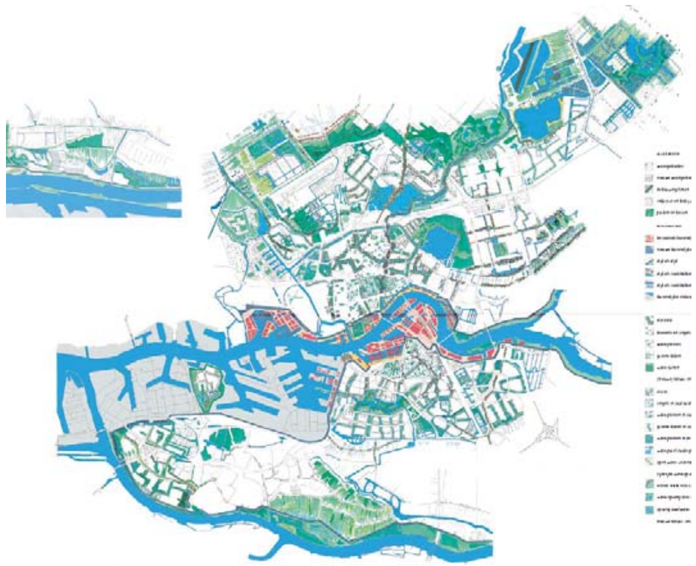
Increasing precipitation will result in 600000 cubic metres of water that needs to be dealt with. This translates spatially to 80hectares of extra urban surface water needed in the municipality.

The question is raised how the city could be made attractive and solve waterproblems simultaneously. The traditional solutions for this issue have been found insufficient

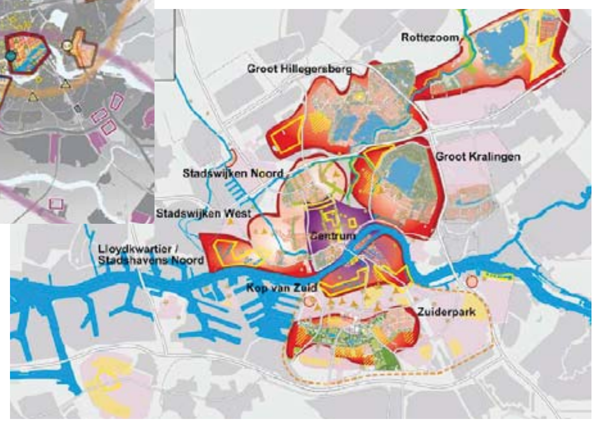
Whereas the north can strengthen its 'singels' and 'boezems' system, the south of the city needs a more radical approach

More collaborations should take place between the municipality, the water boards, water specialists and urbanists.

City Vision 2030
Also in the municipal vision, the need and ambition is shown for creating new solutions to keep a strong and attractive city; a vibrant water city on the New Meuse (Municipality of Rotterdam, in: Guit, 2011)



[Figure 3.4.1]: Map of Waterplan 2, showing a spatial translation of implemented water measures on a municipal scale. (source: Municipality of Rotterdam et al., 2012)



[Figure 3.ccc]: city vison of Rotterdam and the attractive water city (source: Mun. of Rotterdam, in: Guit, 2011)

Pier 1: port and quay characteristics

The area for the urban design will focus on Pier1, the pier just south of Sluisjesdijk. It has the characteristic linear, rectangular pier shape [Figure QQQQ]. It is currently occupied by warehouses, that help store and distribute various goods, brought in by relatively large vessels.

At first, the quays look to form a hard edge with the water. However, more close-up images show the crane tracks that form the north and south edge with the water, are in fact concrete jetty's built from a sloping water edge [Figure WW]. The assumption is made that these sloped walls are similar to Pier2, of which the drawing is seen in the bottom left picture in [Figure QQQQ].

When redeveloping piers, restrictions are in place when it comes to building close to the water edge. Since the quay walls are not designed to withstand the pressure of these new buildings, they could collapse. This is therefore not recommended without a thourough - and very expensive - re-enforcement.

[Figure WW]: sketch of assumed section of Pier1's sloped quay wall with crane track jetty (source: by author)

[Figure QQQQ]: collage to give an impression of the look and feel of Pier1's occupation and quays compiled by author)

3.4 conclusions

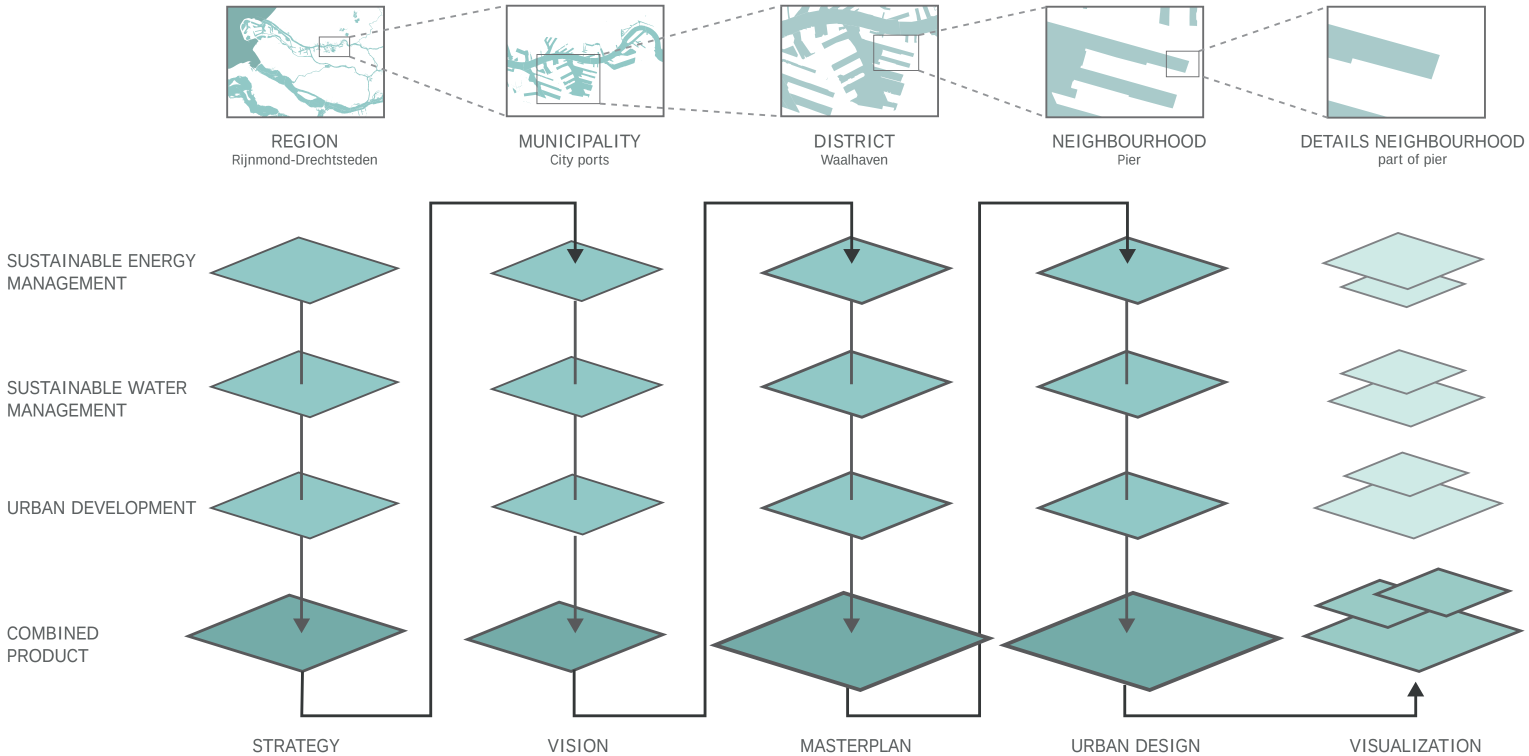
An overview of the results that will be taken along into the creation of the design products is made:

4 design products

- regional vision
- strategy
- masterplan
- urban design
- visualization

introduction

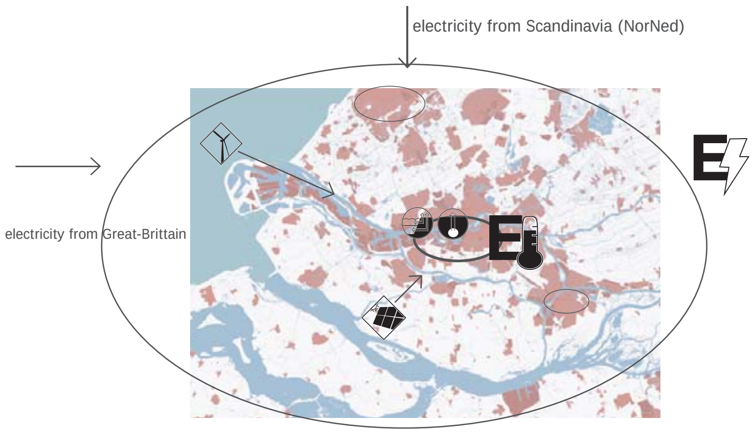
The design products are structurized in the design products assessment matrix. This shows the different scales vertically and the disciplines horizontally. This chapter will meander through the matrix as the grey arrow in [Figure 4.0] indicate. The disciplinary products are combined per scale. Then, these results are taken to a smaller level of scale, ending up with the integrated urban design. From here, the details are shown divided over the disciplines and visualizations show the integrated spatial result.



[Figure 4.0]: scheme of result matrix, organising the design results.
(source: by author)

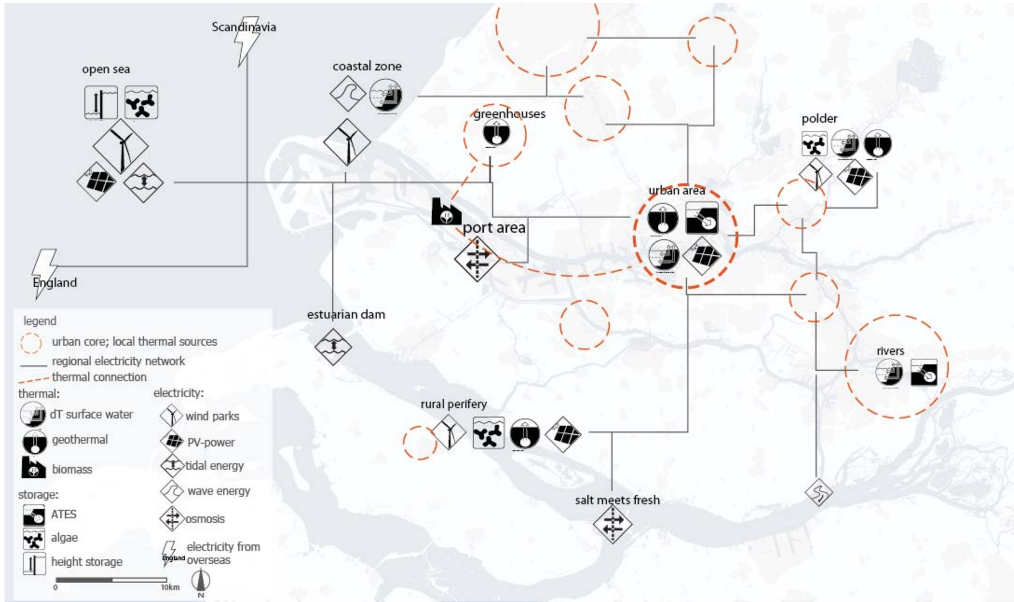
4.1 regional strategy

4.1.1 Energy



[Figure 4.1]:scheme showing strategy for electrical energy regionally and beyond, and thermal energy collected locally within the urban environment (source: by author)

[Figure 4.2]: Envisioned energy system in the region; an electricity network throughout the region, connected to countries overseas, and locally organised thermal energy solutions. (source: by author)

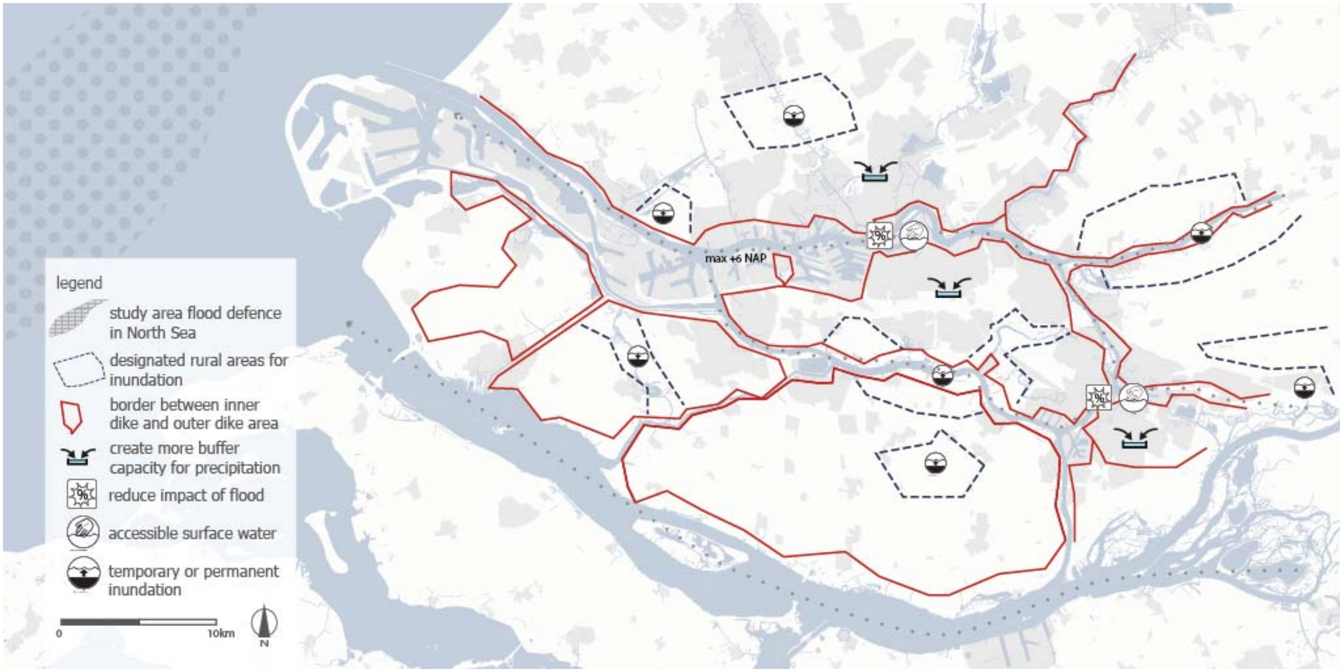


The Rijnmond-Drechtsteden region should make better use of all the surface water in and around the region to power the urban delta.
Gaining electricity from surface water is only feasible in the marine periphery of the region and when new techniques will improve in future. Since electricity can be transported over large distances, these large and tedious installations can be placed far away from occupied area, where it is not considered a nuisance. Investments should be made to find feasible areas for tidal energy installations in the southern estuaries, as well as algae farming. Wave energy can be harvested from the north sea, together with the secondary water related energy source: wind power. Creating energy islands such as Plan Lievense (SOURCE!!!!) are not feasible, because peak demands can be met more easily and cheaper by getting it from overseas.

The general strategy for the region will make a distinction between locally harvested thermal energy and electricity harvested from the rural and marine peripheries of the region and beyond [Figure RE1]. This is based on the energy loss of thermal energy when transporting it over large distances, whereas transportation of electricity over large distances hardly involves losses.

This leads to a regional electricity network with international connections that is feeding the urban cores. Within these cores thermal energy solutions should be implemented. Exception to this rule is the residual heat from the industry that can be transported by water from the port area into several district heat projects in the urban cores.

The surface waters in the urban cores should not be seen as merely a coolant – for instance to counteract the Urban Heat Island effect – but also as potential source of heat.



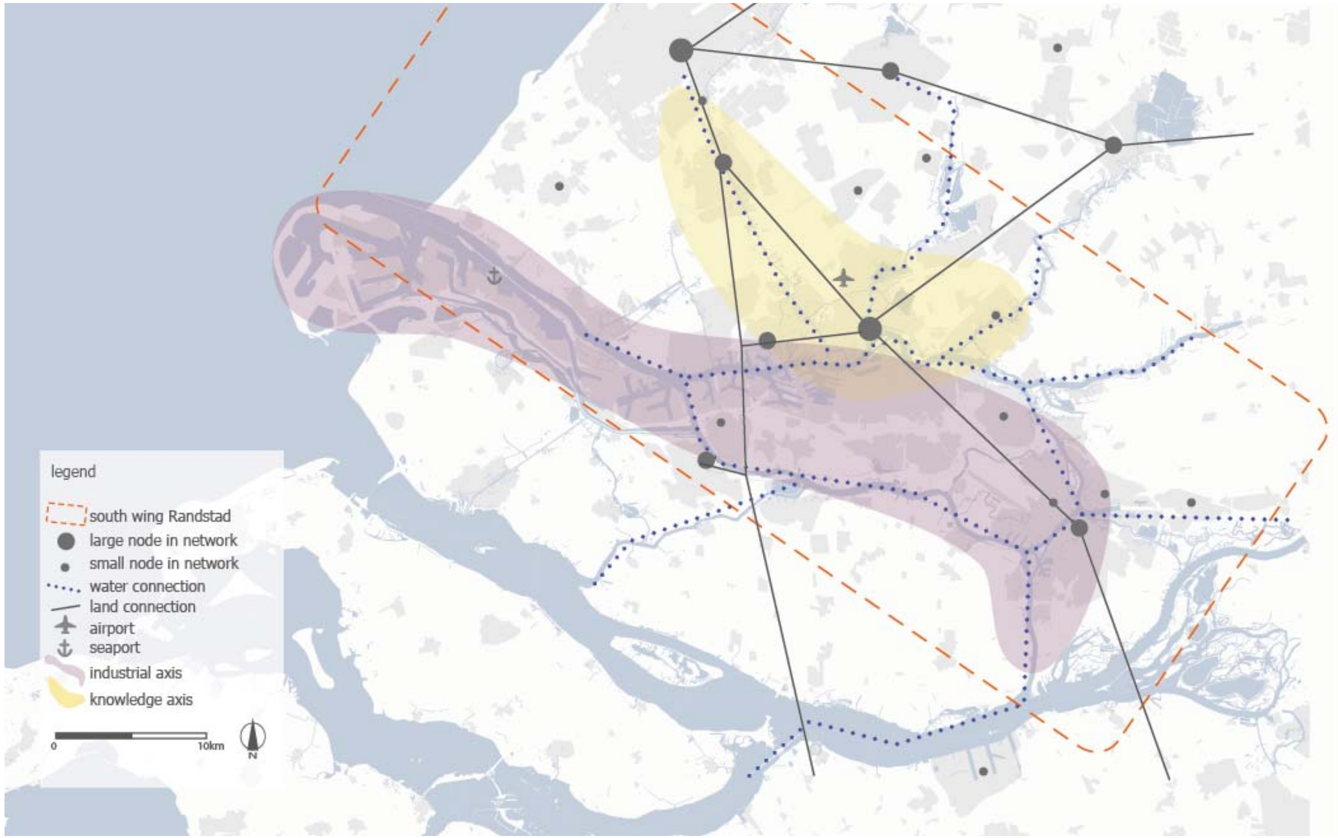
[Figure 4.2]: an open system is chosen for the region to give more space to the water (source: by author)

4.1.2 Water

The climate change will bring more water to the region. This water must have more space to find its way back to the sea. This means implementing an open system (Meyer, 2010). This seems to go against the Dutch DNA of fighting the water and create (polder) land. However, backtracking shows us that there was a sustainable equilibrium in the pre-industrial era. Here, nature was respected, with some areas protected by dikes and others were susceptive to flooding. People learned to live with the natural conditions. Unfortunately, this has also cost many lives when disaster struck. However, with today's technology, these areas can be occupied safely as well, as long as it can adapt to the climate changes and floods. The floodable areas are determined by the vicinity of streams or rivers and the subsidence of the land.
The north side of the New Meuse river will largely stay as it is today. Dikes need to be heightened and strengthened to withstand water levels of over NAP+4m. These water levels can be reached up river in 2100 during a storm surge. The south side will also need to strengthen dikes, but also requires the installation of overflows to inundate low-lying polder land during a flood.

The precipitation can be drained easily in outerdike areas, but the inner dike areas need to invest in buffer zones that can retain water during extreme precipitation levels. These bufferzones can be realised relatively easily in the rural areas, but smart solutions are needed to implement extra buffer capacity in a clogged-up urban environment.

By creating more space for the water and create more retainment areas, the water is changed more into land. This is perpendicular to the current strategy of changing land into water.



[Figure 4.xxx]: urban development vision of the south wing of the Randstad as a city network in which water way connections play a more important role. Also two main zones defined (knowledge and industry) that meet in the city of Rotterdam. (source: by author)

4.1.3 Urban development

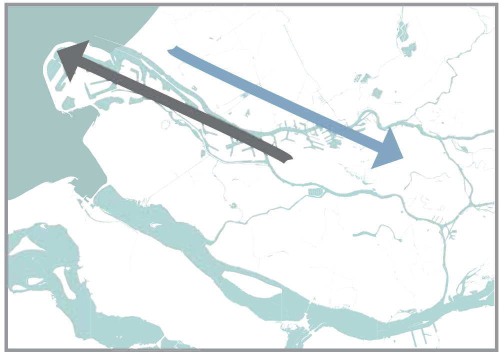
The project area forms the main part of the south wing of the Randstad, one of the most economically important regions of The Netherlands. The area is already developing as a city network and should continue to do so. The network connections via water ways should be intensified.

The Dutch tradition of compact built urban clusters that are well connected will also be the standard for the coming decades. This means, amongst others, that studies for developing new programme should predominantly take place within the city limits.

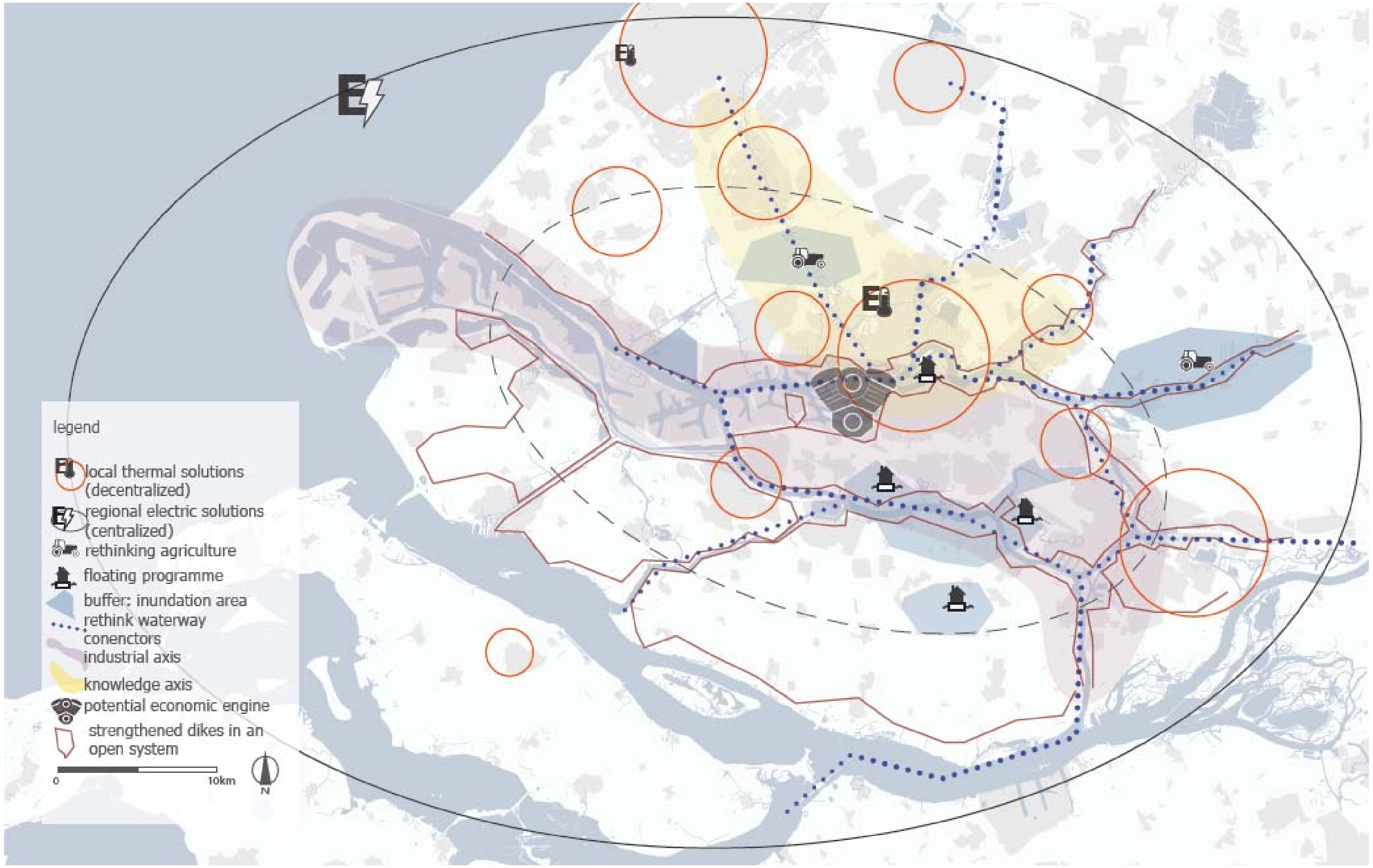
The development of the industrial axis (secondary economies) along the river and a knowledge axis (tertiary economies) from Rijswijk into Rotterdam – also envisioned in the 'Stadsvisie 2030' (dS+V, 2007) and Structuurvisie Stadshavens Rotterdam (Municipality of Rotterdam, 2011) – will be stimulated. Water ways could also play an important role in this development. Both zones will overlap in the city of Rotterdam. The secondary and tertiary economies in the region should create an active and innovative, cutting edge economic region that can compete with the best in the world.

4.1.4 Integrated strategy

When combining the three visions for the disciplines an integrated regional strategy is made. To establish the integrated results on regional scale overlap in the three layers need to be found. In the absence of an overlap the different interests are assessed and the choice will be motivated.



[Figure RC 0.1]: envisioned principle of not just create land in the water, but also create water on land. This will offer an increase in buffer capacity and new possibilities to use the thermal advantages of this water, as well its infrastructural and aesthetic strengths, but also economic advantages. It will create a landscape reminscent of pre-industrial ages , but it should create more resilient areas. (source: by author)



[Figure RC1]: regional strategy, determined by combining three disciplines of energy, water management and urban development. (source: by author)

- Land in the rural areas could be permanently inundated is stead of only during floods. When more land is permanently inundated to create a larger buffer capacity for extreme water levels, this surface water can be used for collecting thermal energy for programme developed on or close around it. This programme could be dwellings, but also agriculture. By re-thinking the possibilities of water agricultural processes can be made more efficient when it is transformed to aquaculture (Deltasync, 2012). [E+W+U]

- Since the most urban expansion is planned to take place within the current city limits, the abandoned city ports are interesting areas for newly developed urban programme. Since these areas are outer dike areas the programme and the urban plan will need to be adaptive to possible flooding. This also matches with 'making room for the river'. On top of that, these city ports can be fitted with a new energy system related to the surface water it is situated next to. [E+W+U]

- The area will be developed as a city network. This means well connected dense urban cores and open area in between. This works in favour of the thermal energy supply that works best in local decentralized systems. Also, the open area between the urban cores is maximised in this strategy. This increases the search area for inundation and to give more space to the water. [E+W+U]

- Electricity can be collected from the rural and marine peripheries of the region, where the forces of nature are strongest and the nuisance is minimal. In contradiction to the sustainable equilibrium, electricity is a modern source that can be generated sustainably but not necessarily used locally. It can even be retrieved from overseas.[E+U]

- Collection of thermal energy should be developed urban areas. This is the best combination between surface water and energy and as the systems is the water's best feature and the systems to collect it take little space. In the periphery of the region the scale of the systems can be increased and the other features of the delta waters are more suitable to extract electricity from. These landscapes are also suitable for wind parks and 'energy storage lakes'. As it can be transported over large distances, electricity will be generated in these peripheries, but peak demands can even be met with electricity from abroad. Electricity can be generated in urban areas, but on small scale via PV-panels.[E+U]

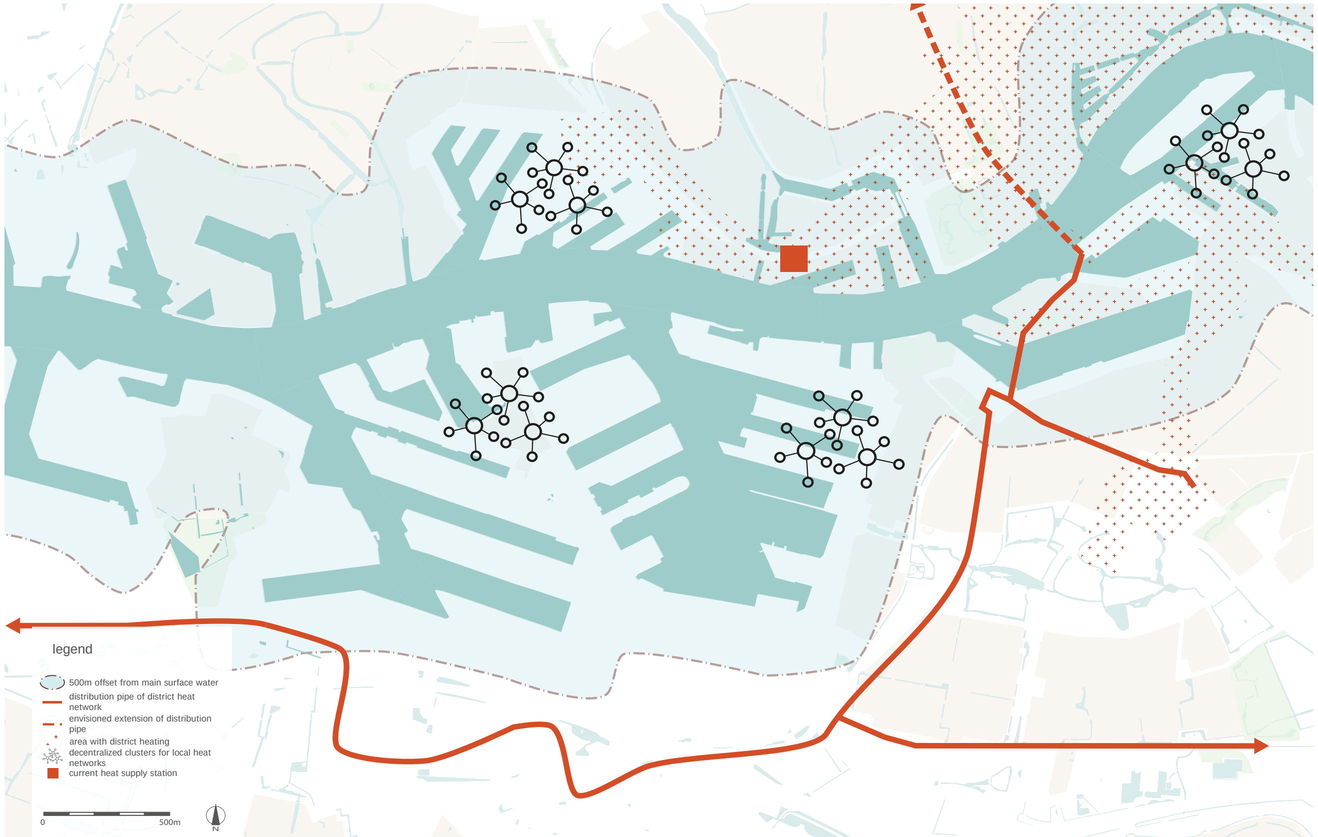
- An open water system will require extra flood defence measures in urban areas along the rivers and estuaries. This call for new spatial solutions, who can be combined with the urban design solutions needed to combine the zones of tertiary and secondary economies in the municipality of Rotterdam. The Waalhaven, in the middle of these activity could be an important economical engine for the region, but also to showcase spatial solutions for a sustainable flood susceptive urban area. [W+U]

envisioned principle of not just create land in the water, but also create water on land. This will offer an increase in buffer capacity and new possibilities to use the thermal advantages of this water, as well its infrastructural and aesthetic strengths, but also economic advantages. It will create a landscape reminscent of pre-industrial ages , but it should create more resilient areas. (source: by author)

city ports vision

4.2

The regional strategy shows the municipality of Rotterdam and its city ports as the heart of the region. Therefore the focus will be on these city ports and a vision is made. Once again, this is done by envisioning each discipline at this scale separately and subsequently combine these three into an integrated vision for the city ports.

