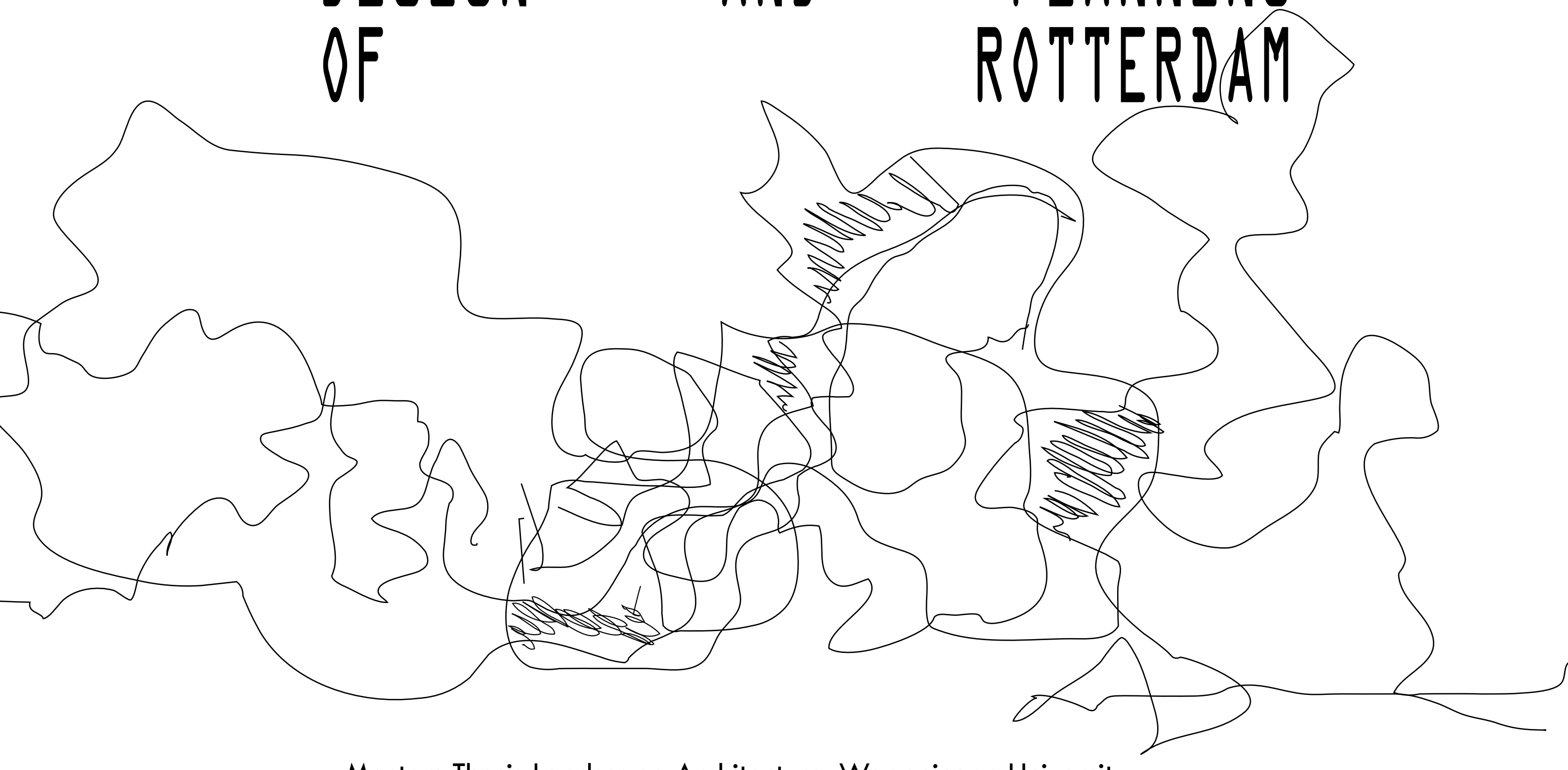
# DISSIPATIVE

# City

## THERMODYNAMICS

## FRAMING A SYSTEMIC APPROACH FOR THE DESIGN AND PLANNING OF ROTTERDAM



Masters Thesis Landscape Architecture, Wageningen University

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# dissipative city

## Thermodynamics framing a systemic approach for the design and planning of Rotterdam

Masters Thesis Landscape Architecture

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# Preface

During the energy landscapes masters atelier of 2011 at Wageningen University, we focused on designing sustainable energy landscape for two islands in the Dutch delta region, which was the point that sparked my interest towards energy transition and designing future landscapes. Afterwords during the climate design studio for the city of Tiel the link between the city microclimate and energy efficiency became more and more evident.