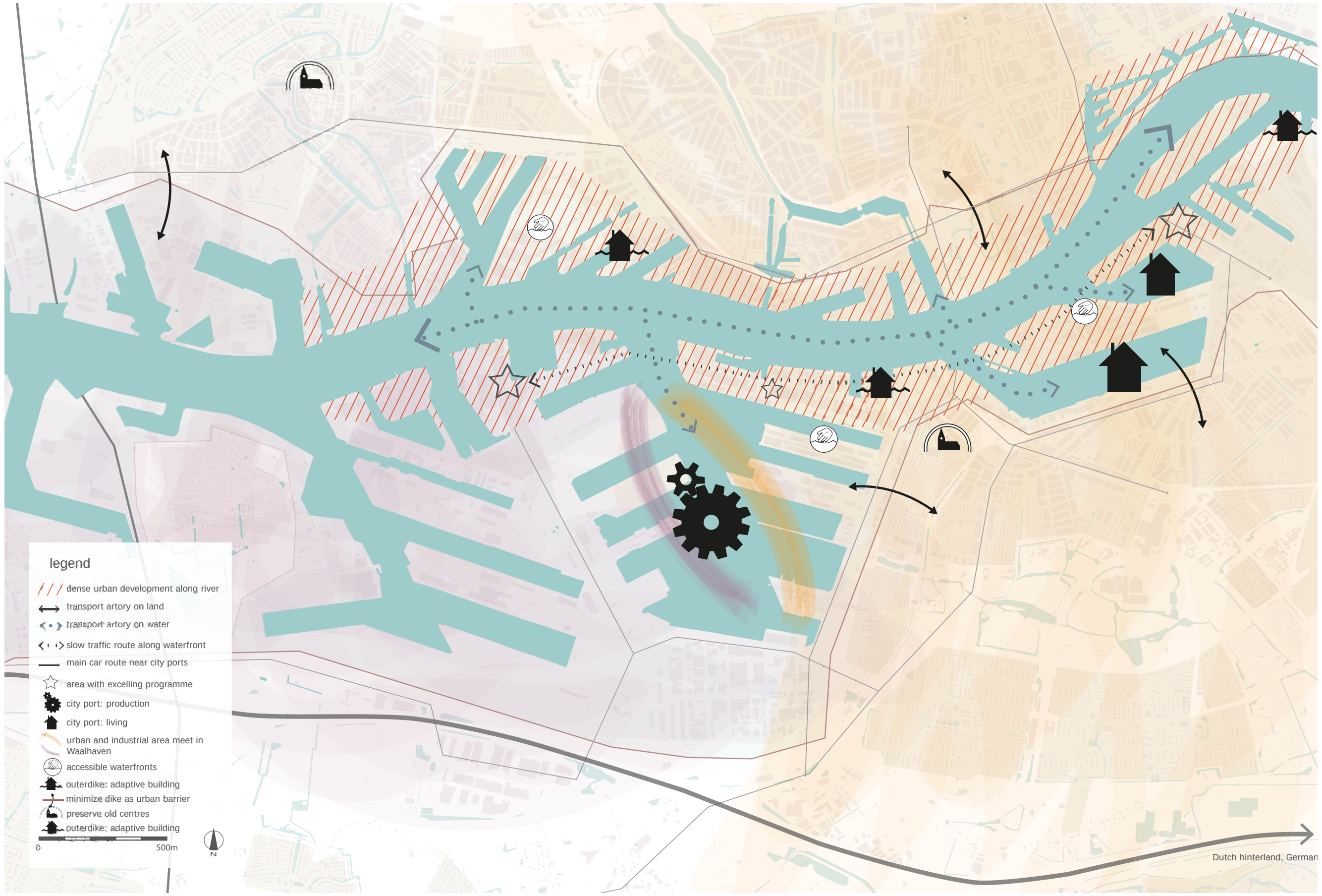


4.2.1Energy

The current developments on creating a district heat network connected to industrial excess heat with not be in vain as this system can coexist with sustainable local systems (see also [Figure x9]). The implementation of these systems can occur in areas that are not covered by the district heat network. The thermal energy networks that use the surface water as source need to be in the vicinity of the water. In this project the assumption is made that the maximum distance is 500 metres (based on Techniplan (2012)). Outside this area, thermal energy projects are by all means possible, but the storage capacity cannot be reduced by using surface water in the intermediate seasons.


immediately draining precipitation
retain precipitation; increase buffer capacity
legend
outer dike area
outerdike: adaptive building
strengthen dikes (water levels 2100)
drain precipitation
buffer capacity for precipitation
organize escape routes out of outer dike area
0
500m
N


2500 feet
1 km


legend
dense urban development along river
transport artory on land
transport artory on water
slow traffic route along waterfront
main car route near city ports
area with excelling programme
city port: production
city port: living
urban and industrial area meet in Waalhaven
accessible waterfronts
outerdike: adaptive building
minimize dike as urban barrier
preserve old centres
outerdike: adaptive building
0
500m
N
Dutch hinterland, German

4.2.3 Urban development

• The city ports will be developed as urban living and recreating areas as the industrial activities gradually move to the west. The Waalhaven is situated at the border where urban area and industrial area meet. This large port will therefore be redeveloped as a more industrious port; there will be urban development, but it will be combined with production and knowledge in light industry, businesses and offices.

• The trend of developing dense urban area along the river banks is continued towards the west, replacing industrial programme that is moving out of the city. This extended high density zone is also connected to a new metro connection. A new metro route is being studied by the municipality, but the main concept is to connect economic centres on the south bank to the north bank, forming a half circle around the city centre [Figure MU2].

• Following the dense urban area, a slow traffic route is created along the south bank to connect the activities at the Wilhelmina pier surroundings to the RDM Campus. This area will be developed as a similarly attractive cluster. It will be characterized by educational programme and research facilities. The main car traffic will be situated more inland, following the route around the city ports.

• Possible functions - besides urban functions, such as dwellings, shops and facilities - for the transition area between urban area and port in the Waalhaven are: port and water related offices; marine knowledge (coherent with Stadsvisie Rotterdam 2030 (dS+V, 2007) and Structuurvisie Stadshavens (Stadshavens Rotterdam,), but also more sustainable possibilities:

o cradle-2-cradle disassembly and reassembly
o agriculture/ aquaponics
o the construction industry of floating buildings

These functions fit the area perfectly. They are showcasing 21st century industries and create job opportunities for the problematic neighbourhoods in Rotterdam-south, that deal with high unemployment rates. Most of these jobs require low skill levels, which makes them accessible for uneducated.

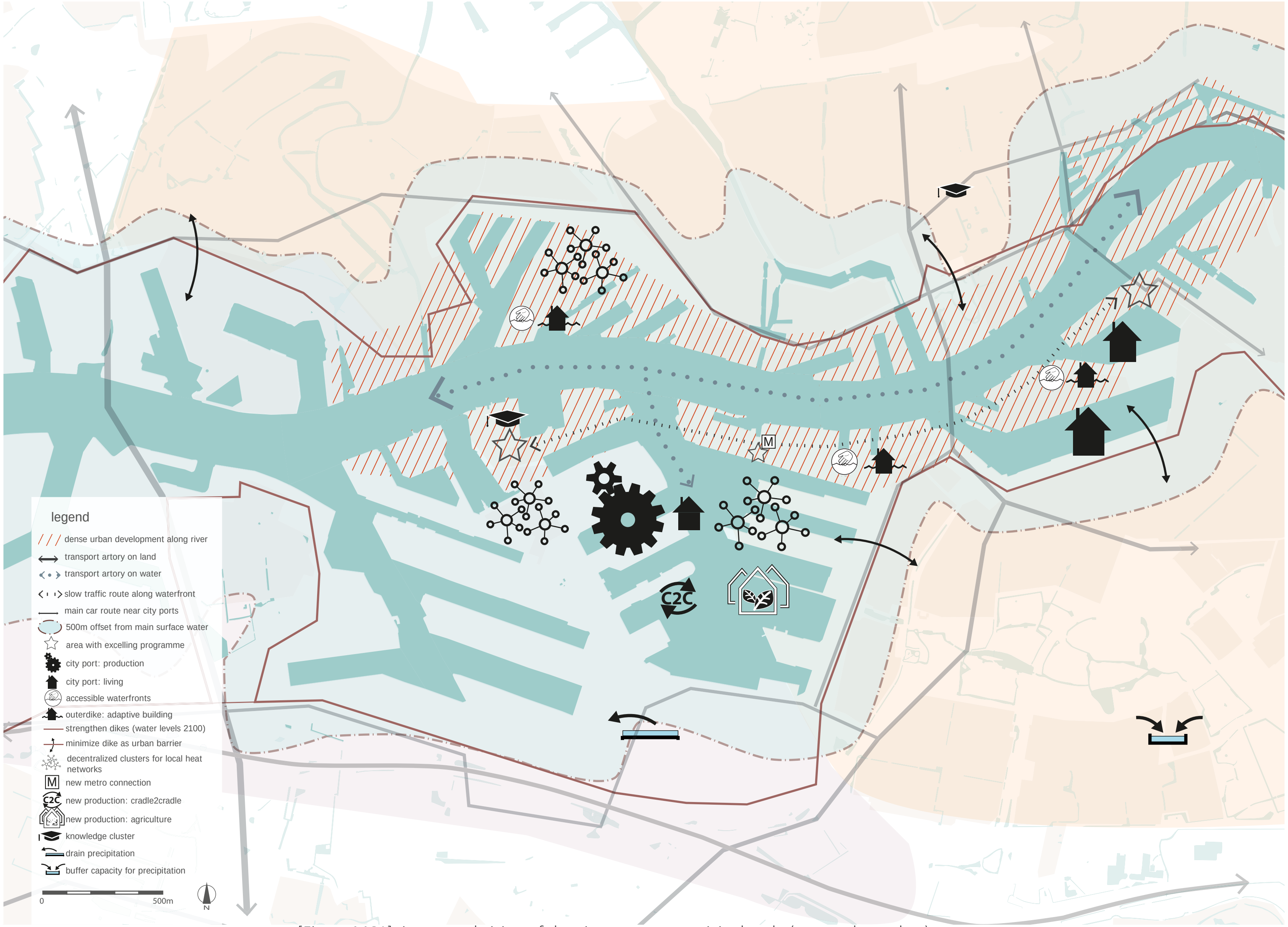
• The city port landscape has many kilometres of waterfront. This aesthetic value should be rated to its value. Attractive and accessible waterfronts should be created. Programme situated along shores should be more oriented more towards the water to make the banks more appealing and accessible. This also means accessibility via water.

• When urban programme is placed in the outer dike areas, the dikes separating inner dike and outer dike urban tissue should become less of a barrier but more a connector between both areas. This can be done by

- o placing programme in the dike or mask flood defences by placing them inside buildings
- o reduce the slope by creating delta dikes
- o make the dike an attractive public space for both sides
- o create elevated public space

• The waterways will be used more for transport of people. It will form a blue highway through the city, taking you from one city port to another. This is also why the urban tissue expands ,more along the river, while the industrial area is located closer to the highway to transport goods by track.

[Figure CPU2]: municipal vision on connecting economic centres across south bank (source: municipality of rotterdam, s.d.)



[Figure MC1]: integrated vision of the city ports on municipal scale (source: by author)

4.2.4 Integral strategy

The area in which one can use surface water as energy source is roughly the same as the outer dike area. Buildings in this area could therefore be thermally powered by decentralized local clusters and these systems should be resilient to flooding. Being more water oriented in outer dike areas will also be translated spatially in organising programme thusly, that it is more oriented towards the water. Since there is no need for buffering precipitation in the outer dike areas, the roof space can be used for energy collection (PV or solar heat collector). Urban agriculture will take place at ground level in public spaces. [E+W+U]

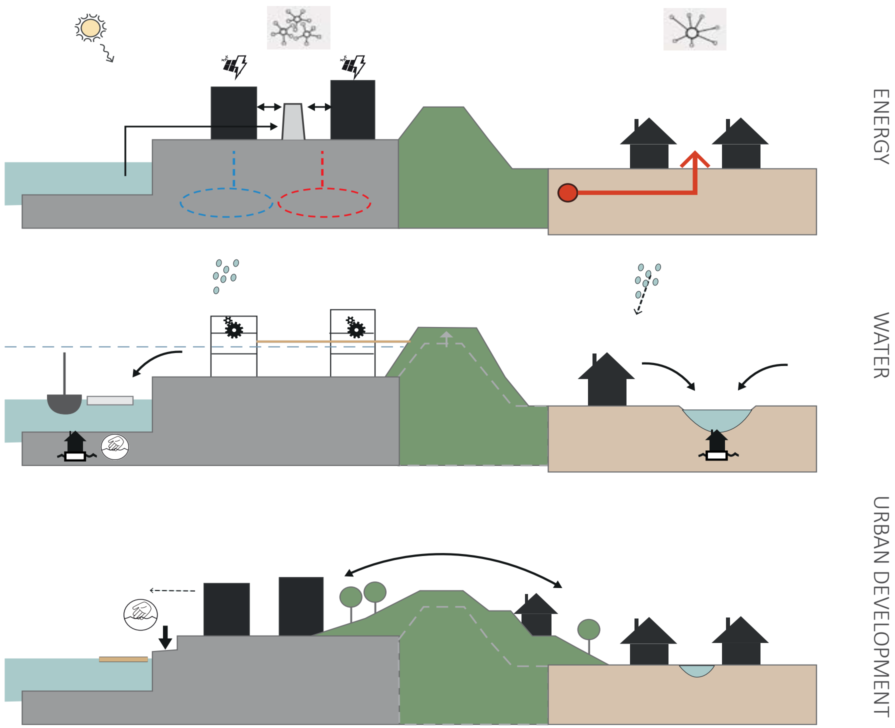
The pier and basin landscape that characterizes the city ports causes a spatial segregation of small areas. This is convenient for the division into smaller communities to organise an energy system, but also an evacuation route. This structure also creates much shoreline. This allows many buildings to be situated near or at the waterfront and therefore could be easily reached by boat, but also collect the water for thermal energy systems. [E+W+U]

The most densely build areas are likely to have the highest cooling demand as this will have the most office space located near the New Meuse river. This can provide the most potential cold and can therefore meet the local demand. [E+W+U]

The industrial activities move out of the city ports towards the west and urban programme will take their places. The new urban edge will be formed by the water of the Waalhaven and the Merwe-Vierhavens. This new programme will still have a strong connection to the water and therefore the pier structure will barely change. There will be space for experimental aquatic building. Also, the dimensions of the Waalhaven are less suitable for creating comfortable urban environments, whereas the dimensions of city ports like the Maashaven and Rijnhaven are more suitable for urban projects.[U+W]

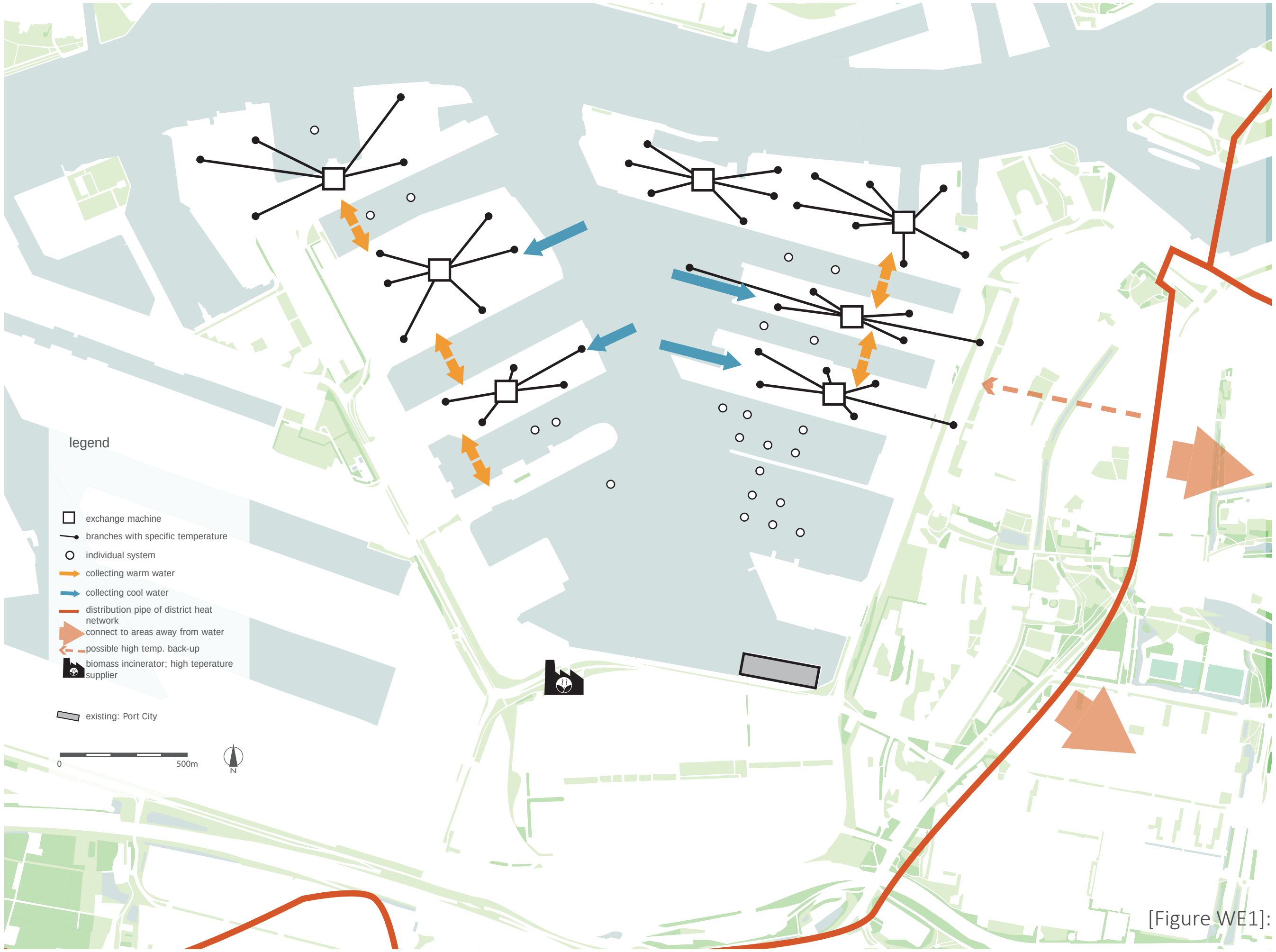
The programme in this new edge between urban and industrial will have diverse programme and forms a powerful engine for the economy. The Waalhaven - on the junction of the knowledge and the industrial axis - should be hosting job opportunities for the well educated (marine technology) but also for the less educated and less wealthy. The south of Rotterdam has a relatively poor community with many nationalities and relatively high unemployment rates. The Waalhaven offers a vast area in which there is plenty of place to start simple businesses or to do labour that requires little skill. This is for instance: urban agriculture and aquaculture, 'C2C'-industry (disassembly and reassembly of used products) or in the construction industry of floating buildings.[U+W]

The division of the urban tissue created by the dike will be reduced by local spatial solutions, such as delta dikes and programme within the dike.[U+W]



[Figure MC2]: visual comparison to show overview of the three disciplines in the urban delta with outer dike and inner dike area (source: by author)

Waalhaven master plan 4.3



[Figure WE1]:

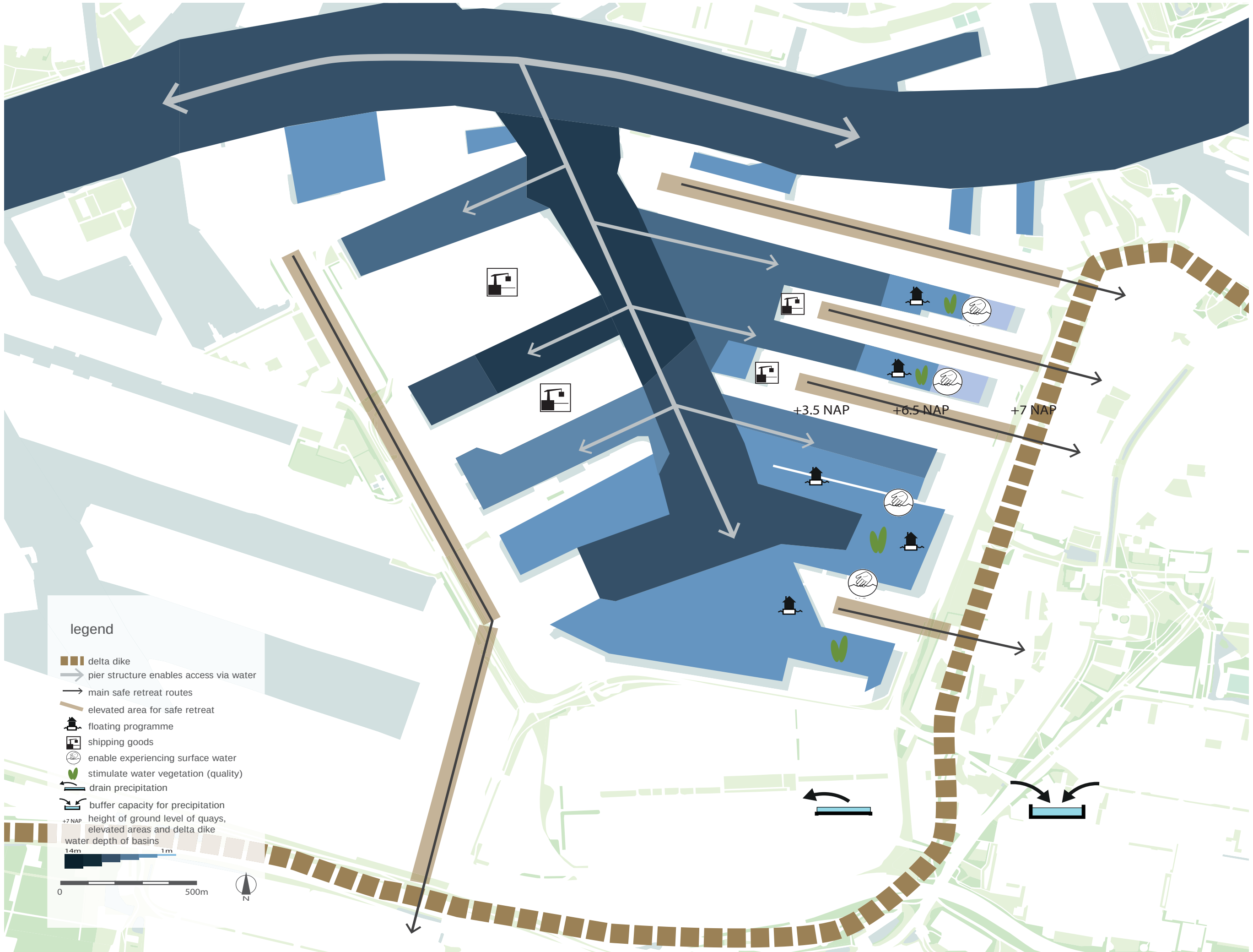
4.3.1 Energy

The pier structure advocates the implementation of a local thermal energy network per pier. The surface water can be approached from almost all around the pier. This gives much freedom in the spatial planning of the distribution network; the installations will always be near to the water. The west ends of the basin will be less under the influence of the tidal movements in the port and will be slightly warmer. The deep areas, where the cold water is situated is are in the centre of the Waalhaven.

High temperature is provided by an external source via the pipeline that runs close to the Waalhaven. This heat is provided by port industry, but could be changed in future. To be autonomous, geothermal wells can be implemented in the Waalhaven to provide the high temperature. One doublet will cover an area of 1 by 2 km and will deplete at some point. Therefore a connection to an external centralized supplier is most efficient in the long run.

As the buildings in the Waalhaven will have an alternative thermal source and will be less heat demanding, the main orientation of the district heat network is towards the inland urban area of Oud-Charlois. These dwellings are not very energy efficient and therefore have a larger heat demand.

Between the piers – in the port basins – low dense aquatic programme is thermally autonomous. Because this programme is not connected to a network, it is possible to make very flexible programme



[Figure WW1]: Water masterplan of Waalhaven (source: by author)

4.3.2 Water

The branched structure of port basins makes most of the area accessibility over water. The central axis will remain deep to allow access to large vessels.

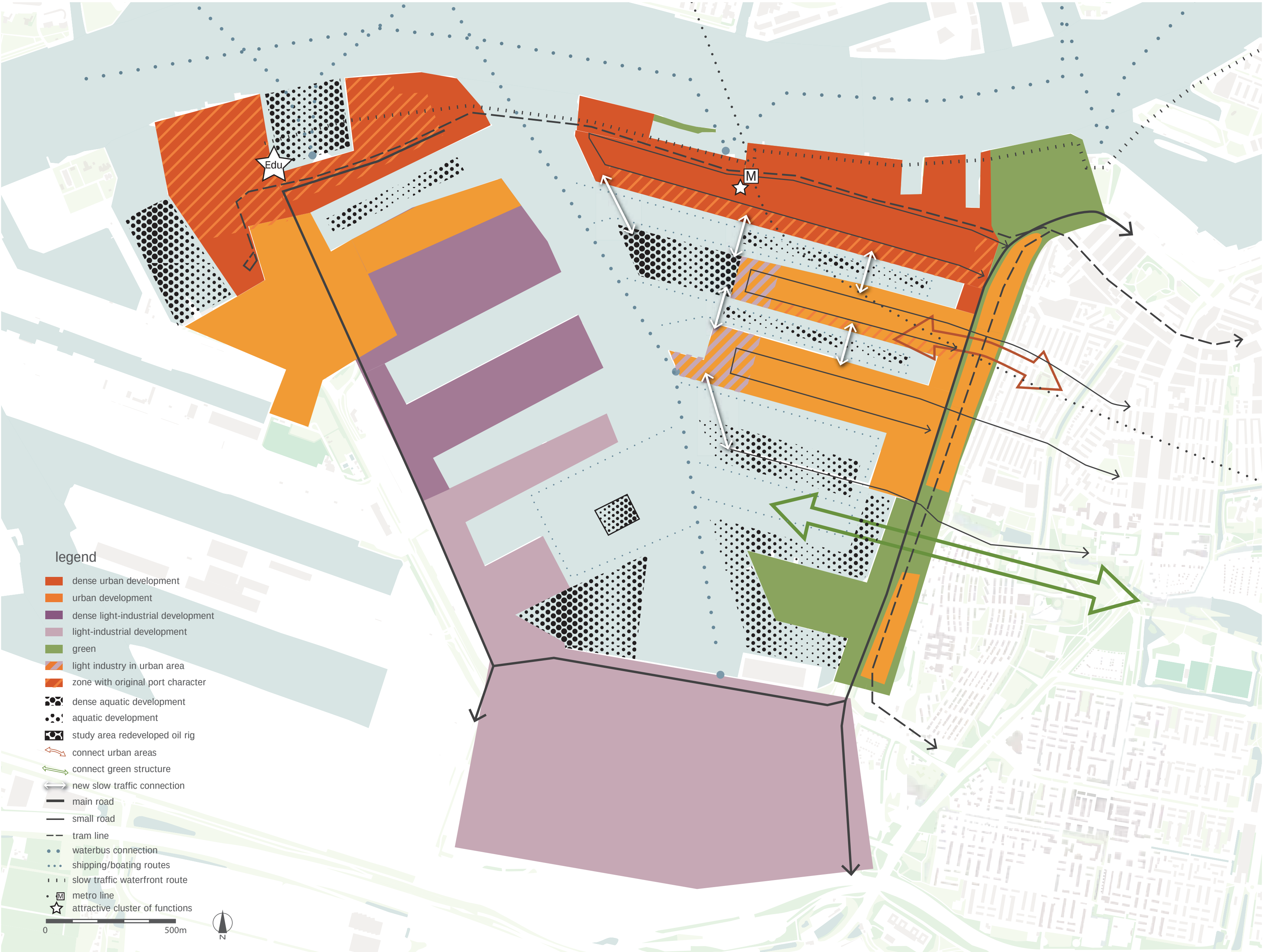
The finger structure of piers and basins also make a very long waterfront. These high quays need to grant better access to the waterfront.

The water quality needs to be increased in the ends of the port basins. Therefore, water plants will be introduced. However, they need more shallow waters. This results in reducing the depth of the end of the basins. In the southeast of the Waalhaven the shallow areas already exist. These will remain shallow to allow vegetation to grow.

The pier structure makes a clear linear escape routing per pier possible. This simple arrangement makes orientation easy. The escape route should be elevated along the pier.

The escape routes will lead onto a delta dike. Because the open system can lead to high water levels exceeding the NAP+4 m, the delta dike needs to be at least NAP+6 m taking in account all the safety margins.

The deep waters are not suitable for the currently available floating buildings. When technique evolves, this might be possible in a later stage. Current options for the programme in the deep water of the Waalhaven can be realised by placing an oil rig and redevelop this for urban or light industrial purposes in the city port.


Edu
M
legend
dense urban development
urban development
dense light-industrial development
light-industrial development
green
light industry in urban area
zone with original port character
dense aquatic development
aquatic development
study area redeveloped oil rig
connect urban areas
connect green structure
new slow traffic connection
main road
small road
tram line
waterbus connection
shipping/boating routes
slow traffic waterfront route
metro line
attractive cluster of functions
0
500m
N

4.3.3 Urban development

Urban programme

The highest building densities will be placed along the shores of the New Meuse river; this concerns the Stieltjesdijk and RDM campus. The lowest densities will be on the southern piers of the Waalhaven, where a recreational area will be realised. This is connected to the green areas of the Zuiderpark area.

The Waalhaven can be divided in two; a western part and an eastern part. This is spatially determined by a dividing strip of water and the difference in angle of orientation of the piers. The urban programme in the east of the Waalhaven will consist of offices, dwellings, light industrial programme and businesses, but also recreational areas. The west side remains industrial area.

The western parts of the pier will be closest to the industry and to the river. The western parts of the piers on the eastern side will be characterized by the more industrial programme. The eastern side will need to connect to the urban tissue by matching programme.

Connectivity

A bridge will connect the Stieltjesdijk and the RDM-campus. This will allow slow traffic and a tramline to continue their path along the riverbank through the dense urban zone.

The industrial areas will connect more to the port in the west and the highway A15. The urban areas will be oriented to the waterways with more aesthetic value and the shortest route to the city centre.

A new metro station on Stieltjesdijk will connect north and east. It will be part of the circular line connecting the economic centres in southern Rotterdam. The station will service the dense cluster on Stieltjesdijk.
From near the proposed metro station connections across the port basins is made, perpendicular to the direction of the pier. These connections are for slow traffic and make the piers more connected, now it is changing to an urban area.

The eastern edge of the Waalhaven is determined by a dike, that will be upgraded to a delta dike. By increasing the height, but more importantly the width of the dike, it will 'protect and connect' the Oud-Charlois district. The delta dike will be mainly green, but with urban programme that will connect the urban tissue of Ouc-Charlois to the Waalhaven. Also the existing infrastructure will be extended on to the Waalhaven piers.

Aquatic programme

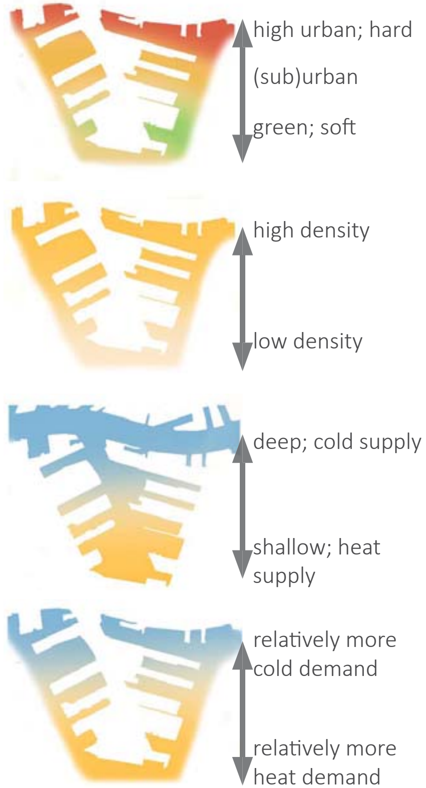
The water in the extension of the piers is available for aquatic buildings (floating or elevated) in similar densities as the pier. This will be realised in a later phase, when the piers have been fully redeveloped. The strip of water is over a hundred meters wide and can also host a strip of aquatic building. To respect the open character of the port basin, this will be done in low density and a small amount of layers.
In the south, where water are shallow, there are more suitable locations to place floating programme. In this area it should match with the green recreational character, therefore, the programme will be placed in low densities, allowing to recreate around the floating programme.

The south-oriented quays will be developed as attractive public space with port identity. In this area original buildings will be preserved and reused. Some of the existing port cranes can remain to give more character to the public space.

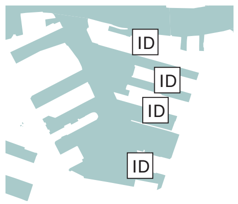
Elasticity

The elasticity that has characterized the Waalhaven over the last century will also be visible in these developments. The gradual transition will change the look and use of the Waalhaven over time, resulting in changing outline shapes. However, it is very expensive to change and rebuild quay walls. Therefore, it is envisioned that the current form will remain for the coming decades. The change will predominantly take place in the new fronteer: aquatic building. With building up the designated zones, new dimensions of the surface water will be shaped, that are more coherent with urban typologies, such as canals. Also , the role of the north-south connections will contribute to shaping a new orientation in the Waalhaven.
The southern part of the Waalhaven could contribute more to its elastic legacy. This more green, low-dense area with shallow waters could be partially removed form its current hard water edge and create a more subtle, natural shoreline. With an expansion of the elevated infrastructure, the shape of the ground level could become barely significant to the functioning of the area. It could therefore change regularly without having a major impact. Even more elasticity is brought by floating programme, which can be placed and changed in a short amount of time.

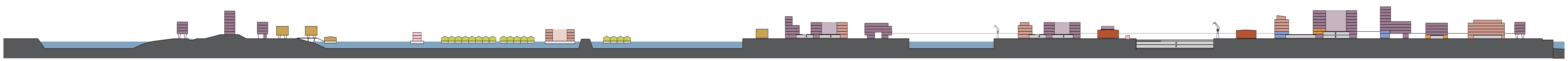
[Figure WC1]: Masterplan of Waalhaven (source: by author)



[Figure WC3]: matching gradients in the different disciplines of the Waalhaven (source: by author)



[Figure WC3]: pier structure Waalhaven creates seperated peninsulas that helps creating identities per pier (source: by author)



[Figure WC2]: section AA; north-south section of Waalhaven (source: by author)

4.3.4 Integrated masterplan

The zoning plan for the Waalhaven is formed by combining the three disciplines. The Stieltjesdijk will have the highest density as it is part of the linear dense zone along the New Meuse river. It will have many offices with a relatively large cold demand. The river is a more efficient source for cooling than a port basin. The two pier south tof the Stieltjesdijk are less dense. This is because they are not on the main routing along the shore, but also to better connect to the archetype of Oud-Charlois and the Waalhaven. The delta dike should also contribute to making a better connection between city and transitioned port.
Since the south-eastern part of the Waalhaven is more shallow and can be connected to the green zone in the Zuiderpark, this area will be more characterized by the green and is most suitable for floating programme. Here also a soft approach can be used, where quays disappear and nature can influence the landscape. The floating buildings have easy access to the water and therefore can be thermally autonomous. Also around the piers 1 and 2 study areas are indicated to place aquatic building. The water depth is considered too deep for the current techniques. Therefore, this can be placed in a later phase.
The western side of the Waalhaven will remain part of the industrial zone. After short seas shipping this area will also be used for construction and C2C-industries. The RDM-campus and its surrounding area will be transformed to an urban zone. This area will be a hosting a knowledge cluster and forms the end of the slow traffic route and dense urban tissue along the New Meuse river.[E+W+U]

The identity per pier is already made possible spatially by having the piers separated by water. This separation helps in organising local energy networks as well as evacuation schemes. Also, by making the energy system more visible on the pier should contribute to creating more unity and identity.[E+W+U]

There will be connections for slow traffic made between the piers. First, the eastern connections across the water are implemented, as the urban redevelopment of the port area will start from the other urban area. As the transition of the piers progresses the western connections will appear. These connections are also part of a flood-safe route through the Waalhaven. Therefore, these connections will be elevated above the water, but also above the piers. This makes crossings with ships and cars possible.[W+U]

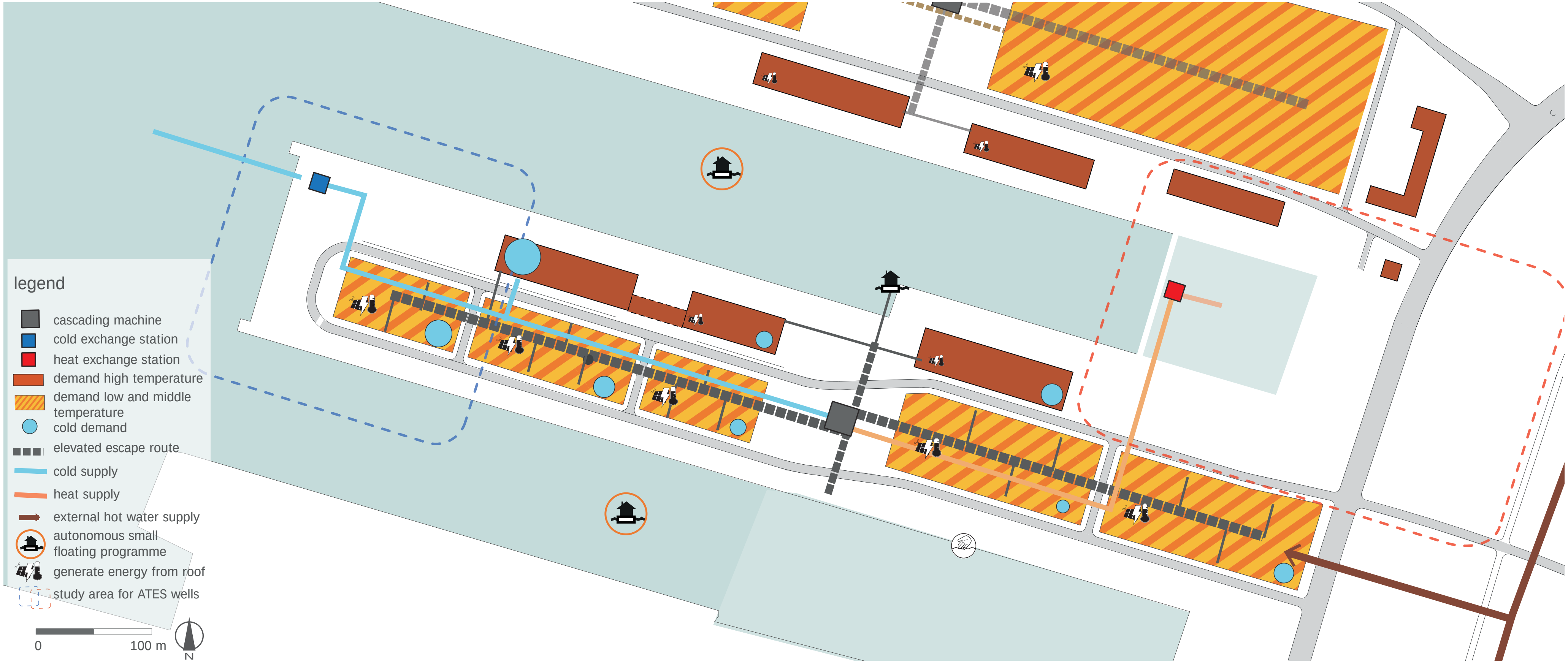
The southern oriented quays of the piers are developed to exploit the quality of its ‘sunny’ public space with characterizing elements. As it will be a pleasant place to stay the connection with the water should be improved as well.[W+U]

The largest heat potential in the surface water of the Waalhaven can be found in the areas that are shallow and/or have slowly moving water. This can be found in the south-eastern part of the Waalhaven and at the tips of each port basin. This can subsequently be linked to the programme. When buildings need significantly more heat than cold, they should be located near these areas. This includes for example housing and farming. It also works the other way around; programme with a relatively high cooling demand, such as offices and shops, should be located near the coolest water, which will be in the New Meuse river and the deep central axis of the Waalhaven.[E+W+U]

Opposing (and therefore matching gradients can be seen in the Waalhaven [Fig. WH1], where the gradient of the water temperature is opposite to the building density. The cooler waters in the northern waters can provide the cooling demand of the dense urban zone at Stieltjesdijk, whereas the southern low-density programme - in warmer waters - needs less cold water. [E+W+U]

The heat demand will also change in time. As the industrial programme leaves, new, more energy-efficient buildings will take their place. This means the demand for high temperature water will be reduced. The district heat pipe, running close by the Waalhaven can therefore be initially important, but its requested heat supply will reduce. Other, locally produced high temperature water, will be used instead to supply the small demand.[E+U]

urban design pier 1



[Figure PE-1]: envisioned measures within the discipline of energy management (source: by author)

4.4.1 Energy

The pier will form a local thermal energy network, which is almost autonomous. The system explained in paragraph 3.3 is spatially implemented on to the pier. This puts it in between the cold water and the warm water supply stations, making the transport equally long. . The cold exchange station will be near the deep waters in the west and the heat exchange near shallow waters in the east. In their surroundings the heat and cold is stored underground.

From this machine, the warm waters and cold water is distributed across the pier to the designated user. Each temperature level will have an outgoing pipeline servicing the need and a returning pipeline supplying a cooler temperature level in the cascading machine. This distribution will take place along a central axis over the length of the pier.

These distribution pipelines should be accessible so that when a transition in the programme takes place, a quick alteration to the pipelines could facilitate the new situation.

The storage systems will consist of an exchanger and switch to charge, discharge or bypass the ATES. These systems are located near their sources on either end of the pier.

There should be a possibility to bypass the distribution station to supply high (or low) temperatures to special users, such as a supermarket or a swimming pool. This programme will be situated near the heat or cold exchange station.

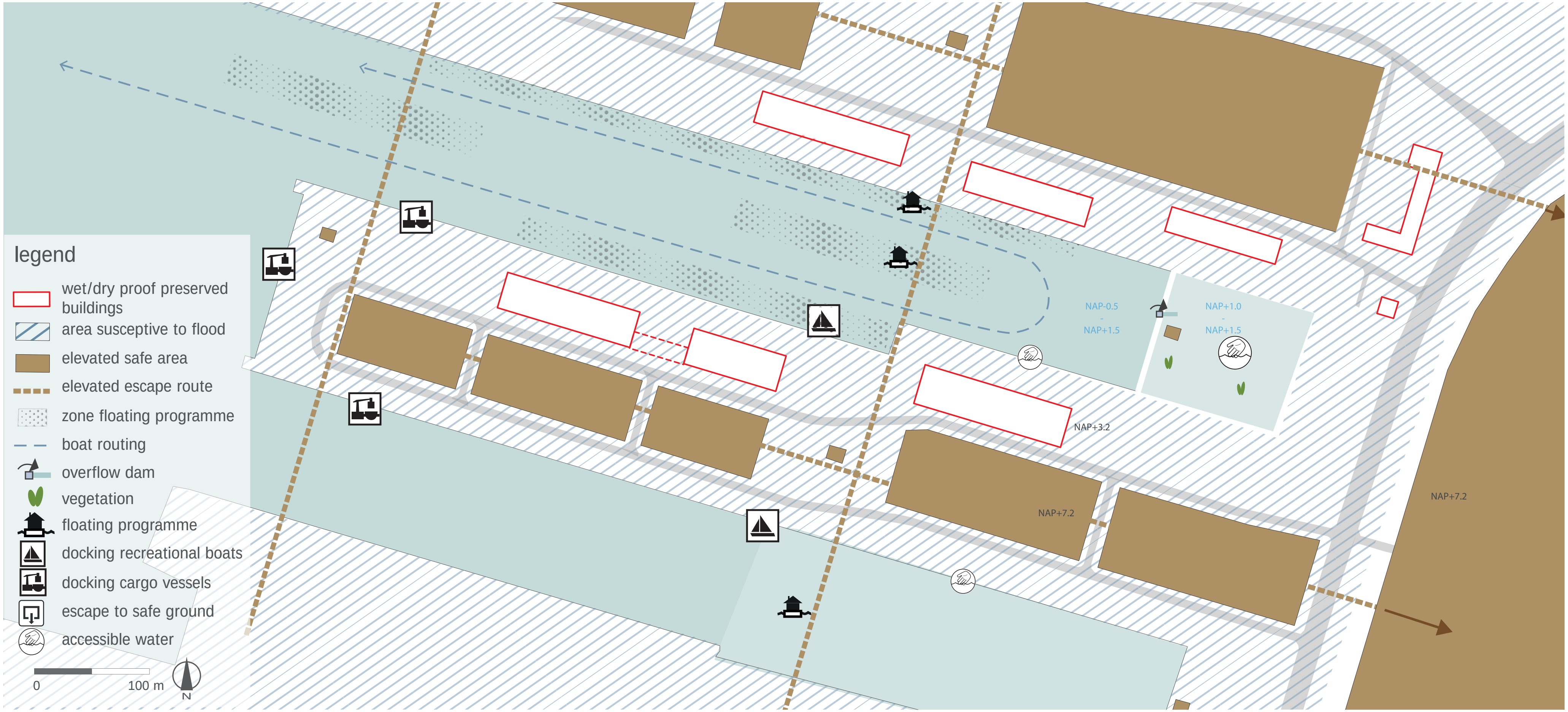
The heat and cold yield from surface water is increased by taking water from either deep port basins or by shallow waters to gain respectively cold water (8’C) and warm water (25’C)

The maximum yield from heat collection can be ensured by making the sun hit the surface water throughout the day. The assumption is made that the sun should cover two-thirds of the surface at 18:00 hrs on September 1st. This means an angle of impact of 14 degrees (Giesen, 2013).

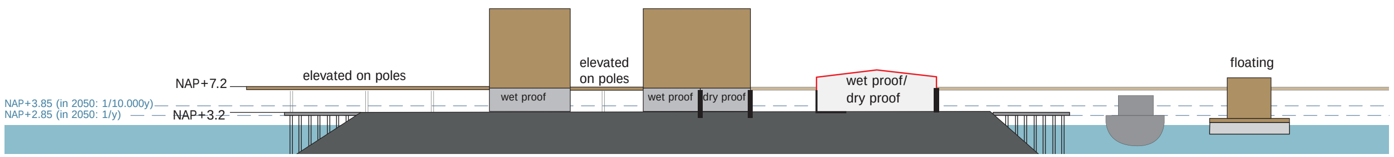
Buildings

Apart from sustainably generated energy, the New Stepped Strategy also indicates that the demand should be as minimal as possible.
The thermal energy loss will be reduced by making placing programme that answers to the latest demands on sustainable building. To prevent thermal loss of buildings, they should be built compactly. Obviously, they should also be equipped with thorough insulation of wall and glass and furthermore, have energy efficient equipment.
The building orientation for reduction of heat demand makes no difference whether building blocks are oriented south or south-west. However, for lighting it does matter; therefore southwest is preferred (Morello et al., 2009).

The cascading machine will distribute the heat and cold to the buildings on Pier1 from a central position. From here the numerous pipelines will distribute the different temperature levels across the pier. The cold exchange station will be near the deep waters in the west and the heat exchange near shallow waters in the east. In their surroundings the heat and cold is stored underground.



[Figure PW-1]: envisioned measures within the discipline of water management (source: by author)



[Figure PW-1]: schematic section of envisioned measures on water manegement. (source: by author)

4.4.2 Water

The pier is situated in outer dike area. This means for instance, that the area does not need to retain precipitation; it can be drained directly into the port. This also means that the rooftops and public space do not need retention systems implemented, which is valuable space that can be used for other purposes, such as energy collection and recreation. However, water retention systems could still be implemented for gray water systems, that help save (drinking)water.
In the year 2050 it is assumed that water levels could reach a mean high water level of NAP+3.85 with a 1 in 10.000 year chance (Veerman, 2008; Kokhuis, 2013).
This means water levels will rarely be life threatening, but very inconvenient indeed.

Flood protection

The central strip of the pier will be having an elevated core on poles, from where a path runs along the pier guiding people to safety behind the dike. This parallel escape route is connected to the other piers by perpendicular elevated connections across the port basins, making the area better connected and offer more access possibility to flee to higher ground.
The ground floor of this central strip will be susceptible to floods. Therefore, it will be either built dry proof or wet proof, depending on the damage that can be brought to the elements behind the facade. Also disaster mitigation is applied by demanding installations as well as bedrooms to be situated on the first floor or up.
The renovated warehouses are also susceptive to flooding. They will host mainly programme to what the water can do little damage. A floor can be built in to the eight meter high building to store electronic equipment and building installations. These buildings will be mainly wet proofed, some will be dry proofed according to the programme they host. Floating programme docked alongside the pier will rise with the water, so will not be damaged by the water. Furthermore, it could also function as place of refuge in case of a flood.

Accessibility

The long waterfront around the pier has different characteristics of the transition from land to water.

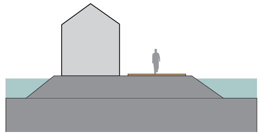
The quay wall can be lowered , bringing people up to the water line. This means breaking down the quay wall, which usually causes construction problems, as quay walls are complex structures. It is therefore not recommended.

High quay walls combined with deep waters allow relatively large vessels to reach the pier and dock. This helps providing the industry and retail with goods via water oriented transport.
The high quay wall can remain and from there a ramp connects the land to a floating platform, that allows access to the surface water.

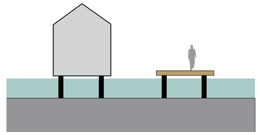
Floating development can be placed against the quay wall. This development has multiple levels allowing to enter the building at the first floor and decent to find water access at ground level.

The pier also should use the deep waters in de surrounding port to be accessible by large vessels. This can benefit the industry. However, moving these ships far up the basin towards the east is not possible, because of shallower waters, but also designated zones for floating development. Placing this on the water helps making the vast water surface into urban dimensions.

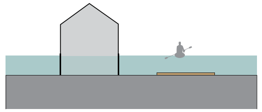
Implemented adaptation measures:



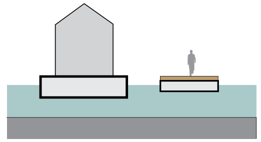
'terp': elevated ground level



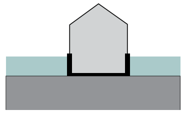
on poles



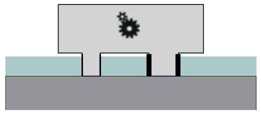
wet proof



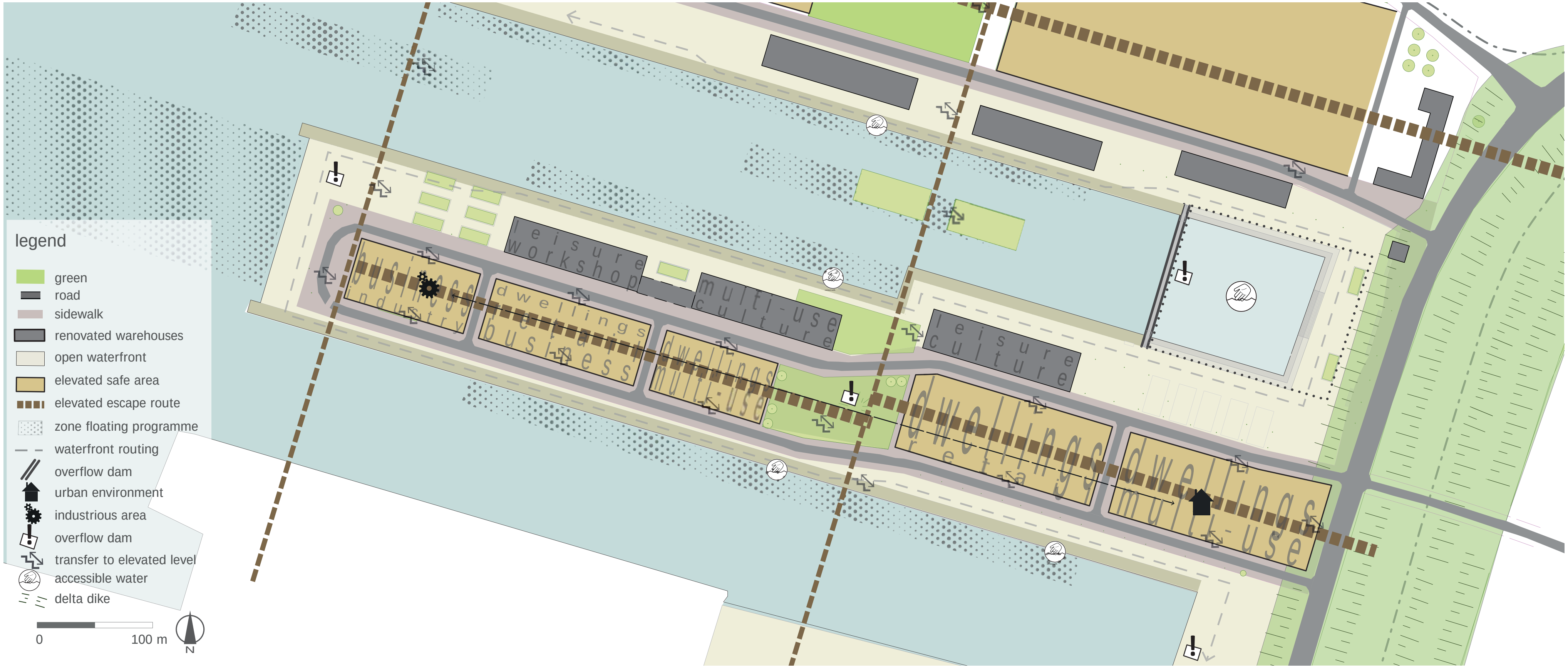
floating



dry proof



damage reduction by shape and interior placement



[Figure PW-1]: envisioned measures within the discipline of urban design(source: by author)

4.4.3 Urban development

Pier zoning

The central linear strip will be used for new buildings. Through the middle of this zone, an elevated linear route runs towards the delta dike. The buildings are attached to this elevated public space. Around this block a road forms the separation between the build up blocks and the outer ring of open public space. Here, the preserved and renovated warehouses give character to the zone, but should keep an open character to the waterfront. This means a selection is made on what warehouses to preserve. This is for aesthetic purposes, but also practical; quay structures cannot bear the heavy load of extra buildings if they are built too close to the quay wall, without severe – and very expensive – fortifications. This excludes of course the already existing warehouses, as their load has proven no problem to the current quay. All development on the quay will therefore be compact and light. The most of the waterfront consists of crane tracks that are constructed to the land as a jetty [Figure DU-0/DW-x]. These are founded constructions and could bear some load. The cranes on these tracks will partly remain, as it gives the area its character.

The port basin is 100 – 130 m wide. This is not a very urban dimension. Therfore zones in the water are indicated, were floating programme can be added. This also gives great opportunity to help the region change, because new programme can replace obsolete development simply by floating the old one out and the new one in. This can be seen as changing the applications on a smartphone (Waterstudio, 2012) [Figure DU-1].

Programme

The buildings on the open, low lying zone, are designated to host small enterprises and start-ups, mainly in the cultural and leisure sector. The middle zone should have a mix of functions. In this mix, a gradient between the eastern and western side of the pier is visible; from urban programme in the east towards more industrial programme in the west [Figure DU-0]. The elevated public space provides the buildings with a second plinth on a different floor. This could benefit the mix also vertically. This elevated public space forms a more enclosed space, contradictory to the open waterfront. This contrast needs to be vouched for in the development of these building blocks concordantly their functions. In other words, shops and public services should not be drawing the crowds to this area. It should give access to predominantly dwellings and offices; the occasional hospitality or small shop is allowed.