The kWh/m2 studio at the Delft University of Technology together with Wageningen University, provided the platform that initiated the research of this thesis as well as the link with Rotterdam as a potential site. Rotterdam as a delta and port, industrial city is facing allot of the global challenges of contemporary relevance with regards to energy supply, climate adaptation and mitigation as well as resource provision and livability.

This research is investigating possible ways of rethinking the ways in which our cities interact with their surroundings in a purely thermodynamic SLT way and how these new interactions can platform climate adaptation, energy provision and even resource provision.

The aim is to show that a landscape approach on even the most extreme thermodynamic and micrcolimatic solutions can reveal attractive structures for people and even be the foundation of a new sustainable society.

During the research numerous persons contributed in crucial ways to its end result and i would like to thank all of them:

First of all my supervisor, Sven Stremke. Thank you for all your sharp comments and guidance along the way. Our tutoring sessions were most inspiring and formed the basis of this thesis.
Also my supervisors from TU Delft, prof. Andy van den Dobbelsteen and prof. Dirk Sijmons. Thank you for all your comments and guidance, especially with regards to energy calculations and framing the approach.

Also a big thank you to Nico Tillie, for all the information and insight on Rotterdam, which would have been otherwise very difficult to come across.

I would like to thank Sanda Lenzholzer and Rudi van Etteger for their sharp comments and critiques during my green-light presentation. Your comments were detrimental in shaping the final version of the design.

I would also like to thank all the experts that so kindly offered their advice and professional insight and shared knowledge and data, either form Rotterdam Municipality, Wageningen University, TU Delft or H+N+S Landscape Architects. My fellow colleagues for their remarks and inspiring conversations and my family for their support.

Last but not least I would like to thank Lavinia, for her support, love and understanding. Thank you for all the great discussions and critical view.

# Summary

In the coming decades, global challenges like never before will force our society to rethink and restructure its way of life and the dynamics it is built upon. Challenge in energy provision due to the depletion of fossil fuels, and a current renewable sector to weak for our consumption; challenges in climate in terms of adaptation and mitigation of climate change effects, which are shaking the very core of our cites; and challenges in resource provision, in terms of food, water and so forth. These are can be framed under a global tendency of urbanization and projections of increasing in global population and urban population in dramatic ways.

Rotterdam is facing the same challenges, and maybe more so than most global cities. It is on the one hand a product of the industrial world, based on fossil industry and commerce; and on the other it is a delta city faced with the challenges of sea level rise and river discharge fluctuations. At the same time it is also framed by the growing urban population, probably more than most cities. The plans show goals of doubling the population living in the inner-city, which will leave heavy imprints on the urban fabric.

This research is focused on finding way of integrating energy transition and climate adaptation in a way which is yielding urban structures grounded in the ecosystem services of their site. The challenge is framed by thermodynamics and Second Law Thinking, and in a systemic way, integrated microclimatic consideration and a regard for resource scarcity; in order to provide exergetic optimization of urban structures, and ultimately potentially guide the cities towards evolving into dissipative structures away from thermodynamic equilibrium.

The main challenge is revealing an ideal thermodynamic and microclimatic solution and integrating it in our current structures in ways which are attractive and engage people. This is initially tacked in the inner-city of Rotterdam, by means of rethinking the urban morphology and integrating new approach to existing structures, in order to obtain the exergetical optimization sought after.

A second challenge is revealed in terms of population and growth and limited carrying capacity of the system and a new, large scale adapted approach is explored. For this the district of Pernis in Rotterdam is studied and a integrative system which provides not only energy but water and food as well is proposed. Its dramatic impact on people and the landscape is addressed by a set of specific measures meant to mitigate its adverse effects and reveal its attractiveness. In the end a self –sustaining urban structure is generated which provides energy and mater grounded in ecosystem services, in a sustainable growth oriented way.

## Guide to the reader

This research focuses on the city of Rotterdam in the context of energy transition and climate proofing challenges; in particular it searches for solution which could yield exergetic optimization of the city, in an attractive way which allows room for growth and provides ecosystem services. It focused on two specific sites: Rotterdam Inner-city an the district of Pernis.

In order to reveal the perspective on the research the first 4 chapters are dedicated to framing the context and research. Here the position of the author is made clear within the theoretical debate on the problem as well as specific lens chosen for the research. Chapter 4 frames the research question and methodology, concluding the first part of the research.
The next 5 chapters are dedicated to the search of solutions through research by design. First a method for framing the designs in light of the research question and analysis is identified in chapter 5 as systemic design, and is further tested in chapter 6 on current initiatives for the inner-city. The testing allows for a clarification of the approach and farming of the conceptual model in chapter 7. The concept it the elaborated in a design on the inner-city of Rotterdam in chapter 8. Concluding chapter 8, the need for a more comprehensive approach for larger scales is revealed. Chapter 9 is exploring this on the district on Pernis.
The last pat is focused on a extensive discussion on the approaches, comparing and concluding on their outcome as well as examining the scientific relevance of the study and discussing major challenges.