Building height

Pier 1 will be built up with urban densities. This means working with an FSI (Floor Space Index) around 1,0. Also the number of layers will be limited. There will not be too many large shadows casted to keep daylight available for most buildings and also the quays.

The number of built-up layers will be mostly between 3 and 5. The building height should vary regularly to show multi-form building blocks. This also means that building heights of 6 or 7 layers are occasionally allowed.

Routing

The pier will have a car route from the main road – the Waalhaven Oostzijde - going round the pier. This gives access to both quay programme as the programme in the central strip. The ground floor of this strip will be mainly parking and storage space.

Where the car is limited in its routes, the slow traffic - predominantly pedestrians - have great freedom of movement. On ground level a waterfront promenade forms a wide continuous route, meandering through the Waalhaven. This network is via ramps and stairs connected to the elevated network, which forms the flood proof escape route of the outer dike area. This route forms the central public space in between the buildings. Perpendicular to this route along the pier are two pedestrian bridges; one halfway down the pier and one at the end. These bridges form the connection to the other piers, shortening the distance when travelling from one pier to the other.

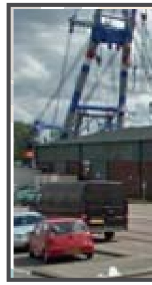
Quays

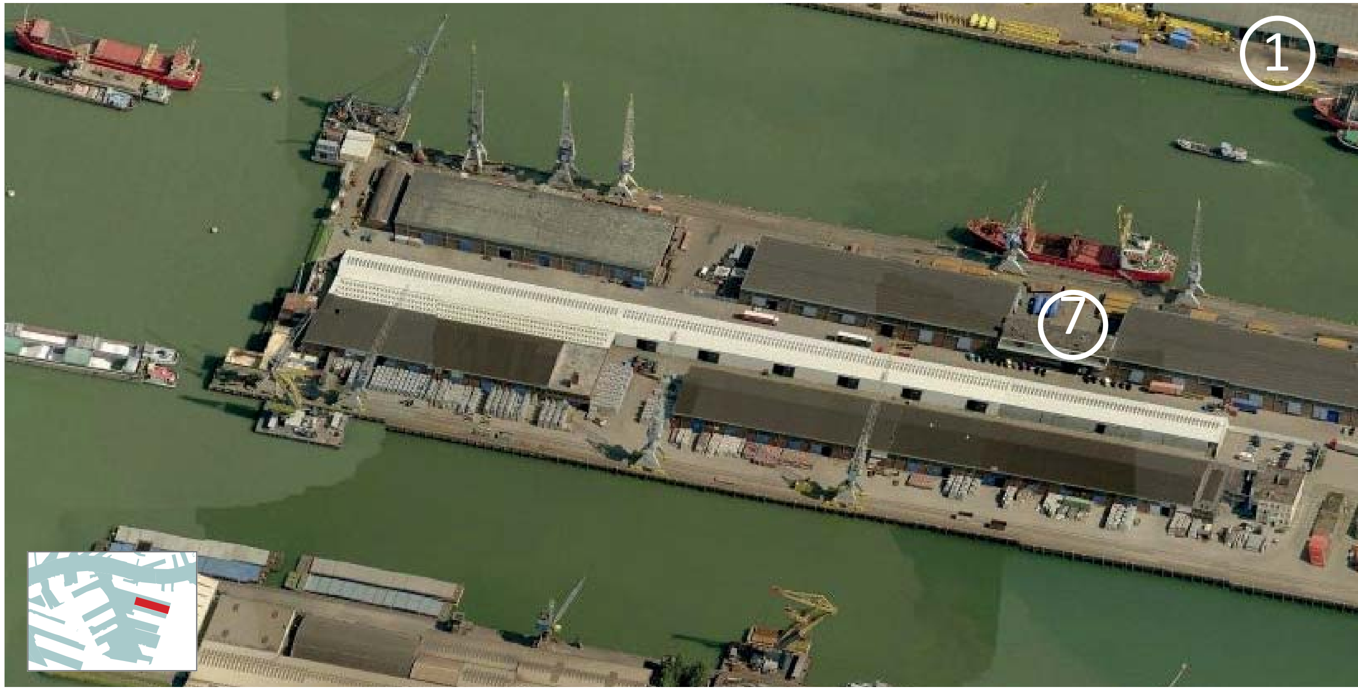
Since the exact calculation for the distance to the quay wall and the amount of load to bear, is not a field of expertise for this project, the exact rules are unclear. Since the concept is to keep an open environment along the waterline, the quays will have no extra heavy loads to bear. Small pavilions are allowed. Larger programme along the waterline will therefore be placed in the water. Thusly, it can also form a connector between the high crane track jetty and the water surface. Beacause these jetty's are preserved, the water accessibility needs to be increased by creating aquatic public space - either on poles or floating - connected to the quays. This allowes a better experience and use of the surface water.

Preserved buildings

The following selection is made for the preservation of buildings. Most of them are warehouses that all look very similar.

The warehouses should, together with the cranes contribute to the more industrial feel of the pier. The open waterfront should therefore show similarity in material and look; warehouses along the water and open space in between, materialized with concrete, steal and brick.





[Figure DU-2]:overview of buildings that will be preserved in the urban design

(source: Google maps, assembled by author)


2


3

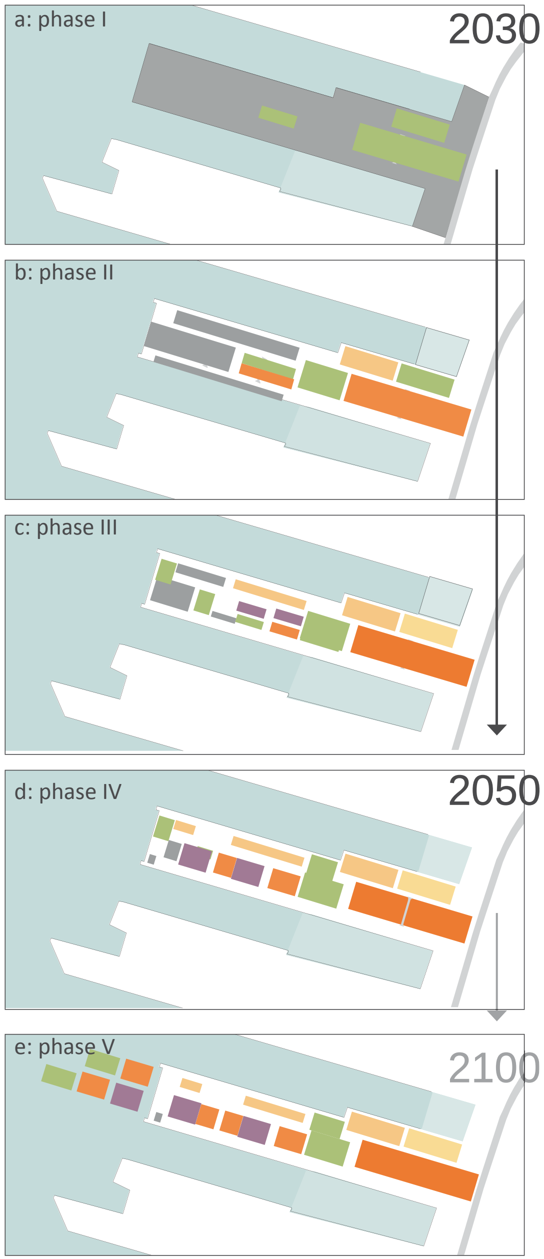

2
3
4
5
6


4


4


6


5



[Figure DU-2]: schematic overview of phasing between 2030 and 2050 towards 2100 (source: by author)

Phases of transition

As the redevelopment of Pier 1 is a transition progress from industrial to urban, it will not happen overnight. The plots will most likely become vacant at different moments in time. The exact end of the current contracts at Pier 1 could not be given for this project, but the current contracts on the Waalhaven-East and Stieltjesdijk will end between 2020 and 2035 (De Vries, 2013). The energy system chosen for the pier is very suitable for these transitions, but how to approach this from a spatial-functional perspective?
Firstly, the directions of development should occur in western direction, because this area is situated closest to the existing urban area.

Phase 1 [Figure DU-2a] :
Opened up areas on the pier can be turned green. Soil examination should determine whether this can take place in the pier’s soil or on top of it (when pollution is indicated).
Green areas can function as recreational, but also as agricultural land. Here, people from the surrounding neighbourhoods could be given the space to start urban farming or gardening.

Phase 2 [Figure DU-2b]:
Urban programme is being developed in the middle strip of the pier. The temporary green that was situated here before, will reappear elsewhere on the pier. Also warehouses in the open zone are assessed and renovated. More industry disappears and is turned to green.
More temporary programme can be implemented onto the pier when more people are attracted to the Waalhaven-East. Possible options are shown in [Figure DU3].

Phase 3 [Figure DU-2c]:
The majority of the pier is currently under redevelopment. The pier hosts definitive programme in the eastern developments, characterized by mainly dwellings and offices. The waterfront is developed concordantly. The middle section of the pier is still a mix of businesses, temporary programme, green plots and light industry.

Phase 4 [Figure DU-2d]:
The pier nears its full transformation. More plots in the west are filled with durable development. The industry here will slowly be replaced by small businesses that benefit from their location at the waterfront, accessible by small cargo vessels. The routing along the waterfront is fully developed, making a continuous promenade along the pier. Also floating – flexible – programme can be placed at the waterfront, accessible from the promenade.

Phase 5: [Figure 2e]:
The new frontier in this phase is expansion of urban programme along the extended line from the pier towards the west as industry is moving more and more to the west. This requires new technology and will not occur before 2050.

possible temporary programme

The transition will come with unoccupied plots. Here, temporary programme can be placed. This could be occupying the plot for a few months, but it could also be around a decade. Temporary programme should make an industrial port area more intrersting for the inhabitants of Rotterdam (and perhaps even from outside the city). Events and recreation, but also jobs and schooling should lure people towards the Waalhaven. This temporary programme should also contribute to the community feeling and should support the bottom-up initiatives.
The advantage of the port area is that floating programme can easily be towed in and quickly replaced by new programme when the demands change.

Some examples of temporary programme are:
- agriculture
- sports
- events, fairs, concerts
- studio space, start-ups
- temporary housing
- recreation, gardens
- education

In a transition area, temporary programme will also mix with definitive redevelopments. It should contribute to a more pleasant and more vibrant urban area, that is in the making.


legend
green
road
sidewalk
crane tracks
renovated warehouses
newly built, flood proof
open waterfront
elevated safe area
floating public space; jetty
recreational path on water
zone floating expansion
waterfront routing
overflow dam
structure stands out
accessible water
delta dike
marina
preserved port cranes
0
100 m
N

4.4.4 Integrated urban design

Triple gradient

The programme on the pier will be an integration of disciplines. The western end of the pier will host industrious logistic functions, that can be linked to transport over water. These buildings will be in between urban functions and the industry that can be witnessed across the water in the west. This requires accessible quays and deep waters. These deep waters are suitable for cold water collection and the cold exchanger is, as said before, situated at this same end. This way, it can also supply cold water directly to peak cool demands, such as cooled storage units or industrial activities. Also, a more urban programme can be placed here as well, when the transition continues. A large supermarket, a food court or even a theatre or convention centre needs cooling and could be accessed by boat. The programme would attract also people from land and will create a flow of people up and down the pier, preventing it from becoming a slightly desolated area. Dwellings and offices will be on the more urban side of the pier, connecting more to the urban programme in Oud-Charlois. In this more urban programme the larger public space comes to justice. Here the water depth is also reduced to make a more pleasant water for recreation, but also to use the shallow waters for surface water heating.[E+W+U]

Linear structure

The linear structure of the pier forces all three disciplines to work in the same direction. This makes it easier to spatially combine the three layers. In this project, the energy distribution matches the escape route as well as the orientation of development and the routing [Figure DC3].

Elevated public space

The elevated public space is a good example of the integration of the three disciplines. It forms the backbone for new development on the pier, as new buildings are connected to the public space, which creates a second plinth and a route to safety. But on top of that it also distributes the thermal pipelines from the cascading machine to the building blocks and back. The elevated pipelines are therefore not susceptive to flooding and also easy accessible when an adaptation needs to made to the system or a repair is needed. The elevated thermal transport is also the shortest route, as the cascading machine and the installations in the buildings are also at elevated levels [Figure DC2].
With this system, the entire pier can undergo the transformation in sections. First the pathway is made and after that programme is placed against the walkway and is subsequently attached to the thermal system. [E+W+U]

Appearance energy system

The pier will have its own heat distribution system. This is formed by a centrally situated distribution station, fed by a heat exchange station (east side) and a cold exchange station (west side). Since the project is all about implementing the thermal energy network in the urban environment and showcasing new ways to rethink the power of water, the elements of the system should be standing out. This can – and will - be done by remarkable architecture, but also by elevation, which will also prevent it from flooding. People may see that this is the heart that is fuelling their pier community.[E+W+U]

Safety & distribution

The elevated land the cascading machine is on is part of an elevated linear route across the pier, providing a safe exit in case of flooding. This escape route will be at around 4 metres above the quay, which is 7,2 metres above NAP. This height is above the assumed threat line of NAP+6 and makes it possible to organise a building layer of programme underneath. On top of that, it also connects to the elevated connections across the port basins and allows cars and trucks to cross underneath.[W+U]

Reducing demand

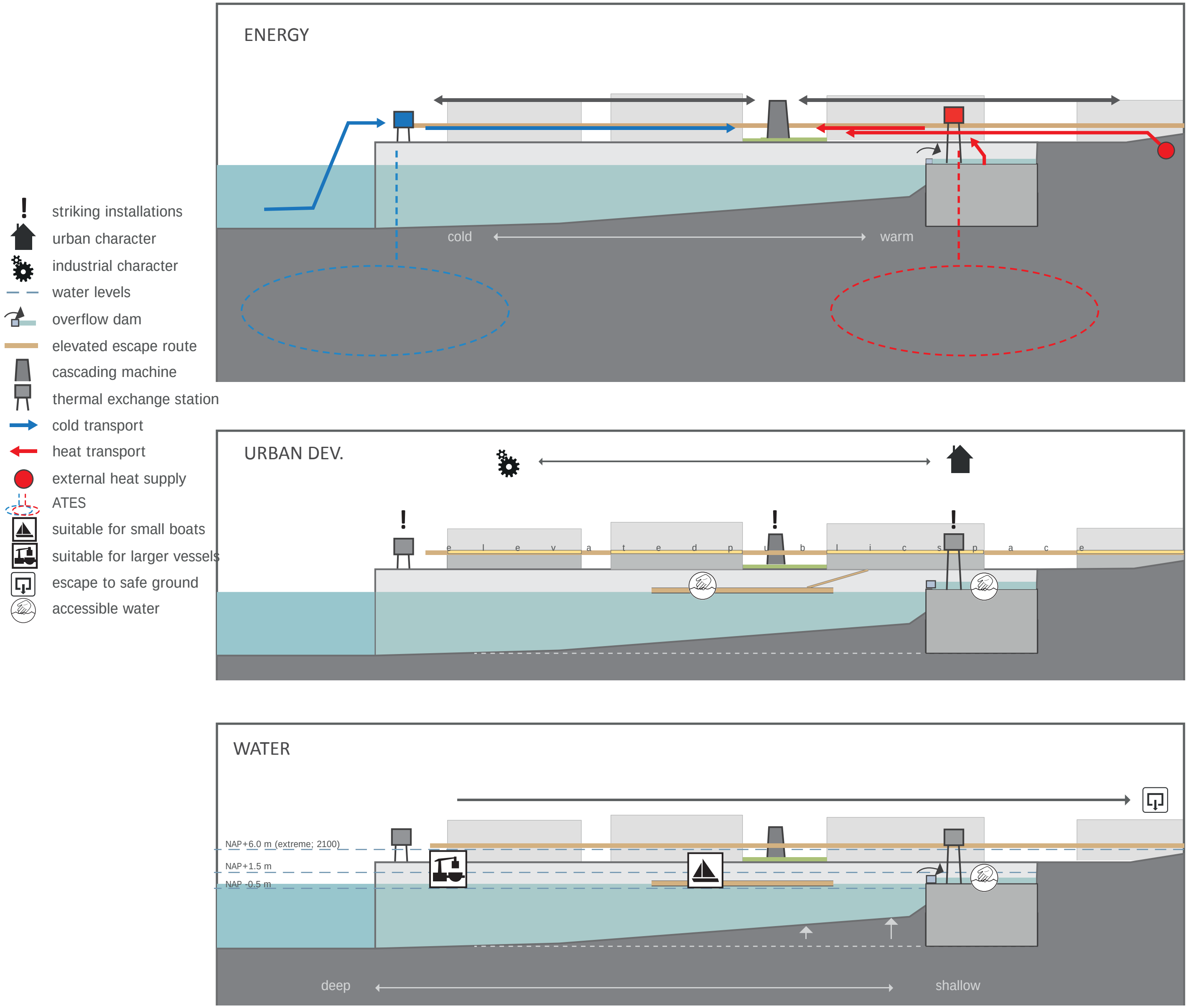
The buildings on pier 1 will be mostly in closed building blocks. This is to honour the large scale plot of the port identity, but also to build compactly and reduce heat demand. Due to technological advance, buildings will get more and more energy efficient. The heat demand for dwellings will be reduced from 200 kWh/m2/yr to an average of around 50 kWh/m2. Offices have a current heat demand of around 450 kWh/m2/yr and the assumption is made that this will be reduced to 200 kWh/m2/yr. A lower heat demand also means a lower temperature connection to the central distribution station. This can be reconnected at this station and requires no new pipelines to the new building. These pipelines will run underneath the elevated public space, so they are easily accessible.
The heat network will consist of the distribution of three different temperatures. The high temperature will supply the old, existing buildings with low thermal efficiency. The medium temperature will be distributed mainly to offices, but also a part of the newly built dwellings. The other part of the dwellings will be built very energy efficiently and can be supplied with a low temperature thermal source.[E+U]

Urban rules

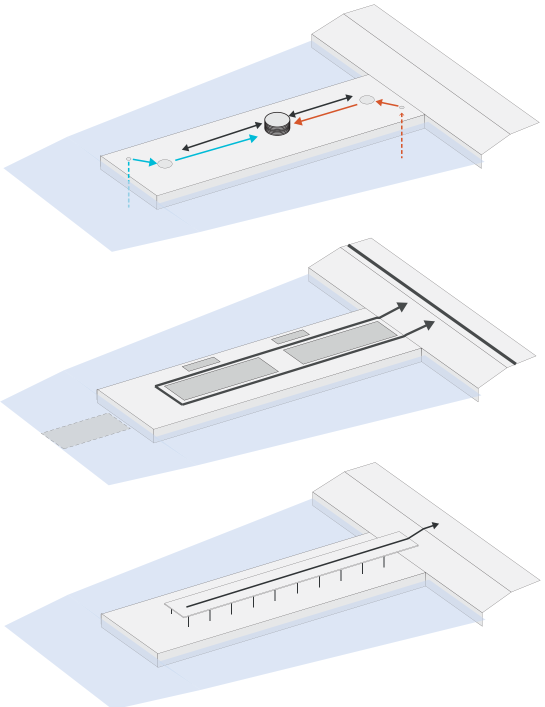
To make sure enough sunlight can hit the water from where most heat is extracted, there will be maximum building heights on the pier to guarantee sunlight on at least two thirds of the basin between 10:00 and 18:00 hours during the heat collecting months. Studying the azimuth of the sun tells us that an imaginary line with a 14 degree angle with the surface from the middle of the basin forms the limit to building heights. An occasional exception is allowed, when other arguments prescribe an exceeding building height. In practice, this means that the zone directly south to the basin will be restricted; the middle zone of the pier has a restriction that makes a 5 layer building easily possible [Fig. CD4]. [E+U]

Suitable landscape

The pier and basin landscape is very suitable for implementing temporary floating programme around the pier. The deep and wide waterways make it easy to manoeuvre large vessels into urban area. When the circumstances change, the programme can simply be changed by towing the obsolete programme out and the new programme in. This can be done in a day and won't require long construction time at the site, as in conventional systems. Regularly changing programme also fits the adaptive energy system. When the programme has a high thermal demand, this cannot be generated by an autonomous system. Then, it can be attached to the thermal distribution system. The transition development could also benefit from placing temporary floating programme around the pier. As the character of the pier changes, the programme at the waterfront can adapt to that by simply replace the building.[E+W+U]



[Figure DC2]: comparing the three disiplines in a schematic section (source: by author)



[Figure DC4]: The linear structure helps molding the three disciplines: energy (top), urban development (middle) and water (bottom) (source: by author)

Phasing of the transition

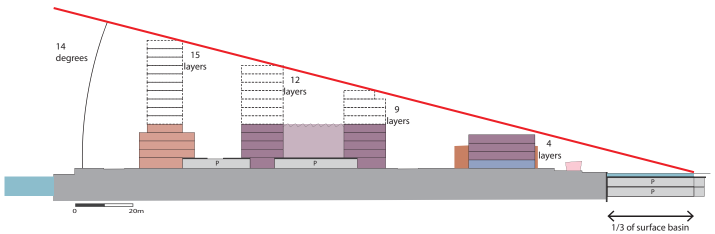
Phase 1:
The first plots of industrial area on the pier will be turned into green recreational or agricultural land. The first section of the elevated public space is constructed. This concerns the section between the main road and the cascading machine.

Phase 2:
Permanent built-up programme is appearing around the elevated connection. It becomes a mix of open and built-up plots, connected by an elevated public space. Also, the first development on the waterfront starts. Further west on the pier, more green starts replacing industrial area.

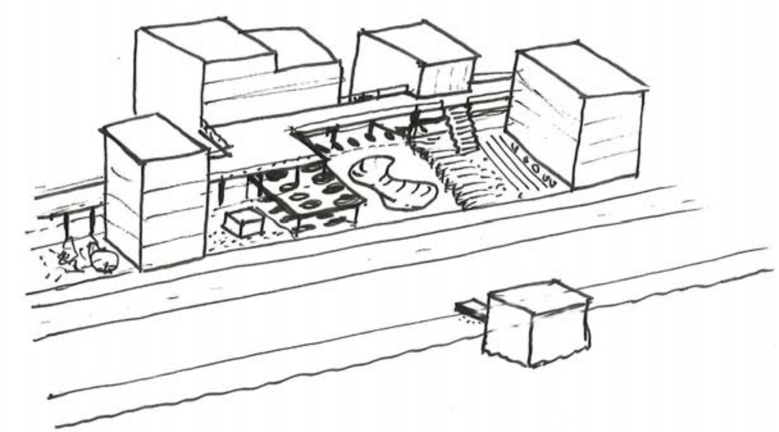
Phase 3:
The urban character starts to show its complete form in the east with all the plots built up with definitive programme. The open waterfront functions as pleasant outdoor space for the dwellings and office space. The western side of the pier has developed the elevated public space. Along which the first definite programme start appearing. The circular routing is completed; the southern road is constructed and the continuous promenade along the waterfront is complete.

Phase 4:
The pier transforms the final remaining plots to become a fully completed urban area with a more industrious mix on the west side of the pier – towards the industrial port. The east side blends into the urban tissue of Oud-Charlois across the delta dike.

Phase 5:
This step, after the completion of the land based programme, is characterized by aquatic development. This can be developed as large floating blocks or elevated on poles. New technologies will make this possible and affordable; something that is not the case today. Extra connectivity between the piers and a more blurry boundary between land and water are advocated in this phase.



[Figure DC4*: building height restriction based on azimuth regulation still offers large potential for dense urban areas. (source: by author)



[Figure DCX]: impression of pier segment in transition. It shows the central elevated public space and the mix of permanenet and temporaty progamme. (source: by author)

Calculating demand programme Pier 1

The programme for pier 1 is determined. The calculation is determining the size of the storage wells needed for the programme of the volumetric design made.

Surface per programme

Per strip calculations are made to determine the programme. The division of programme is done by dividing all the functions into five different categories that can be characterized by their heat and cold demand:
- The category 'multi-use/service' holds besides office space also museums and other public service programme;
- The category 'Dwellings' simply contain dwellings;
- The category 'Shops' contains retail, shops;
- The category 'Business', which holds besides businesses, some light industrial programme, but also restaurants;
- The category 'supermarket' also covers functions such as theatre or ocnvention centre and (large cooling demands per m2).

A division of functions of entire strip is made to give a quick estimate of the Gros Floor Space (GFS) of each category:

multi-use /service	30%
Dwellings	35%
Shops	15%
Business	19%
Supermarket	1%

The total GFS of the Pier 1 programme is 151 381 m2. The total surface area of Pier 1 is 185 000 m2. This results in an FSI of 0,81 [Figure Calc1].
This is relatively low for an urban environment, due to the included large open waterfront. When calculating the built up centre strips, results show FSI = 2.0 (see appendix C for more explicit calculations).

The heat demand (for the heating of space, no tapwater heating) and cold demand for this programme is calculated. In research of the consummation of heat and cold, different results were found. For example, office heat supply could differ between 50 kWh/m2/yr (Wisse, 2013) or 140 kWh/m2/yr (ECN, 2010). On top of that, buildings will become more energy efficient in future. In an area with a gradual transition process, many different demands within one category will occur. Therefore the following assumptions have been made based on the found data and have been used to determine a heat and cold demand. This figure is most likely too high for the amount it could be in 2050. However, there is no guarantee that all new buildings will be built according to the latest energy-efficiency.

<u>Total heat demand</u>

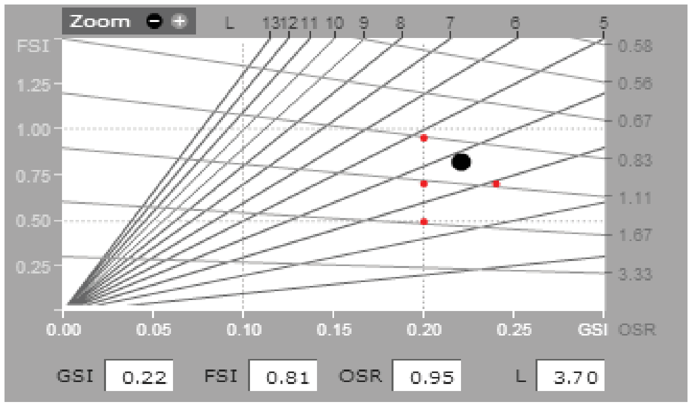
multi-use	30% with 100 kWh/m2/yr heat demand =	4541427 kWh/yr
Dwellings	35% with 50 kWh/m2/yr	demand = 2649166 kWh/yr
Shops	15% with 300 kWh/m2/yr	demand = 6812141 kWh/yr
Industrious	19% with 200 kWh/m2/yr	demand = 5752474 kWh/yr
Supermarket	1% with 300 kWh/m2/yr	demand = 454143 kWh/yr

TOTAL DEMAND: 20.2 GWh/yr

<u>Total cold demand</u>

Multi-use	30% ; 50 kWh/m2/yr	demand = 2270714 kWh/yr
Dwellings	35%; 0 kWh/m2/yr; cooling by ventilation or (electrical) air-conditioning systems	
Shops	15%; 40 kWh/m2/yr	demand = 908285 kWh/yr
Industrious	19%; 300 kWh/m2/yr	demand = 8628711 kWh/yr
Supermarket	1%; 1400 kWh/m2/yr	demand = 2119333 kWh/yr

TOTAL DEMAND: 13.9 GWh/yr



[Figure calc1]: graph by Spacemate, showing the density data of the urban design on Pier1 (source: Spacemate.nl)

Irregularities of water

The low temperature heat and cold will be harvested from the surface water. The calculation of the yield, again, is influenced by multiple variables. The main one is the fluctuating temperature of the surface water [Figure...]. This affects both heat and cold collection.

The assumption is made that the cold temperature can be collected at 5°C, whereas the heat can be colelcted from the shallow basin can be collected at tempreatures up to 26°C (see appendix C).

Dimensions of ATES footprint

With this in mind the dimensions of the storage wells are calculated (see also appendix C):

- A heat demand of 20.2 GWh/yr normally requires a footprint of 61575 m2 (280 by 280 m).
- A cold demand of 13.9 GWh/yr requires a footprint of 36106 m2 (190 by 190 m).

However, the fact that surface water can be used does have effect on the size of the footprint. Here also many uncertainty about the actual percentage of reduction. This depends in the firstly on the shape of the aquifer, but also the temperature plays a role. The efficiency shown at the Maastoren system, 75% (De Ingenieur, 2007), is almost too good to be true. Both Molenaar (2011) and Wisse (2013) suggest it is far less. Therefore the assumption is made that the addition of the surface water could result in a 40% reduction:

- Heat footprint: 31360 m2 (177x177m)
- Cold footprint: 14440 m2 (120x120m)

These area needed for the warm water storage is available in the design. The large public space offers a place where multiple wells can easily be accessed; via the waterfont and the underground space underneath the shallow basin.

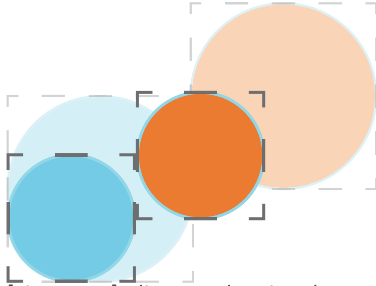
The cold storage has the some open public space to create wells. However, there are larger wells necessary or smaller wells under the water to meet the number of square metres that is needed to support the pier's cold demand.

There could be the opportunity to use more surface water directly at the cold collecting to reduce the storage capacity.

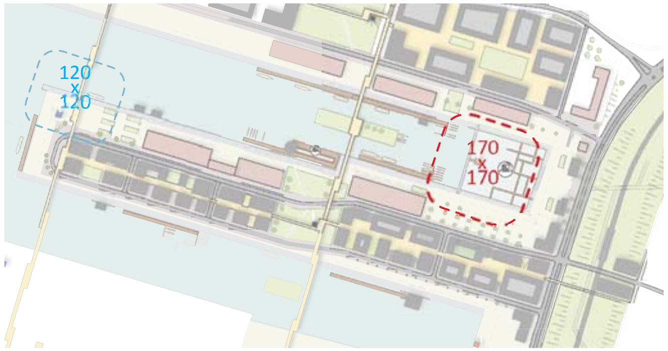
Surface water to reduce unbalance

The surface water is also used to adjust the unbalance between the heat and cold demand of the pier. These adjustments will help reduce the footprint. On top of that, thses adjustments are ideal to cope with changing demands. These will occur when programme is changing during the gradual transition of the area.

As the transition progresses, the buildings at the pier will become more energy efficient and less heat demanding. A shift will take place from the higher temperatures towards the lower temperatures. This means an ever growing percentage can be covered by the low-temperature energy extracted from the shallow basin. This makes the pier more self-sufficient over time.



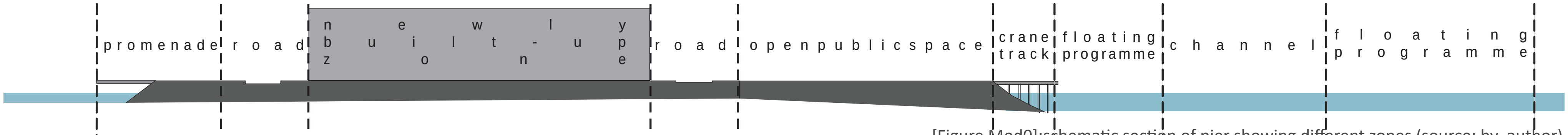
[Figure ccc]: diagram showing the possible reduction in storage footprint when using surface water directly in the intermediate seasons.However, the exact percentage wis still quite vague due do many variables (source: by author)



[Figure ccc]:calculated footprint projected onto the pier. The shape of the footpint will change in the actual placement; this is a schematic.

The cold wells have less public space to be placedm (source: by author)

Zoning of Pier 1

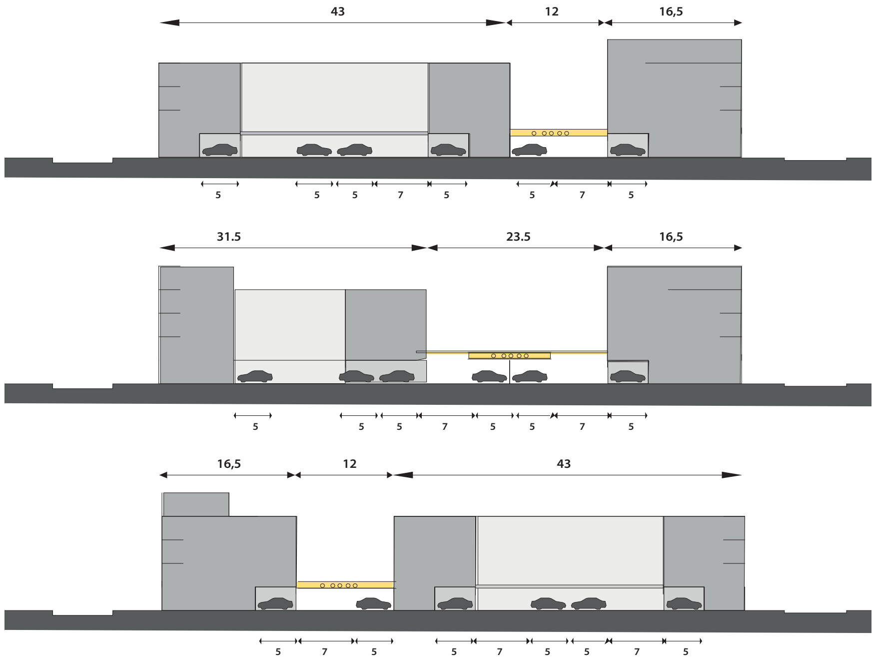


[Figure Mod0]:schematic section of pier showing different zones (source: by author)

The design of Pier 1 can be categorized in different zones as indicated in [Figure ZONE]. This shows that the northern waterfront is much wider that the southern. This makes is suitable for small scale programme to be placed together with the continuous routing of the promenade. It also guarantees more direct sunlight on the promenade. The promenade is separated from the sidewalk by landscape elements, such as a slight difference in elevation, street furniture, green patches and trees.

The central zone, where the newly built development will arise, consists of three to five layers of urban programme. In the plinth at ground level, mainly interactive programme is placed. The rest of ground level is – in fully transformed situation – used for parking and storage. The plinth at level 1 will be mostly private, making it a more intimate public space for inhabitants and people working in the surrounding.

The zone is divided into two built-up zones connected to the elevated public space in between. This division will differ along the pier to offer a variable building typology and also to prevent an 800 metre long straight line along the pier in between the buildings.



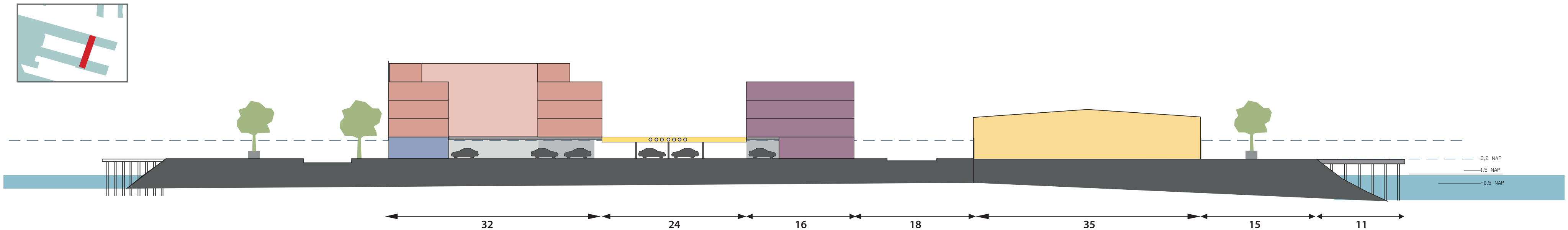
[Figure Mod1]:schematic sections of combining different placings of the elevated public space module and the left over space between the module and the road to be built up. More variations possible (source: by author)

For determining the spatial organisation of the zone the public space is determined to have a width of 12 or a double module of 24 metres. This module is places in the centre of the zone or on either side of the centre. This has its effects on the building typology on either side. It is also possible to place the buildings partly over the module or away from it. In this last case, an additional elevated public space is added to the module [Figure Mod1].

Beneath the surface of the elevated public space, the pipelines for the distribution of thermal energy are more easily accessible than put away underground. This is convenient for when adaptation have to be made to connect new or changing users of thermal energy to the system.

At ground level the parking is also determining the dimensions of the elevated level as the space underneath has to match with the dimensions needed for parking. This also explains the 12 meter: 5 meters for the parking space and 7 meters for the connecting road.

[Figure mod3]: cross section of pier showing the module implemented(source: by author)



[Figure mod4]: cross section of pier showing second option for implementing the module of elevated public space (source: by author)

visualization of segments 4.5

4.5.1 Focus shallow end of basin

Of the possible spatial solutions to make a shallow port basin [Figure VS1], the fill-up construction is chosen.

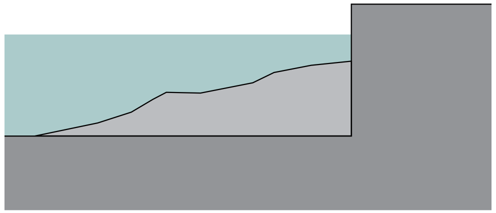
Th dam construction makes a hard edge and thus an immediate height difference, allowing relatively large vessels to enter the basin . The dam also makes a controllable construction, not susceptive to erosion. This is an important quality when estimates for warm water supply need to be quite accurate.

The dam has a height of NAP+1. This means that it will overflow during high tide, when the water level is assumed to vary between NAP+1,0 and NAP+1,5. During low tide the water levels are assumed to drop to around NAP-0,5. This is based on data from live.getij.nl (accessed april 2013).
In the shallow part behind the dam the bottom will be constructed one metre below the top of the dam. Calculations show that the water depth of one meter will not cause the water to become too warm. This might be inconvenient for the warm water yield, but it is favourable to the water quality.

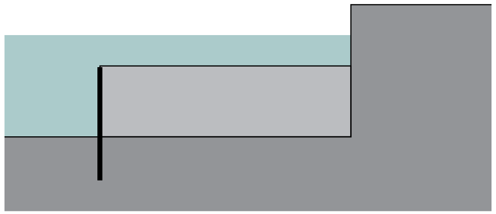
An exemplary calculation is made to illustrate the effects of a shallow basin from where heat is collected. It shows that a one metre deep basin of 100 by 100 metres can be heated 2,6 degrees Celsius during summertime [see appendix D], raising the water temperature to just over 25 degrees Celsius. Because this water should also be accessible for recreation, the water quality must be guaranteed. With the estimated temperatures, this requires oxygen and movement, created by the tide, fountains and water vegetation. This estimate is a maximum. Due to tidal influences the water level will differ and water will flow in and out, taking some captured energy away.[E+W]

The basin being influenced by tidal differences means the water level will change during the day. The water levels differ between +1.5m NAP (high tide) and -0.5m NAP (low tide). By creating a dam with a height of +1m NAP, even with low high tides, water will flow over this dam and refresh the water in the shallow basin.

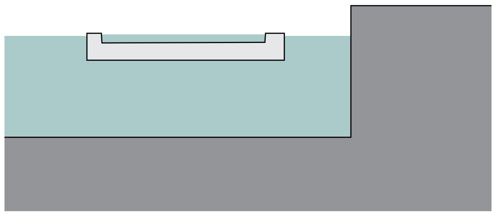
Programme
The space that is filled up, will be used as programme. It can partly be space for the heat exchange station, but predominantly to function as a parking space for the surrounding buildings. When a two-level parking garage is placed on the bottom of the port basin, a metre of water will be left on top to be heated. The entrance to the subterranean parking garage needs to be resilient to flooding. Two solutions can be implemented: entrance is located +6m NAP or the entrance below this level can be closed off with flood doors.
In the later phases the space could be transformed into a storage space for warm water, but these techniques are currently not perfected yet. On the other



fill up with gradual slope; soft transition, natural



fill up behind dam; hard transition, man-made



(floating) shallow basins

[Figure VS1]: visualization of possible spatial solutions for creating a shallow end of the basin in an urban environment (source: by author) hand, the pier will not have the parking capacity in the middle strip during the first phases. This can be placed in this underground space. Also, the parking space can be used to facilitate the high-dense urban programme along the Stieltjesdijk, just north of this area and the old town centre of Oud-Charlois, a couple of minutes walking form the planned underground parking. During the transition stage, large events, such as concerts, can also use the parking space. In the final phases, the public space on top of the parking space can also host events, such as festivals or markets. This requires parking space that cannot be found elsewhere on the pier.

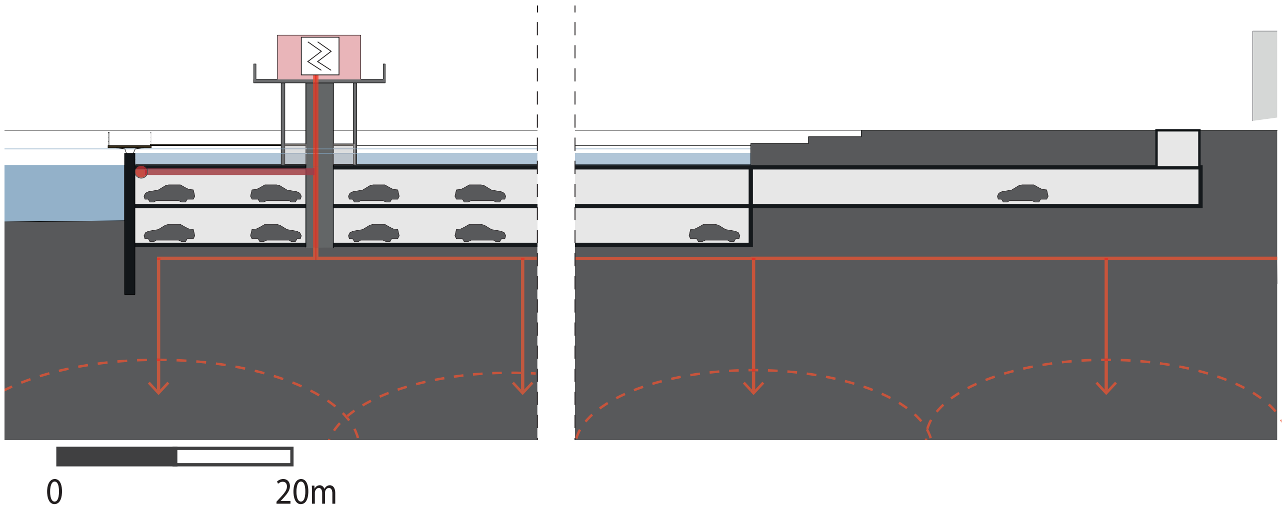
Accessible water

The water in this basin is shallow and therefore relatively safe to enter. Also, the shallow water allows water plants to flourish.

Because the quay construction is replaced by the parking garage, it is also possible to redesign the waterfront and lower the quay towards the water level.

To gain even more access to the water, a network of jetty's are constructed just above the water level of NAP+1. This means that during high tide, this network is not accessible. It raises the awareness of the fact that the area is subject to tidal movement.

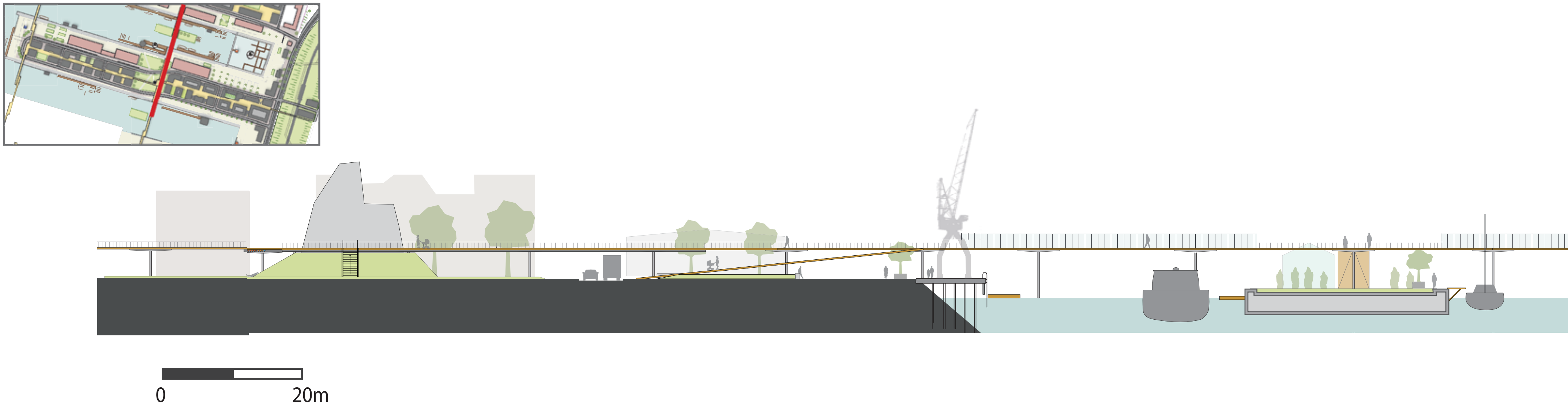
Elevated pipelines and exhausts form the parking garage make up a visible industrial network. This is essential for flood proof installations, but also gives character to a former industrial area. This is combined with the preserved port cranes and the materialisation of the pier. Much concrete and large dimensioned elements are combined with more urban related areas characterized by green, trees and more refined paving.

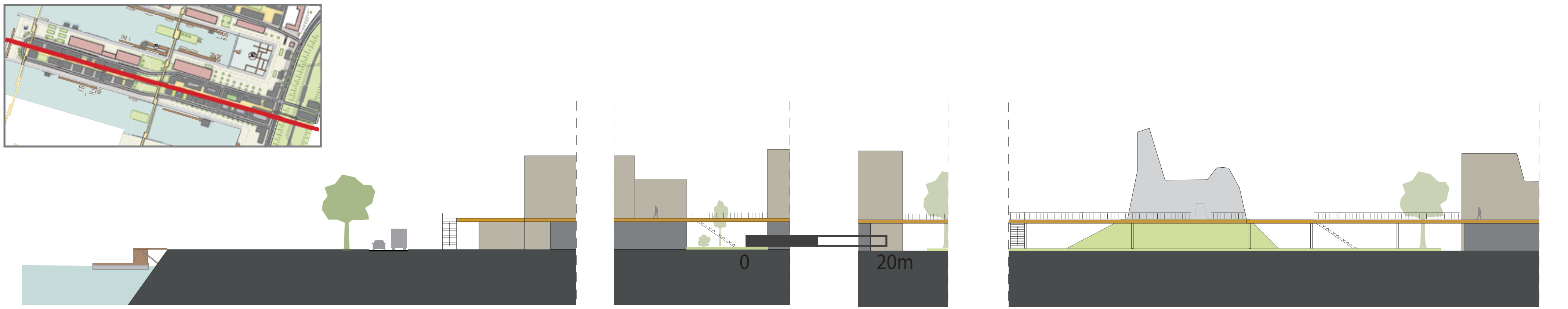


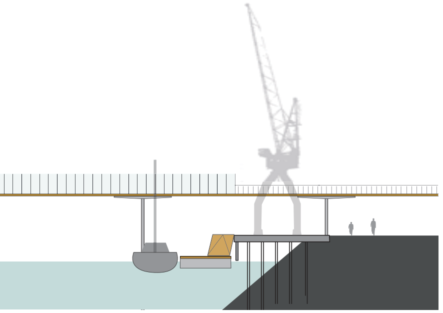
[Figure VS2]:west-east section of shallow basin with the double parking deck and wrm well distributor (source: by author)

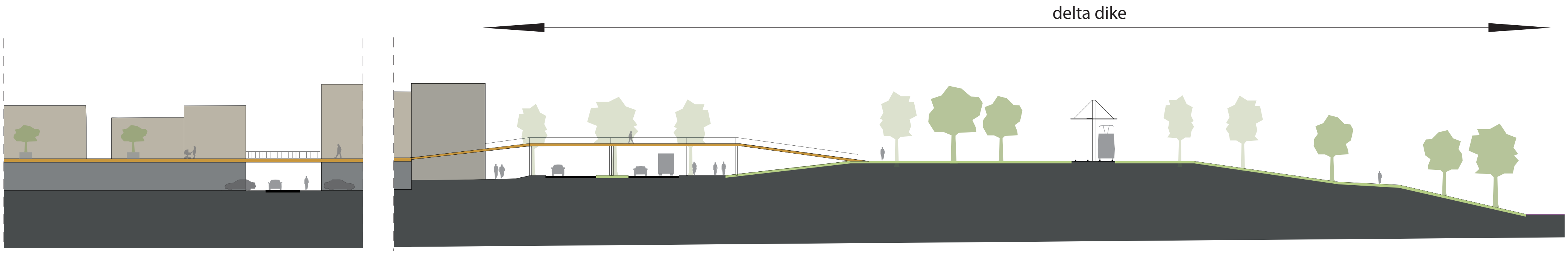
[Figure VS3]: bird's eye impression of shallow basin (source: by author)

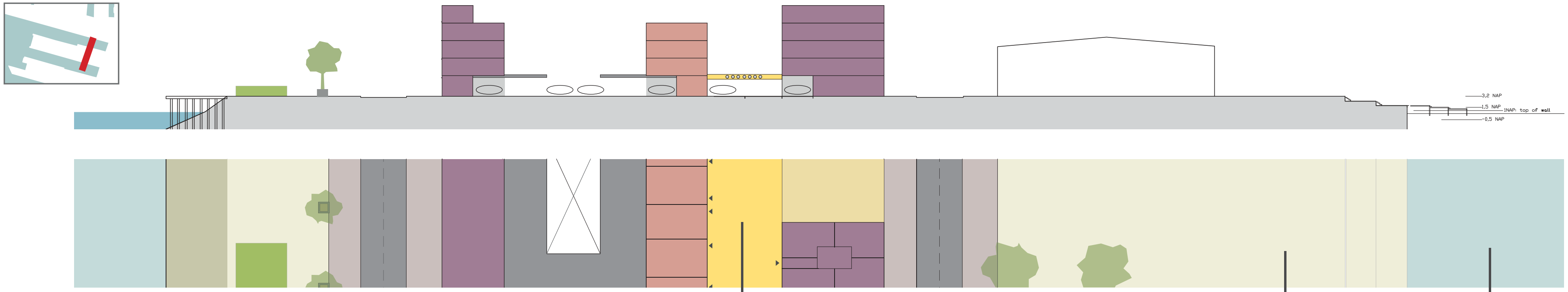
sections pier



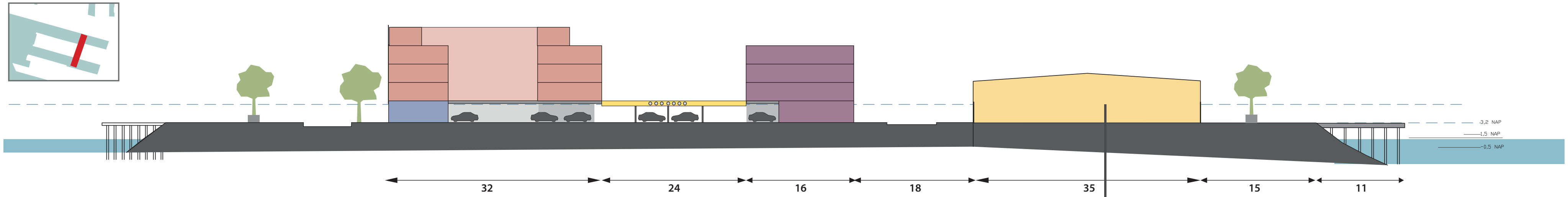




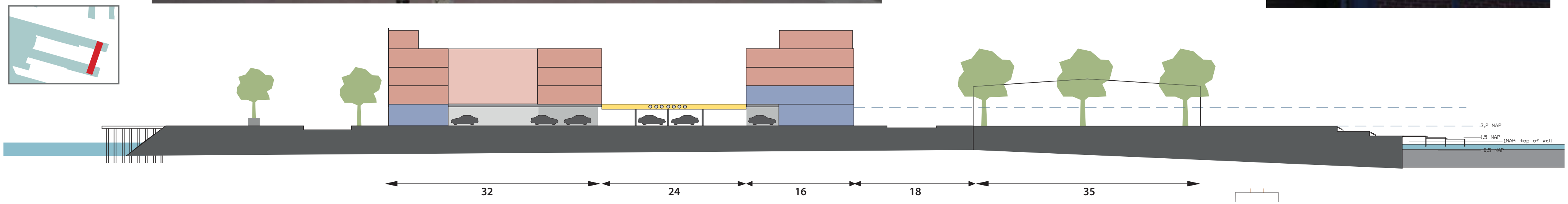

delta dike



[Figure]:Impression elevated public space (by author)

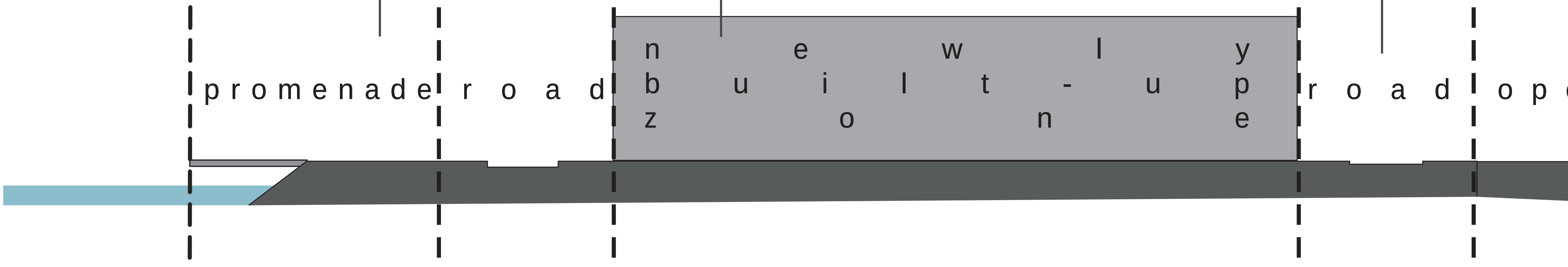


[Figure]:renovated waterfront in Rouen, FRA (image by author)



[Figure]:Quay in Hafencity, Hamburg (Hafencity.com)

[Figure]: Islands Brygge, Copenhagen (Google Streetview)

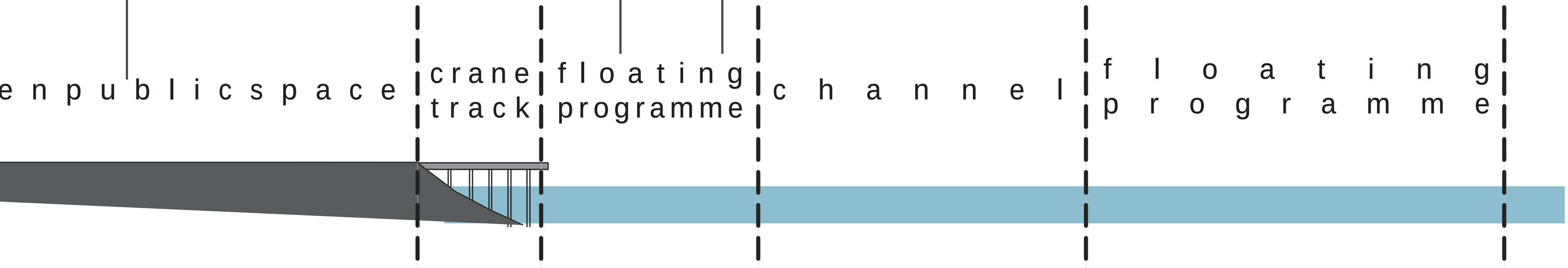


[Figure]: floating pool, Copenhagen (s.n.)

[Figure]:Kalvebod waves (KLAR & JDS Architects)

[Figure VS10]: irecreation at Islands Brugge, Copenhagen (source: Eva Fabricius)

[Figure]: Waterfront Toronto (west8)



5

thesis evaluation

5.1 Conclusion

The conclusions of the this graduation project are categorised by giving answer to the research questions posed in the beginning of this report. First the sub-research questions are answered, which leads to an overall conclusion to answer the main research question.

How to define sustainability in urban development?

This is the first step to take when asking the main question. Urban development can be sustainable in two ways:

- creating environmentally friendly solutions. This means to use sources for an urban area that have little - but preferrably no - impact on the environment
- creating long lasting solutions. This can work in two ways:
  - > creating adaptive programme that can overcome changes in the environment, such as natural elements
  - > combining disciplines to create solutions that are supported by multiple stakeholders, since it meets their demands

How can sustainability be used urban delta development?

The problem is stated that the urban delta faces threats that require to rethink the way we handle these issues today. This concerns the disciplines of water management and energy management, together with urban development.

The approach of forcasting,backtracking, backcasting helped in defining a sustainable path for sustainable development. After forecasting the threats, inspiration for the solution is derived from backtracking towards the time when the disciplines were still in a sustainable equilibrium. This can be found before the Industrial Revolution, when men did not have the equipment to overpower nature and had to co-exist with it. For the three disciplines the following can be concluded:

- energy management: use renewable locally gathered resources
- water manegement: give more space to the water; have some areas controlled by men, others by nature. Strive for more anticipative water management in urban delta development instead of an offensive attitude towards the water.
- port city development: port and city have grown apart, mainly due to increased levels of scale. Reintegrate them by forming a more mixed programme mosaic in a networked city.

Today, these mindsets need to be re-interpreted to fit the modern age to work towards a future in which we can face the threats. Integrating these disciplines should create even longer lasting results.

Where are the disciplines of energy management and water management best combined in spatial development?

To answer this, the combination between energy- and water management is sought after first. Spatial implementation requires to focus on energy systems within the energy management and the wide arrange of spatial implementations of flood resiliency and adaptive qualities as well as the governance that leads to these implementations.

Electricity systems have a large yield, but they do not fit in urban environments. They are also new systems that were not available in the sustainable equilibrium and can be seen as a major progress since then. On top of that are many of the new techniques not properly developed yet to be implemented in the near future without hesitation. However, there is a large potential in combining some of these systems with flood defense: tidal dams and energy islands could be implemented in a regional strategy.

The best combination lies in thermal energy from surface water. This is available today and has high potential in implementation into urban tissue (Deltares, 2008). On top of that, thermal energy suits local decentralized networks and bottom-up strategies. This has been established to be a healthy approach.

Then, research is done on what role aqua-thermal systems can play in the Rijnmond region, especially in the municipality of Rotterdam, since most thermal systems work decentralized. An important economic region is in search of solutions to increase the economic and environmental resiliency. New integral approaches are herby advertised. The REAP programme helped understanding the possibilities of implementing new thermal systems in existing programme in the municipality. An assessment shows the cascading machine to be the best match with the vision of creating local (energy) communities and the flexibility required for a transition area. Local systems can be combined with the existing district heat network that is already in place.

The thermal energy in this cascading machine can be used in full potential when the heat and cold from the surface water is stored and used in the season it is required. Therefore, the combination with ATES is made. Inspired by the Maastoren case, two systems were put together. However, since this is not a field of expertise of the graduate, extensive research was needed to get a grip on the topic. Reading many reports also led to contradictive data, which did not help with making

progress. By working with assumptions progress could be made. Nevertheless, an expert review still showed some improvements in the system. These can be recommended to be researched deeper by specialists to further improve the applied system.
The experimental thermal energy system can be also be justified by attitude of the municipal visions, that encourage new, creative solutions for the redevelopment of the city ports, that concern the surrounding water and support the economic growth of city and region.

How can this combination play a role in a regional vision for the Rijnmond region?

After forecasting the desired situation, now, via backcasting, design products will help showing how this sustainable result can be achieved. This is done by assessing the three disciplines on a regional level and finding overlap in the three to form an integrated vision. The idea to make a vibrant area in an outer dike area might be contradictive, but this is exactly the rethinking that creates new urban landscapes. The overlap between the disciplines can be found in the city network approach. Densifying urban clusters and better connections creates space for the water. This extra water can be used as a connector, but also as a source of energy or concentrated aquatic activities. The land expansion into the sea should be rethought; moving water into land is against our DNA, but is is a cheaper option to create adaptive power and economic yield.

The design products for the sustainable urban delta are affecting many levels of scale. This, in combination with the three disciplines and an integrated product, calls for a organising framework. By meandering through the product assessment matrix from scale to scale, a structure and a storyline was created. This matrix helped organising the many ideas that were generated in all the disciplines. The meandering storyline came as an improvement on the horizontal and vertical storyline, which were basically two stories.
So, after the regional role the intrgrated systems can play, the focus shifts to the municipal implementation strategy.

What is the potential of implementing this combination in a strategy for the city ports of Rotterdam?

The city port structure in the region is very suitable for the integration of the three disciplines spatially.

<u>Pier-and-basin structure</u>

The pier-and-basin structure forms an interwoven pattern of water and land in the city ports; this long edge makes many connections and interactions with water possible (technical as well as social). The river with all these man-made branches forms a blue connection that runs through the heart of the city, which makes it attractive to be connected to. The pier-and-basin structure makes large water access possible.
The spatial structure makes a division into small communities possible by spatial separation. On this segregated area, a linear organization creates a clear routing and allows a systematic approach to spatial design and implementation of energy systems.
The linearness also shows in the gradients this structure helps forcing in a certain direction. Gradients are can be seen in the port entirely - but also per pier – in each discipline. This helps to create a smooth transition from one landscape to the other, although it looks very binary.

<u>Outerdike area</u>

This area can remain outer dike area in an open system, making the water more accessible. These areas need spatial solutions to increase flood adaptation. The requirement of adaptive building in this area poses no problem, because the existing buildings do not match with urban programme. Therefore much of it needs to be replaced.
The area remains accessible by relatively large vessels, creating options for water transportation and distributing temporary floating programme. This can be used during the transition phases, but also offers the possibility for change after completion, whereas the programme on land is more permanent.

<u>Vicinity of accessible water with thermal quality</u>

The vicinity of water helps reducing the footprint of the ATES considerably because it can be included in the nearby system and helps meeting the thermal demands of new urban development in an environmentally friendly, decentralized system.
Also, the aesthetic power of surface water is significant. Living near the water is considered a quality, which makes it an attractive area to live and work, or recreate.

How can integrated strategies be translated spatially into an urban design?
First, create a range of principal spatial solutions for a certain strategic goal. Then assess the options to fit the location. The product assessment matrix helps here to organise the possibilities in each discipline and shows how they can be combined into an integrated result. Form each discipline multiple spatial solutions are generated to be implemented in the project. The first step was to make a masterplan for the Waalhaven. This masterplan helps the transformation of the goals towards spatial implementation onto the urban design of Pier1. Here, many of the choices for the spatial implementation are based on local preferences and urban patterns. This mainly helped in understanding how the pier should be connected to its surrounding and how it forms a gradual transition between urban and industrial. When the focus came to gradients, many more were found in different disciplines. Surprisingly, most of them matched wonderfully well.

The elevated backbone forms the umbilical cord for a gradual transition of city ports. As a flood proof solution that distributes thermal energy it forms the main spatial arrangement of a pier. Along this multidisciplinary construction - combined with a flexible thermal energy system – the industrial area can be transformed gradually into urban area with mixed programme. Modern urban planning shows more and more small scale development and private initiatives. With this spatial system the preconditions are met by the municipality but the building projects can be initiated by private parties – as long as they build according to the spatial preconditions.
It is recommended that for city port transformation the municipality defines in a zoning plan the areas were building is allowed and what should remain open. Accordingly, the routing should be detremined to establish the safe zone and the 'people-and-pipe'- distribution. This helps determining the spots for ATES, preferrably in between the collector and the distributor.
By planning along an elevated backbone and building all vital elements at a save height, the ground level can more easily be changed. This matches with the elastic character of the Waalhaven. Also, it helps creating more urban dimensions in a formal insutrial area:
- enclosed space in built-up area with high FSI
- it contrasts with the vast openess of the waterfronts.

The unfamiliar field of expertise and complicated calculations made it difficult to determine a the specifications of the programme. Calculations on the maximum programme possible to be supplied by this thermal system proved difficult, because there are besides many ways to calculate, also many variables, such as soil conditions, use of the building and the demand reducing measures. The leading role is therefore urban development; it should match with the density and building heights in the environment and the characteristics of an urban environment. This spatial design is subsequently tested on technical-spatial feasibility. The mixed programme planned on Pier 1 can be thermally supplied by the cascading machine in combination with ATES.

However, the expert review (Wisse, 2013) did reveal some more points of attention that are recommended to research in future, by or with more skilled parties with technical background.
- The cascading machine does imply that the different temperatures are interdependent; one uses the entropy from another. If this entropy disappears, others will feel the effect. This can be compensated with extra heat from the surace water, so this can be solved. However, it is perhaps not the simplest option.
- The distance between the storage wells and the cascading machine is relatively large. This could perhaps result in no immediate supply of heat and cold when it is needed. Although a central distribution system is most likely to have a continuous demand, it could still pose a problem. A solution is to move the wells closer to the cascading machine. This means finding new locations to do so. The most appealing option is to make the wells underneath the backbone; this is constructed first, already has a column structure and accessibilty to installations on a flood proof height. The current design, with a favourable open space ratio (OSR=0.95) has plenty of opportunity to find more convenient locations.
- In the intermediate seasons one can use the benefits of the surface water. However, it is relatively complicated to use this water directly. It is better to use the medium temperatures for heating and the cold source for cooling. The wells can be recharged by using the surface water. Also, it can help counter the unbalance between the cold and warm ATES's.
- This connection to the surface water as an external input for the heat/cold balance helps adapting to change in thermal demands due to changing programme.

The answers to these subquestions can be summarized in answering the main research question:

How to spatially integrate flood adaptation and renewable energy systems with urban development to design a sustainable urban delta?

By backtracking to the more balanced conditions environmentally friendly and long lasting approaches can be used on modern planning.
By finding the optimal combination between the disciplines of water and energy management that is spatially implementable in a port city, backcasting shows what systems can be implemented to reach the sustainable goal. It is at the same time a type of forecasting in the sense that the results of the spatio-technical inventory need to be implemented in a design.
Then, backcasting by creating design products helps creating the sustainable spatial design solutions for the specific location. This process is guided by the product assessment matrix, which meanders through the products per scale, taking conclusions from one level of scale to the next, working towards the most spatially related scale: the pier.
The pier-and-basin structure of the city ports turns out to be an ideal area to execute an integrated approach for redevelopment as all three disciplines need to be rethought in these areas. The linear structure helps in forcing the three disciplines in the same direction but then these disciplines integrate very well. This is best shown in the implementation of the linear elevated public space. This element forms the backbone of the redevelopment of the port area as it safely distributes 'people and pipes' across the pier in case of flooding. It also creates a more urban environment with urban dimensions in an area where industrial dimensions dominate.
It facilitates local networks that work multidisciplinary, creating awareness for the forces and benefits of nature, facilitating local communities and bottom-up initiatives, making the Waalhaven fit for the coming century.

5.2 mandatory reflection

**mandatory reflection as a sepe-
rate part of the thesis report**

C.T. Lysen
1169238

Re-thinking the Power of Water

integrating sustainable water management and renewable energy systems in a surface water oriented strategy to design future living quality in the Rhine-Meuse delta

Short mandatory reflection on project

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Environmental technology & Design

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Urban Design, Theory and Methods

Committee member: Ir. F.W.A. Koopman

Department of Urbanism
Faculty of Architecture
Delft Untiversity of Technology

Delft, September 26th, 2013

As a mandatory part of the graduation programme a reflection is included in the thesis report. This reflection will elaborate on how the expected approach of the project turned out in practice and why this has occurred accordingly (or not) to the initial plan.

The products that were expected in January, are still the products that are and will be realized at the final presentation. There will be additional products though. The expected end products were expected to be on a regional and on a local scale, but products on intermediate scales have been added.

This was due to the change in the process. When the step needed to be taken from the regional scale to the local scale, the gap appeared to be quite large. To research that was done revealed that the effects and the systems involved in the decision making process were operating on different levels of scale. These were vital to make the step from regional to local scale. This led to a study on five scale levels.
Also, the structure needed to be made more clearly, striving to make the project with so many parameters more understandable. By connecting each level of scale to the discipline of energy management, water management and urban development, the layer-method was made more prominent in this project. This resulted in a more clarifying matrix of design solutions ending up in the final vision, strategy, master plan and urban design.
Because the project is now integrating several levels of scale, the clear distinction between large scale project and key intervention has faded.

Numerical research versus spatial design

The quantification of the results are not very extensive. This has two reasons:
Firstly, this is a graduation project for an urban planning and design studio. There should be more emphasis on the spatial elaboration than the quantitative data of technical solutions.
Secondly, the data that was found during the research was sometimes confusing. Reports showed different values for heat demand and were often also expressed in different units. This required a conversion of the found data before being able to see the connections. This meant that this part of the process has taken more time than was planned beforehand.

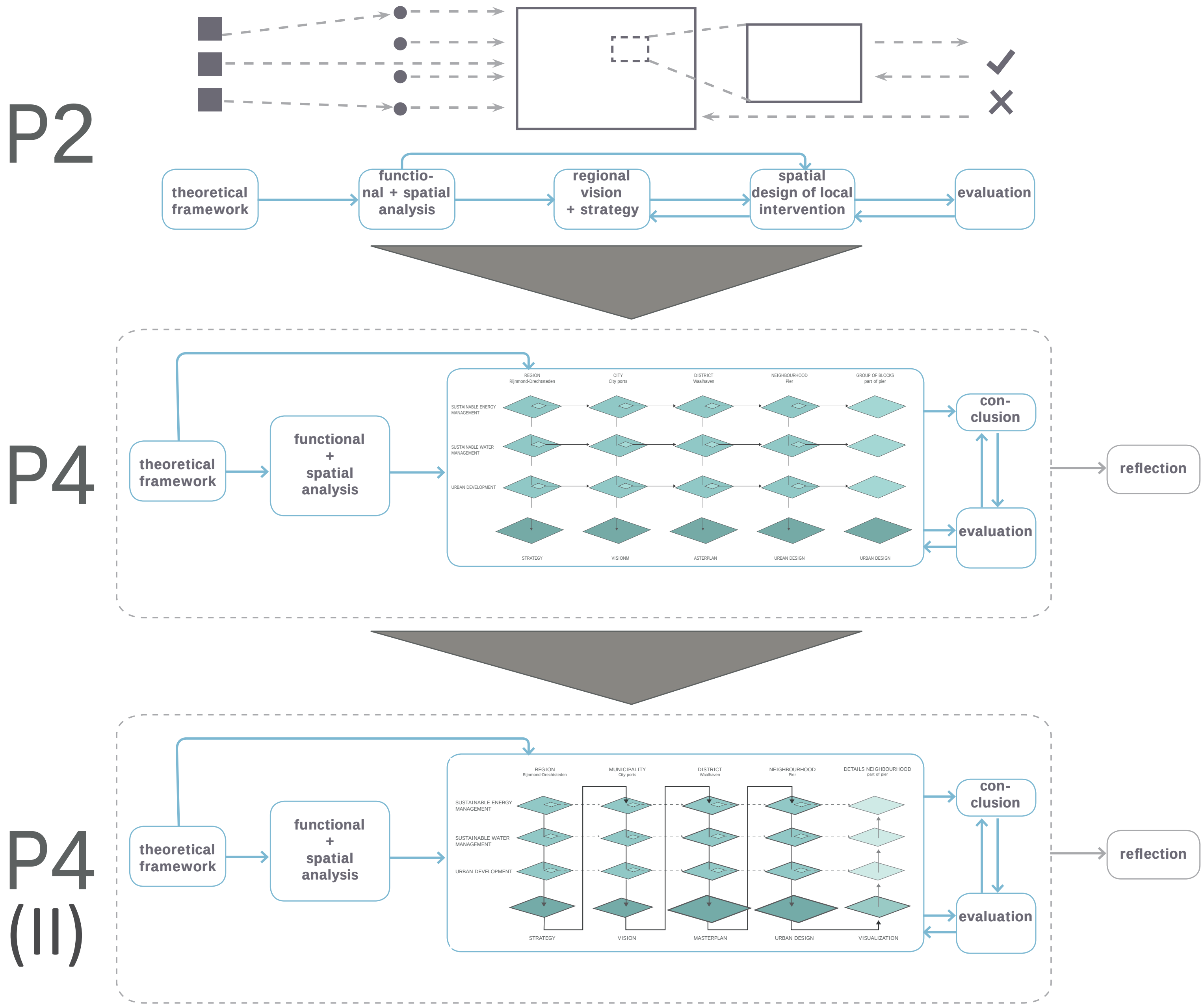
Because there seemed to be enough time to do some more research and calculations on the quantitative research, too much time was taken to find the right data. This was one of the reasons there was a time shortage in the run-up towards the P4. In hindsight, it would have been better to start earlier with making assumptions for the calculations and work with those. Then, progress is made more quickly. Also, if more accurate date would have been discovered, it would be relatively easy to adjust the calculations. Disadvantage of this approach is that if the calculations have much effect on the spatial design, a late change in the calculations could result in redesigning large components of the project. This is also an argument for the long period of time spent on collecting the right data.

Working according to the P2-planning

The planning that was made at the P2 has been realized quite well. Although there was a change in the process and including more levels of scale, the work was accordingly to the planning. This is because the planning shows a large amount of time to do the local analysis and design. It also has overlap with the regional research and design. This led to a rearrangement of the planning, but hardly any extra time.
However, in finalizing the products, the planning is too optimistic. Most products take more time than anticipated. For the remaining products more time will be planned to realize the planned results. Shorter set deadlines should be respected more thoroughly. This is one of the reasons why the first P4 moment was not successful; due to lack of time the products were too poor to concince the committee.

The relationship between research and design

The functional analysis has been taking more time than anticipated. This meant less time to research by designing. In the end this has been the right approach, because the outcomes of the analyses were important for determining the preconditions for the design, this would be the most efficient way to divide the project in research and design. When the design process started, there was still additional research to be done guided



[Figure R1]: overview of changed perception during between P2 and P4. Subsequently, the result matrix shows some slight adjustments at P4-II. (source: by author) by the developments in making the vision, strategy and designs – better known as 'research by design'. In this additional research the expected case studies were not all used, e.g. Melbourne and Copenhagen. Instead, projects in Goteborg and Antwerp were inspirational precedents. In the extra time towards the second try, Copenhagen did become useful as reference though.

The relationship between the theme of the studio and the subject chosen

The studio Delta Interventions has a relatively distinct theme already. When entering this studio it was already clear the subject for the graduation project would concern water issues and is quite certainly located in a delta.
This still leaves a vast range of possibilities to choose a topic and add your personal affiliation to the topic.

The location chosen for this project matches the subject very nicely. The Dutch are famous for their leading role in water management. It is a nation with water in their DNA. Therefore, concepts on rethinking water management would find cooperation here.
Since there is also a personal affiliation with sustainability, this had to be part of the project. Rotterdam is one of the leading cities in the world when it comes to programmes and policies on creating a more sustainable urban environment. There are many plans to reduce CO2-emissions and find smart solutions for waste and energy problems. This was therefore an inviting region to try exploring the combination of water management and energy management in an urban environment. Since the municipality expresses the need for creative solutions and new ideas for the redevelopment of their city and meeting their sustainability targets, an integrated approach to rethink some existing patterns or stigmas, should be interesting.
This also shows the amount of graduation projects at the TU Delft that are situated in the Rotterdam region. Another reason is of course that it is located near the university, which makes it easy to visit project sites and find documents and actors involved in the chosen topic.

The relationship between the methodical line of approach of the studio and the method chosen

The layer method was promoted in the beginning of this year by the studio mentors. This is being considered as a valuable approach to analyse an area. In the first half of this graduation year, this method had disappeared slightly to the background, but was rediscovered when trying to organize the results of the research of the three disciplines on five different scales.
This research works with the disciplines of water management, urban development and energy management. These first two disciplines are very common for the studio. The third discipline is not very common within the field of the studio, but it is also part of the problem statement. This discipline required the most research as it was the most unknown. Spending much time during the project on the discipline of energy management is perhaps not according to the studio standards. However, most research was done on water and energy combined. Also in the end, it has been worth spending this time to create the final result, in which the three disciplines are integrated. The layer method also helped in organising the results and telling the story. The result metrix that was developed also served as a visual tool to define how the story works through the matrix. This study shows in the changed storyline through the matrix at P4-II as seen in [figure R1].

The relationship between the project and the wider social context

More and more people in the world will be living urban deltas. This habitat needs to be safe and serviced to prevent social unrest or catastrophe.
By creating smaller energy distribution systems, a district or neighbourhood can be given an extra form of identity. It also fits in a modern trend that is taking its distance from the top down institutions that rule most parts of our lives. It could give a great feeling of satisfaction to manage an autonomous energy network with a neighbourhood. It is a great way to create more unity each energy cluster. By bringing this energy system back to a small scale, it becomes more comprehensible for the users. They can therefore be more in control of the systems and are a better in finding local solutions. This new system requires people to work together with their neighbours and creates more awareness of the systems that are active in the urban environment.

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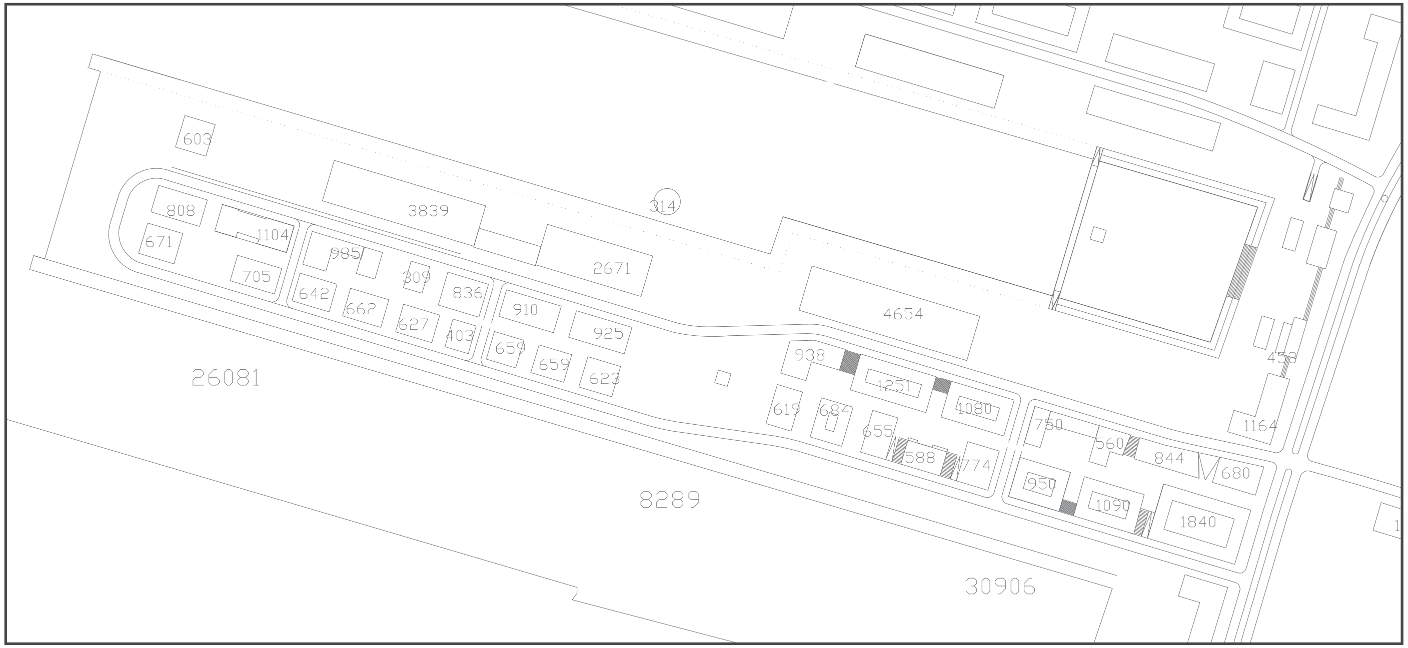
appendices

A possible combinations energy & water

Optie	Principe
Thermisch	
Warmte uit zeewater	Onttrekking warmte aan zeewater
Seawater Air Conditioning	Onttrekking koude aan zeewater
Drijvende woningen	Onttrekking warmte aan binnenwater
Airco op waterdamp	Koelen en ventileren door verdampen water
Solar Pond	Onttrekking warmte aan sterk verhit water
Koelvijvers	Onttrekking koude aan diepe vijvers
Warmte uit rivieren	Onttrekking warmte aan rivierwater
Mijnwater Energiecentrale	Onttrekking warmte aan mijnwater/aardwarmte
IJsbanken	Opslag van koude-energie in ijsmassa's
Kinetisch	
Waterkrachtlens	Concentreren kinetische energie in rivierwater
Bundeling van watergolven	Concentreren kinetische energie in zeewater
Drinkwater productie en transport	Onttrekken kinetische energie uit water(druk)
Energie uit regen	Onttrekken kinetische energie uit regenwater
Pompturbines in de polder	Onttrekken kinetische energie uit polderwater
Elektrochemisch	
Brandstofcel - B, Zn, Mg, Al e.a.	Waterstofproductie met boor en directe benutting
Brandstofcel - Water en Lucht	Waterstofproductie met metaalhydriden
Biologische brandstofcel	Directe elektr. productie uit organische materialen
Biogekatalyseerde electrolyse	Waterstofproductie met en uit afvalwater
Microkanaaltjes in glasschijven	Opwekken en aftappen van statische elektriciteit
Dialyse met hoogfrequente golven	Waterstofproductie met hoogfrequente golven
Potentieel	
Valmeer in de Noordzee	Buffering energie in een watermassa (meer)
Haakse Zeedijk	Buffering energie in een watermassa (meer)
Witte Steenkool	Buffering energie in een watermassa (mijn)
Overig	
Opvang regenwater	Indirect energie-effect door besparingen
Liesgras	Onttrekking elektriciteit aan syntheseproces plant

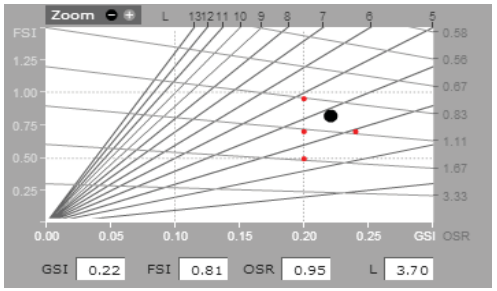
source: CE Delft (2009) Energie uit water - een zee van mogelijkheden

Surface and density calculations



Density calculations:

Total surface area: 185 000 m2
Total footprint: 40 857 m2
Total Gros Floor Space (GFS): 151 381 m2
This results in: **FSI = 0.81**



However, this includes a vast area of open waterfront. This does count in the calculations, but if we differentiate the two built up strips on either side of the cascading machine we see other figures:
- east side: Area=30906m2, footprint=13303m2, GFS=62191m2 => FSI = 2.0
- west side: Area=26081m2, footprint=11528m2, GFS=52767m2 => FSI = 2.0

	m2	building layers	Gros Floor Space (m2)
footprint buildings new (east of cascading machine)	680	6	4080
	1840	5,5	10120
	1090	4,5	4905
	844	5	4220
	560	4	2240
	950	5	4750
	750	4,5	3375
	774	4	3096
	1080	4	4320
	1251	4	5004
	588	5	2940
	655	4	2620
	684	4	2736
	619	5	3095
	938	5	4690
	1164	4	4656
	436	2	872
	800	6	4800
	1245	7	8715
SUBTOTAL	**16948 m2**		**81234 m2**
footprint buildings new (west of cascading machine)	925	5	4625
	910	4	3640
	623	5	3115
	659	4	2636
	659	4	2636
	403	5	2015
	627	4	2508
	662	5	3310
	642	4	2568
	985	5	4925
	309	5	1545
	836	5	4180
	1104	5	5520
	808	5	4040
	671	4	2684
	705	4	2820
	603	2,5	1508
	314	1	314
SUBTOTAL	**12445 m2**		**54589 m2**
footprint buildings preserved	4654	1,6	7446
	2671	1,2	3205
	3839	1,2	4607
	300	1	300
SUBTOTAL	**11464 m2**		**15558 m2**
TOTAL:	**40857**	**TOTAL:**	**151381 m2**

thermal energy calculations

SPECIFICATION OF GROS FLOOR SURFACE	
mix-use/ service	40%
Dwellings	25%
Shops	15%
Industrious	19%
Supermarket	1%

HEAT DEMAND:	% of program	total GFS (m2)	GFS (m2) per type	kWh/m2/yr	kWh/yr
mix-use/ service	0,40	151381	**60552**	200	12110472
Dwellings	0,25	151381	**37845**	50	1892261
Shops	0,15	151381	**22707**	300	6812141
business	0,19	151381	**28762**	200	5752474
Supermarket	0,01	151381	**1514**	300	454143 +

TOTAL: 27021491 kWh/yr
27,0 GWh/yr

Dimensions of storage wells

Heat storage:
Q(t)[kWh] = 1.16 * Vgem * dTgem (Calje, 2010)
27021491 = 1.16 * Vgem * 5
Vgem = 5308990 m3/yr

dTgem(°C) is determined as follows:
[water temp. in basin/storage] – [desired temp.] = 25°C – 20°C = 5°C
The predicted basin temperature during the summer is calculated to be able to reach 25°C (see insert block to the right).

The thermal radius of a well is calculated as follows:
sq.root (V/(2.2*H[aquif])) (Calje, 2010)
Based on calculations from Maastoren casestudy (De Ingenieur, 2007): H[aquif] = 80,6 m
Sq.root (5308990/177.32) = 173
This means a thermal radius of 173 m and a total surface of 94024 m2. This is over half the pier's surface. With a similar size needed for the return water, this will be difficult to fit at the project location.
However, by analyzing the data from the Maastoren casestudy, a significant reduction is possible. When using surface water directly during the intermediate seasons, the Maastoren alledgedly has a Vgem which is only 25% of the volume needed when only stored heat in aquifers was used:

94024 * 0.25 = 23506 m2
These wells do not connect seamlessly to each other. Therefore a square around the circle is calculated as a measurement to represent a more applied situation.
Wells: r = 173; diameter of square surface = 346m;
Surface of this square = 119716 m2
Reduced surface: 119716 * 0.25 = 29929 m2
This means with the return well the surface doubles: 59858 m2, or 244 x 244 m

Calculations water temperature heated by sun

Sunrays deliver 1 kWh/m2 with a full sun (SolSolutions) .
In the summertime this is during 5 hours a day, In wintertime during 0.5 hours a day, making a yearly average of 2.7 hours a day of full sun.
The assumption is made that through the angle of the light, reflection, absorption and evaporation 0.6 kWh/m2 transfers into the water.
Per day: 5 * 0.6 *3600 = 10800 kJ/m2/day
Basin: 100 x 100 = 10 000 m2 -> 108 GJ/day

One degree Celsius change in temperature of water equals 4.2 kJ/litre.
10*10^6 litre has 10.8 kJ/litre energy, making the temperature difference: 10.8 / 4.2 = 2.6°C

(source: SolSolutions (s.d.),[URL] http://www.solsolutions.nl/zonnestroom/opbrengst-zonnestroom/, accessed May 2nd, 2013)

Reviewing this result led to a new calculation. Hereby the heat demand (kWh/m2/yr) was redetermined to more up-to-date values, that match the conditions towards 2050 (Wisse, 2013; Lysen, 2013.
Also the division of Gros Floor Surface (GFS) was adapted to new conditions of the design.
This leads to the following heat and cold demand :

SPECIFICATION OF GROS FLOOR SURFACE	
mix-use/ service	30%
Dwellings	35%
Shops	15%
Industrious	19%
Supermarket	1%

HEAT DEMAND:	% of program	total GFS	GFS (m2) per type	kWh/m2/yr	kWh/yr
mix-use/ service	0,30	151381	**45414**	100	4541427
Dwellings	0,35	151381	**52983**	50	2649166
Shops	0,15	151381	**22707**	300	6812141
business	0,19	151381	**28762**	200	5752474
Supermarket	0,01	151381	**1514**	300	454143 +

TOTAL: 20209350 kWh/yr
20,2 GWh/yr

COLD DEMAND:	% of program	total GFS	GFS (m2) per type	kWh/m2/yr	kWh/yr
mix-use/ service	0,30	151381	**45414**	50	2270714
Dwellings	0,35	151381	**52983**	0	0
Shops	0,15	151381	**22707**	40	908285
business	0,19	151381	**28762**	300	8628711
Supermarket	0,01	151381	**1514**	1400	2119333 +

TOTAL: 13927043 kWh/yr
13,9 GWh/yr

UNBALANCE; compensate with heat or cold directly from surface water

Dimensions of storage wells

Q(t)[kWh] = 1.16 * Vgem * dTgem (Calje, 2010)
20209350 = 1.16 * Vgem * 5
Vgem = 3484370 m3/yr

The thermal radius of warm well:
sq.root (V/(2.2*80.6) (Calje, 2010)
Sq.root (3484370/177.32) = 140.2 m radius
This means a thermal radius of 140 m and a total surface of 61575 m2 (or square of 280x280m).

With a potential 'Maastoren reduction' of 75%, it could be:
0.25*(280m diameter)^2 = 19600 m2, which means a footprint of 140 x 140 m
With return well this is 197 x 197 m.

However, a reduction of 40% is more likely (based on: Molenaar, 2011; Wisse, 2013). This means a square footprint of: 0.4*(280m)^2 = 31360 m2, or 177 x 177 m (354x177m with return)

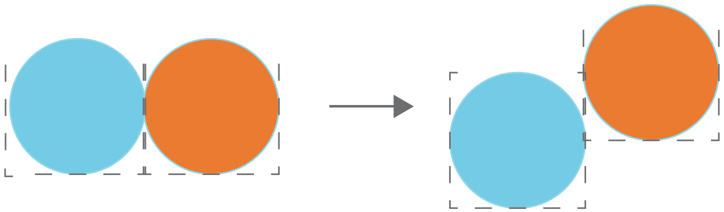
Dimensions of storage wells

Q(t)[kWh] = 1.16 * Vgem * dTgem (Calje, 2010)
13927043 = 1.16 * Vgem * 7.5 [dT=7.5 is based on Maastoren efficiency calculations by Molenaar (2011)]
Vgem = 1600809 m3/yr

The thermal radius of cold well:
sq.root (V/(2.2*80.6) (Calje, 2010)
Sq.root (1600809/177.32) = 95 m
This means a thermal radius of 95 m and a total surface of 36106 m2.
With a potential 'Maastoren reduction' of 75%, it could be:
0.25*(190m diameter)^2 = 9025 m2, with return well this is means a footprint of 134 x 134 m.

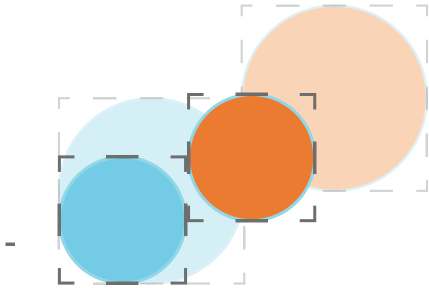
With a reduction of 40%, this results in a square footprint of:
0.4*(190m)^2 = 14440 m2, or 120 x 120 m (240 x 120m with return)

case of Maastoren (source: De Ingenieur, 2007)



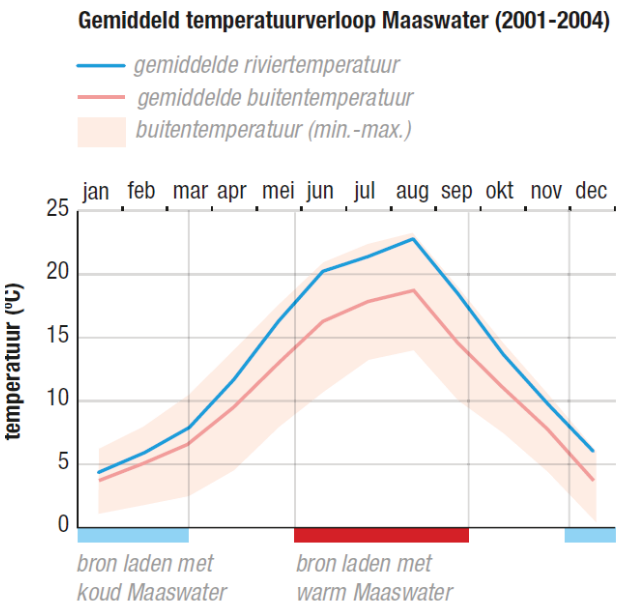
diameter per well would normally be 140 m.
probably used surface larger; square

offset wells to prevent contact between cir cular wells



much smaller surface needed

surf ace water in intermediate seasons:
diameter per well is 70 m

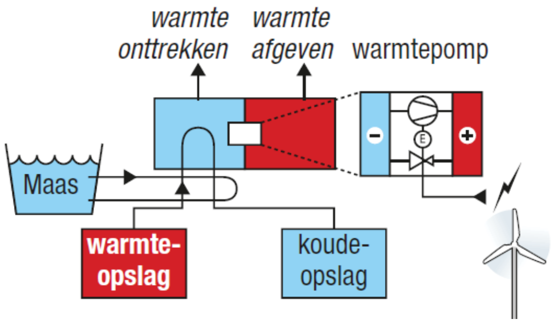


Figure]: reduced footprint by direct cooling from surface water. (by author & s.n., 2007)

space office & facilities: 40 000 m2

diameter well = 140 m -> 19600 m2 (square surface)
-> 39200 m2 per doublet
FSI(max): 40000 / 39200 ~ 1

diameter well = 70 m -> 4900 m2 (square surface)



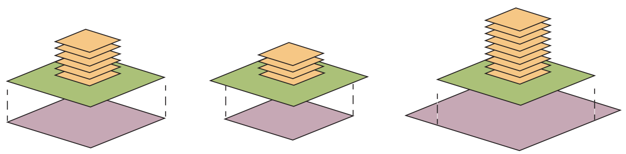


Figure: diagrams of building energy footprint (green) exceeding the limits of the underground storage footprint(purple). This will cause interference with other wells if they are placed too close to each other. (source: by author)

extensive theoretical exploration

The theory that is used to help finding an answer to the research questions of the graduation project is organised as follows in this thesis plan report:
Firstly, a historic development of both water management and energy use are presented with a view on future developments expected to evolve from the different historical eras.
Then, a selection of applicable sustainable energy systems and water management systems is presented.

Different eras in energy use
The different stages of used energy sources over time can be best categorized according to the different stages in energy landscapes, described by Pasqualetti (2012)pp.14-40).

I - energy of the organic economy.
First, thousands of years BC, man only had the power of its own muscles and that of its animals. The energy needed to fuel this, came from food. Fire, fuelled by wood, was used for heating.
Later wind and water power were used for small scale industry and transportation, for example by means of windmills, sailing boats and water wheels.
In the Dutch delta harvested peat was mostly used as energy source to generate heat.

II – energy of the mineral economy
Already in the 13th century coal was used to fuel fires, but its true success started in the eighteenth century at the dawn of the Industrial Revolution. It was the main source to fuel steam engines.
Mid nineteenth century, when industrial equipment was developed to drill deep into the ground, oil and natural gas mining emerged worldwide. When techniques improved during the twentieth century, the unconventional fossil fuels became accessible, such as oil from oil sands and shale gas. Fossil fuels facilitated a giant leap on a technological level. With the access to so much energy, man could conquer many forces of nature by creating machines to assist in building, transporting and living. Also, centralized distribution systems started to appear.

III – energy of the electric economy
At the end of the nineteenth century electricity was generated, powered by fossil fuels. With generating electricity it became possible to transport energy over large distances, creating a large hub-and-spoke system to distribute energy.
Mid twentieth century nuclear power became a clean substitute for the polluting burning of fossil fuel to generate energy. This form of generating energy had its disadvantage; it produces lethal radioactive waste.

IV – energy of the sustainable economy
In the 1970's the first awareness of our energy consumption and to our 'limits to growth' (Meadows et al., 1972,). This results in the use of sustainable sources. This age can be regarded similar to the first age, based on the use of the same resources. However, with advanced technology the resources can be harvested more efficient. Sources such as hydropower, wind energy and biomass are used to create electricity that powers our instruments.
On top of that, geothermal power is extracted from deep in the earth and photovoltaic panels as well as solar boilers use modern techniques to covert the power of the sun into usable energy.

Today, we still use all of the resources mentioned in the stages above. Today, we are still in the stage of a sustainable economy. Fossil fuels, currently the most used energy source, is depleting and therefore we are only at the beginning of this fourth age. Or one could say a circular process is completed and we have returned to our organic stage. This is a clear example of backtracking energy use.

Different eras in water management
Water management has always been closely related to urbanization. Meyer (2009) states: 'T*hroughout history, in a watery region such as the Dutch lowlands the question of water management and flood defence has been related to the question of the relation between the urban and the rural communities*'(p.433).

Hooimeijer (2011) also focuses on the Dutch delta. Her extensive overview gives a clear guideline to approach the Dutch water management history. It is divided into the following eras (using Hooimeijer's terminology):

I - before the year 1500: Natural power
The country exists of many marshlands in which people adapt to nature. Only small initiatives are taken to control drainage.

II - 1500 – 1800: Power of unity
Technological instruments such as windmills, dams, dikes and sluices make canal systems, poldering and world trade possible. On top of that, a centrally organized approach makes the Dutch get more control on the water.
Added to this, Meyer (2009) states that in this era conflicts between urban and rural areas emerged on con-

trolling the dam. This would also control the inundation of the polders behind the dam. To clean the urban water system, cities that formed around this dam, had to build a buffer to flush out all the waste water. This buffering would also affect the water levels of the hinterland, which the farmers did not like. Governance became more important and this era marked the birth of the civil engineer, a cross between '*what today we call hydraulic engineering and urban design*.' (Meyer, 2009, p.435)

III - 1800 – 1890: New power

This era is marked by the Industrial Revolution, giving new power to man to control the water. Steam powered pumps made poldering on a large scale possible. This created new farmland and building grounds, which caused rapid urban growth. But pumping out even more water also increased the land subsidence.
New connecting canals were dug and water plans were integrated with urban expansion, also to increase the poor water quality of the growing cities. Because the scale of the projects increased, a national water governance became necessary.

IV - 1890 – 1990: Accelerating powers

New technological innovations, such as petrol engines facilitate another increase in scale. Hooimeijer divides this period into three subsections;
1890-1945: machine power
In this 'manipulative phase' (Hooimeijer, 2011, p.155) urban waters start to disappear and are being replaced by roads, rails and sewage systems. This makes the water system no longer the leading urban structure.
1945 – 1970: manpower
After the Second World War standardization marks urbanism. Water is mainly used as recreational area and as separation of neighbourhoods, but still essential in draining the urbanized polders in this urban sprawl. This also causes further land subsidence in these areas.
1970-1990: flower power
Environmental awareness raised by, amongst others, the Club of Rome (Meadows et al., 1972) causes a more harmonious relationship between man and nature. New water management strategies are created together with ecologists, resulting in more balanced urban designs in cauliflower neighbourhoods.

V - 1990 – present: Adaptive power

A continuation of the flower power period causes a more integrated approach, where civil engineers share their knowledge with urban designers to create better engineered plans. Policies are made on national scales and planning start taking place on a network city scale. Urban expansions are developed with water systems as the highest priority. This results in more surface water in newly built neighbourhoods.

Here Hooimeijer also conludes with a similar statement as in chapter:
'The Fine Dutch Tradition expressed in the new Dutch water city can return to its roots: complex urban developments that connect different challenges in the most efficient way' (Hooimeijer, 2011, p.287). This can also be interpreted as backtracking to a time where urban design and water management were sustainably balanced.

A movement to find balance similar to the movement Hooimeijer established, can be seen in the different 'key transition states' (Brown et al., 2008)p.4) in the framework of Brown, Keath and Wong (2008) as seen in Figure 6.1. In this proceeding 'water sensitive urban design' (p.2) is advocated by practicing 'sustainable urban water management'(p.1).

Here Brown et al. (2008) show five eras, seen from a more socio-economical side (pp. 5-9):
From 1800: Water supply city
First modern water city state, large amounts of water extracted that should be publically accessable and delivered by the government
> 1850's - 1945: sewered city
Similar to Hooimeijer's Accelerating machine power age
> 1945 – 1970: drained city
Similar to Hooimeijer's Accelerating manpower age
>1970 – waterways city
Similar to Hooimeijer's accelerating flower power age
> 21st century: water cycle city
Awareness of shortage, sensitive to energy and nutrient cycles
> Near future: water sensitive city
Unprecedented, requiring a major socio-technical overhaul, adaptive and continually evolving

Brown concludes that 'given the significant climate change and population growth challenges facing cities, there is a critical need for strategic investment in solutions that will deliver long-term sustainable outcomes.'(Brown et al., 2008, p.9)

One could state that the stages in Australia are not that different from the Dutch stages. Although they started civilization many centuries later and had to deal with drought much more than wetness.
The water sensitive city is still an idea, it has not been implemented anywhere. But this step also requires a major overhauling. This is also something that can be expected when in Europe we start the transition towards the earliest sustainable state.

Energy and sustainable planning

As seen in the historical overview of the different energy eras, in the last decades awareness for environmental issues is visible. Gradually, the understanding that the used sources were not endless, started to emerge and that it would be wise to reduce our footprint. 'Limits to Growth' (Meadows et al., 1972), 'Our Common Future' (WCED, 1987) and 'Cradle to cradle' (McDonough & Braungart, 2002) are some of the main documents to indicate this trend. They each attend to a different approach of sustainability, but they clearly insist on the fact that if humans should continue living the way they were, they would face an abrupt halt in future (Tjallingii & De Vaan, 2009, pp.5-6).

This change, that has to take place, should occur in multiple ways. Using the Trias Energetica (Lysen, 1996) is a much used approach to improve the sustainability. According to this theory, energy strategies should include the following three steps:

1. Permanent increase in energy efficiency
2. Augmented use of renewable
3. Cleaner use of remaining fossil fuels (p.1)

This strategy could be more current. Inspired by the Cradle-to-Cradle method (McDonough and Braungart, 2002) the New Stepped Strategy (Van den Dobbelsteen, 2008) was created:

1.Reduce the demand
2. Reuse waste streams
3.A. Use renewable energy sources
B. Ensure that waste can be used as food (Van den Dobbelsteen and Tillie, 2011, p.6)

This new version does not differ that much from Lysen's version, only adapting the third step.
In REAP – Rotterdam Energy Approach & Planning – by Van den Dobbelsteen and Tillie (2011) this updated version is applied to a principle for the city of Rotterdam. Together with REAP energy cascading is used (Figure 6.2). This principle shows that unused energy from one actor could be used by another, instead of considering it energy waste (Figure 6.3).

The cascading principle is an insightful means to distinguish two types of energy; used exergy and entropy. Exergy is 'the useful part in energy, the part that can be used to perform work, a measure of energy quality'(Van den Dobbelsteen et al., 2006, p.6). This means that one could think in reusing unused energy – entropy – for other purposes and therefore becoming exergy again. The distribution in the REAP principle can take place in a cascading manner, where the nearest or most needy user could get the energy and then search a next actor that could benefit from the entropy this second user has to offer after use.

When striving for a climate proof region, one should increase the overall fitness (Homan, 2005) of the region. Roggema (2009) translates this into spatial criteria (p.5), that form a complex adaptive system, which is baptised 'swarm planning' (Jacobs and Roggema, 2005). It relies on the influence of one local intervention, that catches on and crosses a tipping point after which it will change the direction of the region (hence the 'swarm').

Project Ground for Change (Van den Dobbelsteen et al., 2006) is a good example of a new approach with the use of local strengths. This embraces the thought that 'there is no one true method or solution to attain a certain goal; every location and situation demands

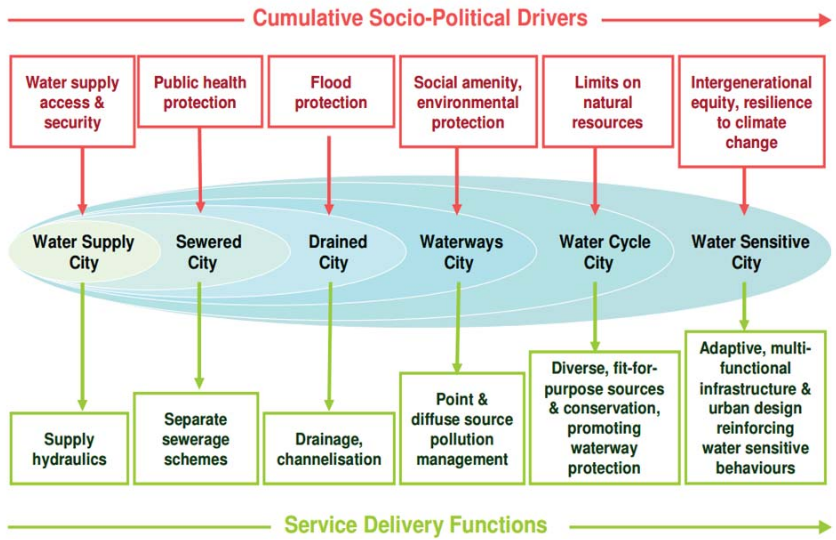


Figure 6.1: Urban water management transitions framework show the different key transition stages in Australian watermanagement history.
Source: Brown et al., 2008

for different measures'(p.2).
By mapping the local energy potentials, an indication of the logical energy sources for that region is created and therefore a guideline for local policy makers. Figure 6.4 shows the complexity that all the different involved parameters bring to end up with an energy based plan. When all the energy potentials of a region are determined including their location within the region, this results in an energy potential map of the region as seen in Figure 6.5.

Sustainable systems involving surface water that can be implemented also form a list. A brief summing of applicable systems:
- Water heat pump for heating but also cooling buildings
- Heat storage from surface water
- Tidal energy
- Wave energy

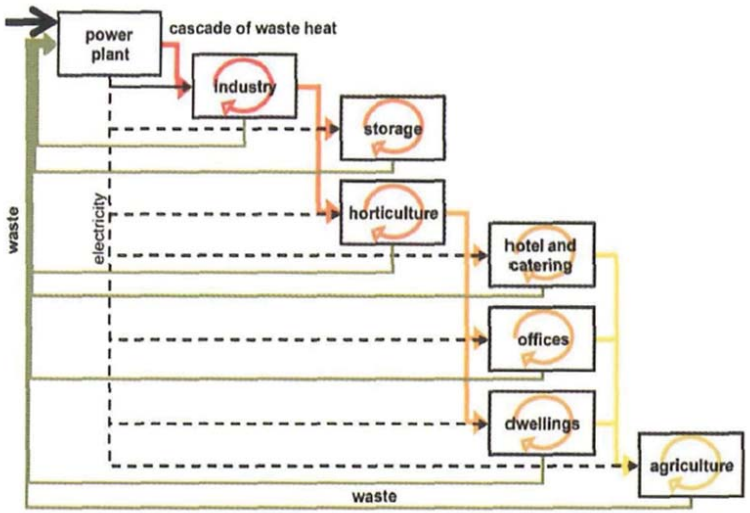


Figure 6.2; Principle of cascading where unused energy (entropy) cascades down to the next step where it partly serves as exergy. Source: Van den Dobbelsteen, 2010

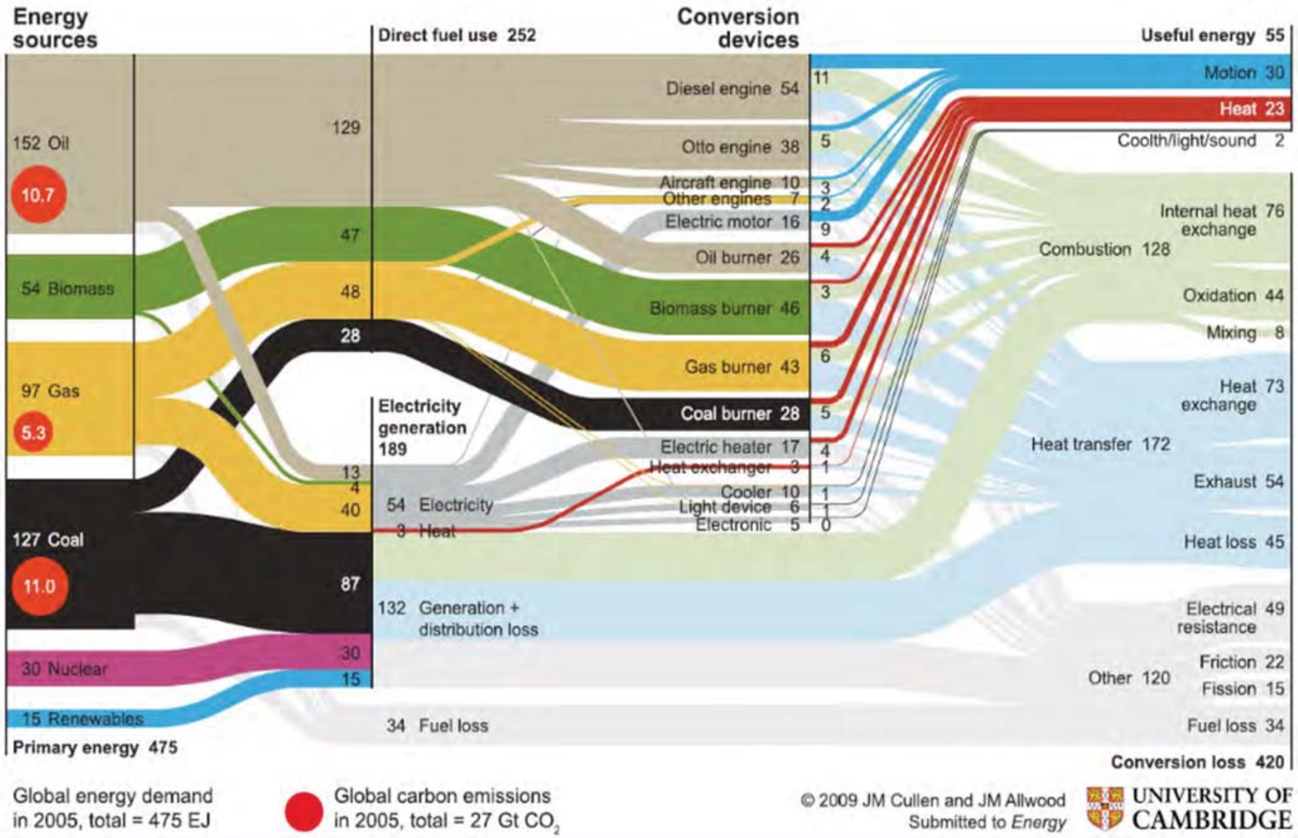


Figure 6.3: The exergy and entropy of energy made visual in a scheme. It shows that the majority of the energy we receive is in fact not used and gone to waste.
Source: Cullen & Allwood (2010)

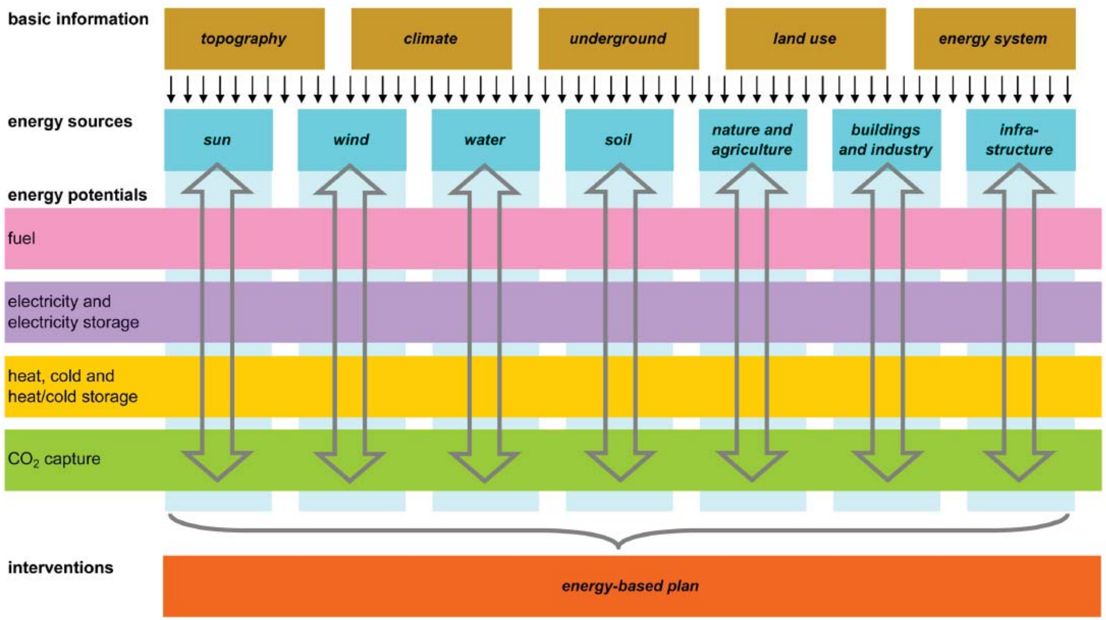


Figure 6.4: Energy potential mapping scheme (EPM) from: Van den Dobbelsteen et al. (2011), Energy Potential Mapping for Energy-Producing Neighborhoods. In: SUSB Journal, Issue no. 14, 2011.

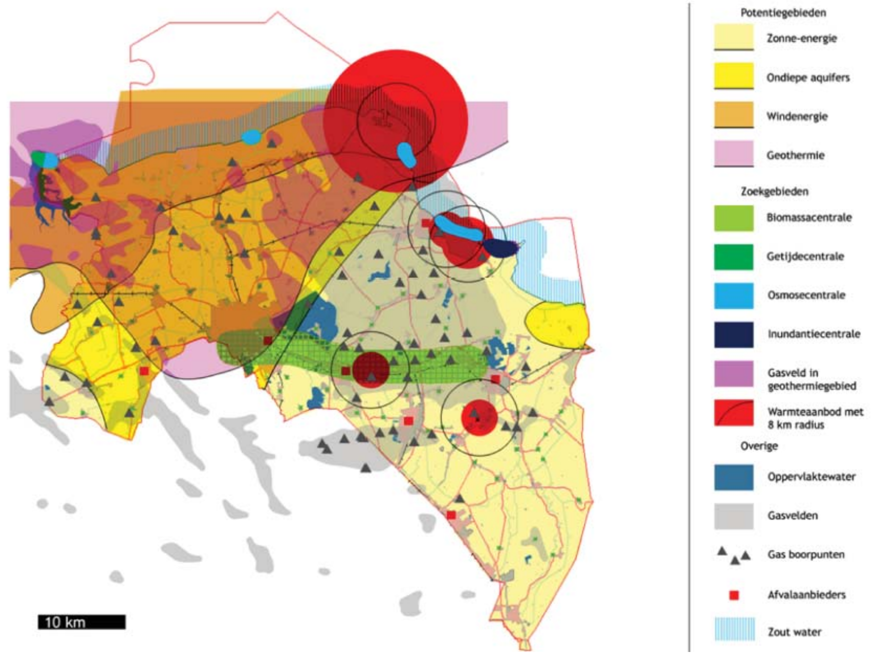


Figure 6.5: Map showing all the energy potentials of the province of Groningen, in the north of the Netherlands. Source: Van den Dobbelsteen, Broersma & Stremke (2011): Energy Potential Mapping for Energy-Producing Neighborhoods

- River energy
- Salt/freshwater energy
- Energy island

But also water in a secondary role contributes to energy use

- Surface water to reduce the UHI-effect (urban heat island effect). This saves energy in cooling the city
- Surface water as a waterway for transportation. Transportation on water is more sustainable than on rail or roads.
- Agriculture on water, mariculture, is according to De Graaf (2012) more efficient than on land

Water management and flood resilience

To determine the scenario or scenarios are most likely to occur in the project area (most likely Rotterdam-Rijnmond region) the reports of the IPCC, KNMI and the Second Delta Committee need to be studied, as well as Rahmstorf's report on sea level rise.

The Delta Committee shows four scenario's that could occur within the coming century where each scenario has different impacts on the urban delta.

Also Brouwers 'Inleiding watermanagement' (2008) forms a valuable source to get a grip on the characteristics of water and the possibilities in managing it. There needs to be an understanding on the effects of implementing flood plains, placing defence works or bypasses. Besides that, it is also important to know the behaviour and effects of water quality and salinization on the surrounding area.

There are different types of surface water definable in the urban delta:

- River
- Canals
- Lakes
- Ponds

- Sea/ocean
- Estuary/bay

Each has different qualities and could therefore play a different role in flood resiliency, but also in generating and storing electricity. For instance, tidal energy can be generated in estuaries, not in lakes or ponds. Since water is the largest solar collector there is, one could extract thermal energy from every type of surface water. For instance, a newly built neighbourhood in Duindorp, near The Hague, is collecting thermal energy via a pipe connection from the North Sea.

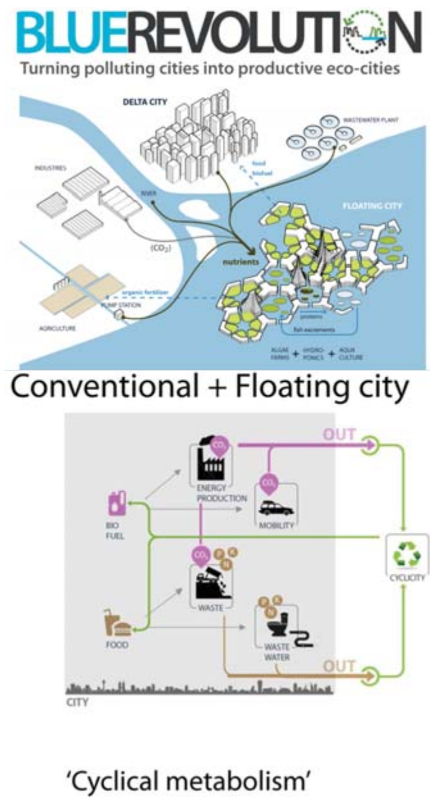
Rotterdam as one of the urban deltas

To understand urban deltas better, the work of Meyer is essential, such as ‘Reinventing the Dutch delta, complexity and conflicts’ (2009) and ‘Delta urbanism in the Netherlands’ (Meyer et al., 2010). For better understanding the development of port cities, the PhD-thesis of Meyer is very useful literature, also because it is comparing four cities. Since this is also a part of this graduation project, it would be useful to analyse Meyer’s approach to this comparison.

The urban deltas in scope at the moment are New York City, Melbourne, Brisbane, Copenhagen and obviously Rotterdam. Delta cities worldwide have already organised themselves in different initiatives to exchange knowledge and experiences. Connecting Delta Cities (CDC), DeltaAlliance and C40 Cities are some examples of these initiatives, of which each has their own body of knowledge that could be tapped on to. In this project these reference cities could be consulted for solutions or designs made that included water resilience. There are hardly any precedents that include energy in the urban environment.

Also, if there will be enough time within the project, a design solution for the Rotterdam region can be tested on generic qualities by implementing it into one of the connecting cities, of which New York City is preferred the most.

In the future urban development can also be taken to the large surface waters, such as the sea. Nowadays small lakes and rivers are occupied by floating buildings, but De Graaf proposes this new frontier in his concept of the Blue Revolution (2012). This holds a long term vision in which we expand delta cities onto the water and use this area to create closed nutrient cycles for the city. A visualisation of this concept is visible in Figure 6.6.



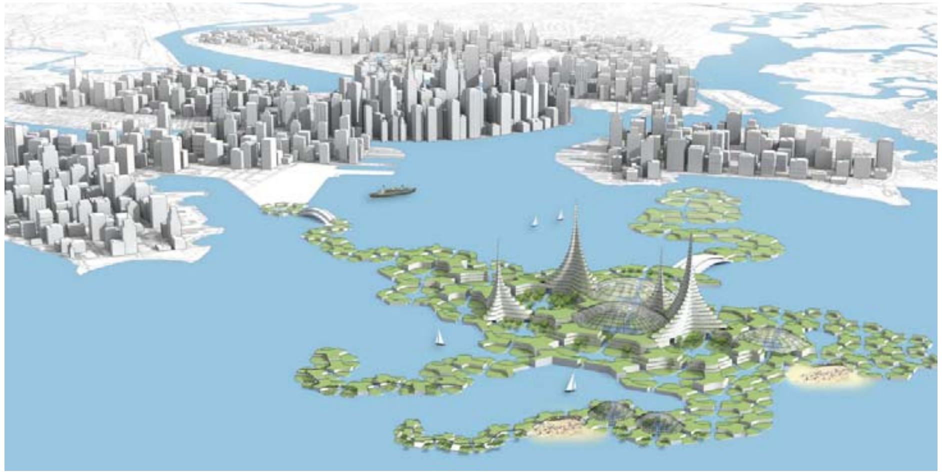


Figure 6.6: concept of creating floating extensions of the urban delta area onto the water to make a more environmentally friendly city, called Blue Revolution
Source: De Graaf (2012)

literature review paper

Surface water as a solution for sustainable urban deltas

Exploring the potentials of water management and renewable energy systems to create a strategy for the Rhine-Meuse delta

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Abstract – Today, the majority of people in the world live in cities. Most of these cities are located near waterfronts and are facing a triple threat from the water due to climate change and subsidence: flooding of rivers, rising sea level and more intense precipitation. This asks for a sustainable solution: more space for the water.

At the same time, these cities are also the largest energy consuming areas in the world. With the upcoming scarcity of fossil fuels and the increasing demand for energy, a more efficient use of sources and a shift to more sustainable systems is eminent.

This asks for a combination of sustainable developments towards water resilience as well as energy resilience. The water surface in urban deltas is the key to make this happen. What is the role of the water in sustainable regional energy and water management in urban deltas and what are the spatial effects to the region? This paper explores the possibilities for this combined approach in the Rotterdam region in The Netherlands.

Through the method of forecasting a prediction of the future situation is sketched. Then, by backtracking a historic overview of both energy use and water management, similarities show, especially in the modern approach. Both are matching the future with a sustainable past.

The current developments in renewable energy systems as well as water management show a lot of potential already. New stepped strategy (Van den Dobbelsteen, 2008) replaces the Trias Energetica. Initiatives such as the REAP and making Energy Potential Maps is just the start of what is already happening in the Rhine-Meuse delta to adapt to future scenario's.

This paper forms an overview of possibilities that make the right ingredients to form a regional strategy for a sustainable urban delta.

Key words – urban delta, water management, renewable energy, backtracking, REAP, EPM, Rhine_Meuse delta, Rotterdam

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1 Introducing a threat to urban deltas

Ever since the Industrial Revolution took place in the nineteenth century, cities have become more attractive and have been expanding rapidly ever since. Today, the majority of people in the world live in cities. Predictions show that in future even a larger part of the world population will be living in urban areas. By the year 2030 it is expected that six out of ten people will live in cities. This number will grow even further to seven out of ten by the year 2050 (WHO UN-HABITAT, 2010). This means urban expansion will take place in the coming decades, together with a densification of the urban areas.

Most cities are located near or at waterfronts. People have settled here centuries ago and have grown to the current urban deltas due to the favourable conditions. In delta areas settlers could benefit from reliable water sources, that could be used for drinking, but also as a mode of transport to dispose of waste. The land is favourable to growing crops because of its fertility and often flat. But on top of that, it offers a great place to start trade from (De Graaf, 2012).

Deltas are apart from very favourable to urbanization also a very susceptible to the threat from the water. Since deltas can be defined as the place where river and sea meet, they also deal are experiencing the effects of both systems on the land (Meyer, 2009). This results in threats of river floods, storm surges from the seas, changes in sea level and dealing with heavy rainfall.

The urbanization of the treacherous deltas can therefore be seen as a *double complexity*, which Meyer (2009) describes as:

"*.. they have to deal with the complexity of the delta, as the meeting of rivers and sea, and with the complexity of urban patterns, as a condition and result of economic, cultural and social life*." (p.432)

This clearly shows that these deltas are difficult to develop, since one has to take the complexities of nature's threat on top of complexity that human beings living together brings to the table.

Over the ages, though, man has developed measures to overcome these threats from nature that deltas have been subjected to. Building dikes and pumping water away from swampy land made safe urban expansion possible. On top of that, man was able to keep feeding and fuelling these ever growing delta populations. This results in today's situation, where the largest cities in the world are located in delta areas and will only increase in number and size.

However, the coming century these urban deltas will face major threats when they continue to grow in the same manner. Apart from planning the rapid influx of people into (mega)cities, climate change affects water systems and many of the currently used energy sources are depleting.

The coming century, urban deltas need to make changes in their flood defence systems and energy systems to adapt to the future circumstances.

The purpose of this paper is to explore the sustainable possibilities for flood resilience and energy transitions to adapt to the future circumstances and to see where they might overlap and how they can be spatially integrated in the urban delta region.

This will be done by forecasting, backtracking and backcasting. Figure 1 shows the principle of these three methods. In short they can be defined as follows (Van den Dobbelsteen *et al*., 2006):

- Forecasting is ' *[..] to estimate the consequences of current developments and our own intervention on long-term effects.*'(p.3)
- Backtracking is basing solutions '*on historical circumstances at the time there still was a sustainable equilibrium*.'(p.3)
- Backcasting is '*involving the description of a desired future state [...] and translating this state back to strategies and measures we need to develop now*.'(p.3)

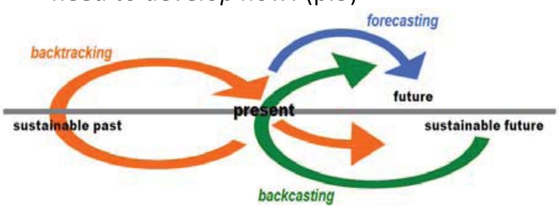

Figure 1: A graphic representation to clarify the principles of forecasting, backtracking and backcasting.
Source: Van den Dobbelsteen et al., 2006, p.3

Firstly, the future threats concerning energy and extreme water conditions are explored. Secondly, an exploration of the historic development of energy landscapes and water management is done. This will also help in backtracking sustainable solutions. Thirdly, an overview of possible solutions and programmes is presented, that could be part of a strategy towards a sustainable urban delta. This knowledge can be applied to the Rhine/Meuse delta in The Netherlands. The results from this literature review will produce recommendations for the graduation project, to which this region is subjected.

2 The future predictions we should adapt to.

Over the past few years several studies have been done to predict the mean sea level rise. These results vary significantly, as can be seen in figure 2:

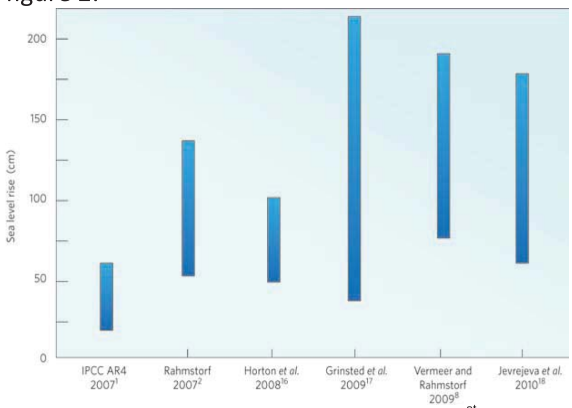

Figure 2: Range of expected sea level rise in the 21st century. This graph shows that the estimates vary more than 150 cm. Source: Rahmstorf (2010), A new view on sea level rise. In: *Nature Reports* [online:] http://www.nature.com/climate/2010/1004/full/climate.2010.29.html, accessed

Regarding the current developments of sea levels and these estimations, the assumption can be made that sea levels will rise.
The Delta Committee also has different scenarios for the Dutch coast, but the most likely prediction is that by the year 2100 the sea level have risen with 65 to 135 cm (Programmabureau Zuiwestelijke Delta, 2011). This is still a large margin, but it matches with the estimates in figure 2.

Urban delta areas will face a triple water threat: sea level rise, more extreme river discharge and more extreme precipitation. This can be dealt with by raising flood defences and increasing pumping capacity. However, the estimates of by how much the amounts of water will alter, are very uncertain.

Therefore a more adaptive strategy would be more suitable, where an increased buffer capacity can handle an extreme inflow of water. This advocates creating more surface water on land; not only in rural areas, but also in urban areas. It will be more difficult to create surface water in densely built up urban area.

Although living close together in cities is relatively more energy efficient than rural living (Owen, 2009), the worldwide amount of energy used is mostly consumed in cities. This will increase in the future, when even more people will live in urban areas. A transition to renewable energy sources is essential to meet our future energy demands, as figure 3 shows.

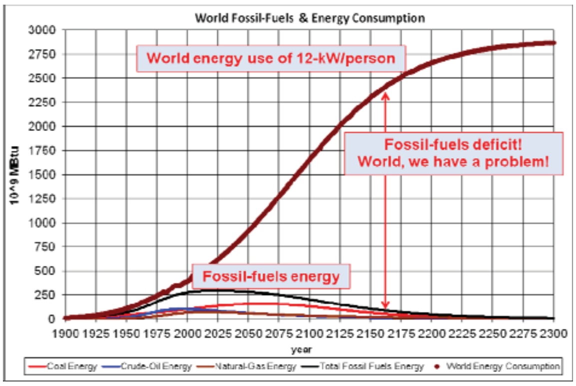

Figure 3: Graph showing world energy deficit between the demand and the availability of fossil fuels. This clearly shows a transition towards new energy sources is eminent.
Source: Roper (2006), *Future Energy*, online: http://arts.bev.net/RoperLDavid, accessed Nov 7th, 2012.

A vast gap is showing in the graph of Figure 3. This is a serious concern, especially since it predicts the shortage will occur within the next twenty years.

3 Historic development of energy use and water management

3.1 Different eras in energy sources
The different stages of used energy sources over time can be best categorized according to the different stages in energy landscapes, described by Pasqualetti (2012)pp.14-40).

I - energy of the organic economy.
First, thousands of years BC, man only had the power of its own muscles and that of its animals. The energy needed to fuel this, came from food. Fire, fuelled by wood, was used for heating.
Later wind and water power were used for small scale industry and transportation, for example by means of windmills, sailing boats and water wheels.
In the Dutch delta harvested peat was mostly used as energy source to generate heat.

II – energy of the mineral economy

Already in the 13th century coal was used to fuel fires, but its true success started in the eighteenth century at the dawn of the Industrial Revolution. It was the main source to fuel steam engines.

Mid nineteenth century, when industrial equipment was developed to drill deep into the ground, oil and natural gas mining emerged worldwide. When techniques improved during the twentieth century, the unconventional fossil fuels became accessible, such as oil from oil sands and shale gas. Fossil fuels facilitated a giant leap on a technological level. With the access to so much energy, man could conquer many forces of nature by creating machines to assist in building, transporting and living. Also, centralized distribution systems started to appear.

III – energy of the electric economy

At the end of the nineteenth century electricity was generated, powered by fossil fuels. With generating electricity it became possible to transport energy over large distances, creating a large hub-and-spoke system to distribute energy.

Mid twentieth century nuclear power became a clean substitute for the polluting burning of fossil fuel to generate energy. This form of generating energy had its disadvantage; it produces lethal radioactive waste.

IV – energy of the sustainable economy

In the 1970’s the first awareness of our energy consumption and to our ‘limits to growth’ (Meadows *et al*., 1972). This results in the use of sustainable sources. This age can be regarded similar to the first age, based on the use of the same resources. However, with advanced technology the resources can be harvested more efficient. Sources such as hydropower, wind energy and biomass are used to create electricity that powers our instruments.

On top of that, geothermal power is extracted from deep in the earth and photovoltaic panels as well as solar boilers use modern techniques to covert the power of the sun into usable energy.

Today, we still use all of the resources mentioned in the stages above. Today, we are still in the stage of a sustainable economy. Fossil fuels, currently the most used energy source, is depleting and therefore we are only at the beginning of this fourth age. Or one could say a circular process is completed and we have returned to our organic stage. This is a clear example of backtracking energy use.

3.2 Different eras in water management

Water management has always been closely related to urbanization. Meyer (2009) states: *‘Throughout history, in a watery region such as the Dutch lowlands the question of water management and flood defence has been related to the question of the relation between the urban and the rural communities’*(p.433).

Hooimeijer (2011) also focuses on the Dutch delta. Her extensive overview gives a clear guideline to approach the Dutch water management history. It is divided into the following eras (using Hooimeijer’s terminology):

I - before the year 1500: Natural power

The country exists of many marshlands in which people adapt to nature. Only small initiatives are taken to control drainage.

II - 1500 – 1800: Power of unity

Technological instruments such as windmills, dams, dikes and sluices make canal systems, poldering and world trade possible. On top of that, a centrally organized approach makes the Dutch get more control on the water.

Added to this, Meyer (2009) adds that in this era conflicts between urban and rural areas emerged on controlling the dam. This would also control the inundation of the polders behind the dam. To clean the urban water system, cities that formed around this dam, had to build a buffer to flush out all the waste water. This buffering would also affect the water levels of the hinterland, which the farmers did not like. Governance became more important and this era marked the birth of the civil engineer, a cross between ‘*what today we call hydraulic engineering and urban design.*’ (Meyer, 2009, p.435)

III - 1800 – 1890: New power

This era is marked by the Industrial Revolution, giving new power to man to control the water. Steam powered pumps made large poldering possible. This created new farmland and building grounds, which caused rapid urban growth. But

pumping out even more water also increased the land subsidence.
New connecting canals were dug and water plans were integrated with urban expansion, also to increase the poor water quality of the growing cities. Because the scale of the projects increased, a national water governance became necessary.

IV - 1890 – 1990: Accelerating powers
New technological innovations, such as petrol engines facilitate another increase in scale. Hooimeijer divides this period into three subsections;
1890-1945: machine power
In this 'manipulative phase' (Hooimeijer, 2011, p.155) urban waters start to disappear and are being replaced by roads, rails and sewage systems. This makes the water system no longer the leading urban structure.
1945 – 1970: manpower
After the Second World War standardization marks urbanism. Water is mainly used as recreational area and as separation of neighbourhoods, but still essential in draining the urbanized polders in this urban sprawl. This also causes further land subsidence in these areas.
1970-1990: flower power
Environmental awareness raised by, amongst others, the Club of Rome (Meadows *et al*., 1972) causes a more harmonious relationship between man and nature. New water management strategies are created together with ecologists, resulting in more balanced urban designs in cauliflower neighbourhoods.

V - 1990 – present: Adaptive power
A continuation of the flower power period causes a more integrated approach, where civil engineers share their knowledge with urban designers to create better engineered plans. Policies are made on national scales and planning start taking place on a network city scale. Urban expansions are developed with water systems as the highest priority. This results in more surface water in newly built neighbourhoods.

Here Hooimeijer also conludes with a similar statement as in chapter 3.1:
'The Fine Dutch Tradition expressed in the new Dutch water city can return to its roots: complex urban developments that connect different challenges in the most efficient way' (Hooimeijer, 2011, p.287). This can also be interpreted as backtracking to a time where urban design and water management were sustainably balanced.

A similar movement to find balance can be seen in the different '*key transition states*' (Brown *et al*., 2008)p.4) in the framework of Brown, Keath and Wong (2008) as seen in Figure 4. In this proceeding *'water sensitive urban design'* (p.2) is advocated by practicing *'sustainable urban water management'*(p.1).

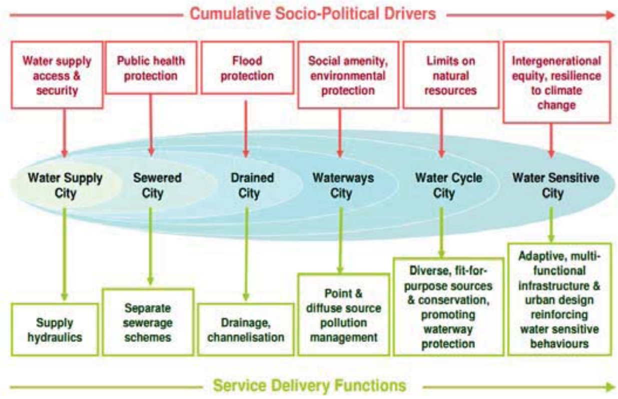

Figure 4: Urban water management transitions framework show the different key transition stages in Australian watermanagement history.
Source: Brown *et al*., 2008

Here Brown *et al*. (2008) show five eras, seen from a more socio-economical side (pp. 5-9):
From 1800: Water supply city
First modern water city state, large amounts of water extracted that should be publically accessable and delivered by the government
1850's - 1945: sewered city
Similar to Hooimeijer's Accelerating machine power age
1945 – 1970: drained city
Similar to Hooimeijer's Accelerating manpower age
1970 – waterways city
Similar to Hooimeijer's accelerating flower power age
21st century: water cycle city
Awareness of shortage, sensitive to energy and nutrient cycles
Near future: water sensitive city
Unprecedented, requiring a major socio-technical overhaul, adaptive and continually evolving

Brown concludes that *'given the significant climate change and population growth challenges facing cities, there is a critical need for strategic investment in solutions that will deliver long-term sustainable outcomes.'*(Brown *et al*., 2008, p.9)

One could state that the stages in Australia are not that different from the Dutch stages. Although they started civilization many centuries later and had to deal with drought much more than wetness.

The water sensitive city is still an idea, it has not been implemented anywhere. But this step also requires a major overhauling. This is also something that can be expected when in Europe we start the transition towards the earliest sustainable state.

4 Array of possibilities in designing a sustainable delta

From a historical point of view it is visible that nowadays the sustainable solutions – in correlation with nature – are favourable, considering their success in a balanced past. Let us look at the possible sustainable implementations.

4.1 possibilities for renewable energy

Deltares (2008) studied the qualities of means that extract energy from water. It shows a division in three primary sources and are organized as follows:

- Sunlight:
  - aquatic biomass
  - waves
  - river discharge
  - desalinated water
  - thermal energy in water
- Gravitational pull from the moon:
  - height difference in tides
  - tidal flows
- Heat radiation from the earth's core:
  - warm aquifers/geothermal energy

These different energy sources are could all be implemented in the Dutch delta, but not all elements are feasible. The result of this feasibility study is shown in Figure 5.

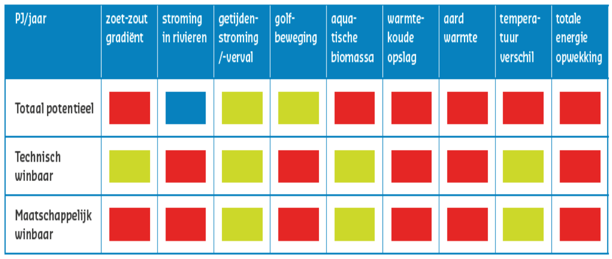

Figure 5: The different energy sources are rated (from top to bottom) on total potential, technically harvestable and societally harvestable. Red = high potential, green average potential, blue = least potential.
Source: Deltares (2008, p.50)

Figure 5 shows that the most suitable techniques to apply are thermal energy in water (hot and cold storage) and geothermal energy. The least potential had the river flux. This is because the speed of the water is too slow to generate enough yield to be efficient.

Another study by Quak (2009) shows that the best place for a blue energy plant – electricity by osmosis between fresh and salt water – would be the most feasible in the Botlek, which is situated in the Rhine-Meuse delta.

Another approach to visualizing yield and efficiency is the Kwh/m2-index by H+N+S Landscape Architects (2008). Here is calculated that a yield of 1500 Megawatt will take 339 hectare of space; hydropower requires 416 hectares for storage, 8 for generating power and another 8 to dispose of the used water. To produce the same amount of energy with biofuel will take over 213000 hectare**.**

4.2 possibilities for flood resilient water system

In the programme for the South-western Delta (Programmabureau Zuidwestelijke Delta, 2011) a strategy for the Rhine-Meuse delta shows that the area most likely have an open/closed system that will be closed during extreme water levels, locking off the city of Rotterdam. A more urgent point of attention are the dikes west of Rotterdam, that need an upgrade as soon as possible. These implementations will help us through the coming century, but if sea water levels would rise more than two meters, these defence mechanisms will be insufficient. Therefore , the more surface waters where excess water can be stored, the better.

More surface water would also counteract the salt water seepage into the fresh water aquifers. This seepage will occur more strongly when the sea water level rises. By closing of the delta to the sea, we can reduce the salt intrusion quite well; in an open system this is very hard. Salinization of the coastal soils will occur. A possible reducing element to this intrusion is the creation of islands in front of the estuary, slowing down the sea water that moves in with the tide.

The storage the extra water during peaks does not necessarily have to be in permanent surface water, such as canals, rivers and small lakes. There are also possibilities to adapt the dry urban environment to store the water temporarily. H+N+S (2012) offers a range of possible adaptations:

- water surplus from streets pumped into parks
- lower level of sidewalks and street to prevent water against the facade
- underground water storage in reservoirs underneath infrastructure
- protect buildings from water by small levees

Currently, the most well known buffer project is the water square, designed by De Urbanisten, that will be ready in 2013**.**

4.3 Sustainable planning

Apart from the implementation of different solutions for water and energy, one could also use methods that support sustainable planning.

When striving for a climate proof region, one should increase the overall fitness (Homan, 2005) of the region. Roggema (2009) translates this into spatial criteria (p.5), that form a complex adaptive system, which is baptised 'swarm planning' (Jacobs and Roggema, 2005). It relies on the influence of one intervention, that catches on and crosses a tipping point after which it will change the direction of the region (hence the 'swarm').

Project Ground for Change (Van den Dobbelsteen *et al*., 2006) is a good example of a new approach with the use of local strengths. This embraces the thought that '*there is no one true method or solution to attain a certain goal; every location and situation demands for different measures*'(p.2). By mapping the local energy potentials, an indication of the logical energy sources for that region is created and therefore a guideline for local policy makers.

The energy potential map can be made more insightful by expressing the results as exergy values. Exergy is '*the useful part in energy, the part that can be used to perform work, a measure of energy quality*'(Van den Dobbelsteen et al., 2006, p.6). This means that one could think in reusing unused energy – entropy – for other purposes and therefore becoming exergy again. An insightful system to show this, is the energy cascade (Van den Dobbelsteen *et al*., 2006).

REAP

The principle of the energy cascade can also be seen in the REAP - Rotterdam Energy Approach & Planning (Van den Dobbelsteen and Tillie, 2011). This approach shows a new, updated version of the 'Trias Energetica' (Lysen, 1996). Inspired by the Cradle-to-Cradle method (McDonough and Braungart, 2002) this was updated to the New Stepped Strategy (Van den Dobbelsteen, 2008):

1.Reduce the demand

2. Reuse waste streams

3.A. Use renewable energy sources

B. ensure that waste can be used as food (Van den Dobbelsteen and Tillie, 2011, p.6)

The New Stepped Strategy lead to the principle of the Rotterdam Energy Approach and Planning (REAP) and was tested on Hart van Zuid in Rotterdam. This principle now mainly focuses on the exchange of heat and cold to balance out surpluses and shortages.

Here comes the principle of cascading into play (figure 6).

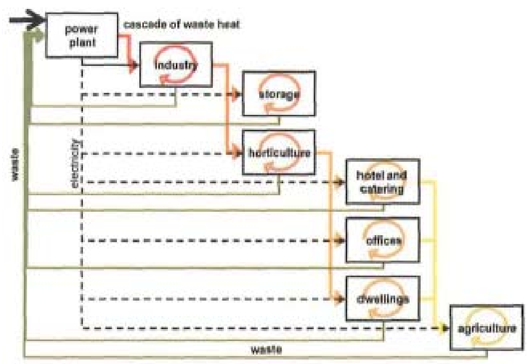

Figure 6: Principle of cascading where unused energy (entropy) cascades down to the next step where it

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partly serves as exergy. Source: Van den Dobbelsteen, 2010

This distribution can take place in a cascading manner, where the nearest or most needy user could get the energy and then search a next actor that could benefit from the entropy this second user has to offer after use.

The energy world is full of innovations, but the implementation still lacks. Perhaps that swarm planning could improve this situation.

5 Conclusions

We have seen in chapter three, that there are similarities in the historical development of both energy and water management. Both are already in a transition phase – although just the beginning. The adaptive approach, more in balance with the environment seems to be the strategy for the coming decades. It is clear that the eras have changed quite frequently over the last few decades, so there is no guarantee there will be new insights in the near future. It has to be said, though, that a scenario in which there is more water to drain, a more adaptive strategy with large buffer capacity seems appropriate.

History also shows that water and energy have been entwined; energy was needed to move water and water was needed to create energy (cooling for example).

The organic era for water management will be easily fitted in the current standards, but this will be more difficult for energy. Storage for example is not that easy with today’s electricity, whereas water can be stored easily.

The choice for energy sources from the water is easy to make with this overview. This is the best overlap of both fields in the urban delta. Thermal energy from surface water and groundwater clearly stands out and is relatively easy to install in small scale. Ideal for a decentralized transition.

This would also fit with the results of an EPM for the Rhine-Meuse delta. Different areas with different energy sources seem likely with a large river, excess heat from the industry and open polder land.

Most of the flood defences in the Rhine-Meuse delta will hold for another fifty to a hundred years. The energy transition is more eminent, since shortages are already predicted within the coming twenty years (Roper, 2006)

In the Rhine-Meuse delta many prevention programmes have been initiated. This is mostly done from a top down approach. There is not much literature on bottom up initiatives to create flood resilient areas. This makes sense, since these are large scale operations and are very expensive. A bottom-up initiative could hardly finance such a project

This study shows that surface water and energy have been linked together for many centuries in the urban delta. Now, the trend is to leap forward to the past, deltas face the threats on both fields the coming century. This could very well be solved with entwined solutions. After all, we have survived for centuries the last time we went into that sustainable adaptive era.

6 Recommendations for the graduation project / further research

An adaptive strategy for the urban delta seems a logical approach. Renewable energy sources were already a prominent option for the energy problem, but the implementation strategy was still vague. A very complex mix of different custom made solutions might be a bit too complicated for a graduation project; it will be very difficult to check the feasibility of the solutions.

It will be very wise to make an EPM of the region to discover the energy potential of the area. This will be most likely a guideline for the regional vision and the design. Additionally, researching the exergy values of this EPM might be worth calculating. This will make a energy network more realistic.

The Australian reference can be used to keep the scope internationally and include solutions for drought and Urban Heat Island syndrome. Water sensitive urban design is a good approach to design for both dry and wet conditions.

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