**chapter 1** Chapter 1 deals with introducing the framework of the study, both in terms of studio platform and collaboration with TU Delft, as well as introducing the global challenges framing the approach and revealing the aim of the thesis.

**chapter 2** Chapter 2 is focused on introducing the theoretical lens or framework and its major informers. Here separate as well as interlinked introductions and discussions on thermodynamics, Constructal Theory and Ecosystem services are structured. This chapter reveals the importance of exergetic optimization of cities and its fundamental need for grounding in the ecosystem services of its site. At the same time the issue of morphology is discussed and linked to energy efficiency, revealing the need for a alternative approach.

**chapter 3** Chapter 3 is focused on introducing Rotterdam, both in terms of history and future. A study on the city's history is presented and its link to food and energy production is revealed as fundamentally grounded in the landscape structure. At the same time, projections for the future are framed in terms of scenarios dealing with energy and socioeconomic projections. This helps frame a set of potential changes for Rotterdam in the next decades and grounds them in light of energy projections.

**chapter 4** Chapter 4 deals with framing the problem of energy transition and climate adaptation and mitigation in the context of Rotterdam and leads to the definition of the research question and methodological approach:
Can exergetic optimization of energy flows and material cycles yield an attractive urban structure that provide ecosystem services and supports human life activity and growth?

**chapter 5** Chapter 5 tackles the research question with a first set of comprehensive analysis on key aspects of the research (energy and climate), and reveals the need for a more comprehensive approach, which is revealed to be systemic design. In the end systemic design is discussed and framed in light of the current research.

**chapter 6** Chapter 6: Is taking the systemic approach framed previously and testing its suitability and potential for results on current initiatives in Rotterdam. Taking the densification strategies for the inner-city the testing aims at adding to the original strategies, consideration for energy, microclimate as well as resource provision and investigate weather the same results in terms of densification can be obtained in a more holistic way.

**chapter 7** Chapter 7: After legitimizing the approach on the site, chapter 7 deals with focusing the approach on a specific area (housing) and framing its potential (in terms of saving). At the same time systemic design is framing the approach in a more integrative way and at the end all is combined to generate the end concept inspired by the Biosphere of Buckminster Fuller.

**chapter 8** Chapter 8 applies the concept and guidelines revealed in chapter 7 onto a specific site in the inner-city. The chapter shows how a alternative approach on designing our housing areas can yield attractive, climate robust and energy efficient solution. The chapter concludes with exploring the potentials in numbers and discussing the outcome.

**chapter 9** Chapter 9 is focused on applying essentially the same approach on a larger scale area and is framing a new concept, inspired by Buckminster Fuller's geodesic dome. It deals with showing how a landscape grounded approach to extreme engineering solutions can reveal surprising and attractive potentials for the future of our cities. The end is again dedicated to expressing the potentials in numbers as well as generating integrative energy and resource systems grounded in ecosystem ecology.

**chapter 10** Chapter 10 discusses in a comparative way the two designs and presents the most important conclusions and discussions on the research.

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# PART I

# RESEARCH CONTEXT AND FRAMEWORK

# 01 INTRODUCTION

## 1.1_ The kWh/m$^2$ Studio.

"Researching the spatial footprint of energy generation"

The framework in which this research was conducted was facilitated by the kWh/m2 studio. The program, lead by Prof. Dirk Sijmons, from the Technical University in Delft, is organized as a collaborative studio between the TU in Delft and Wageningen University. Its scope is to provide a catalyst for an inter-disciplinary approach to energy transition, bringing together architects, urban designers, landscape architects, engineers or technologists.

The results produced within this studio will be consolidated an energy atlas divided into 3 parts: energy consumption (part I), energy sources (II), energy transition (III). The third part presents energy transition scenarios in different regions of the Netherlands and their impact or outcome; while the first two parts deal with basic concepts regarding energy (kWh/m2). Student work, from both the TU in Delft as well as Wageningen will be included in the third and last part , focused on energy transition.

The areas chosen for investigation are Rotterdam, Arnhem, Noord Holand and the Green Metropolis. Within these areas energy transition will be envisioned according to different scenarios but, having as a central objective European Union's goal of 80% carbon emission reduction by 2050 (European Climate Foundation, 2010). The current project works within the frame of the studio, but maintains however its independence and freedom in terms of approach and perspective.

In this sense the research question proposed by the studio "What will the energy transition mean for spatial planning" is being maintained at an elementary, philosophical level but is rephrased in terms of approach and individual perspective on the topic.

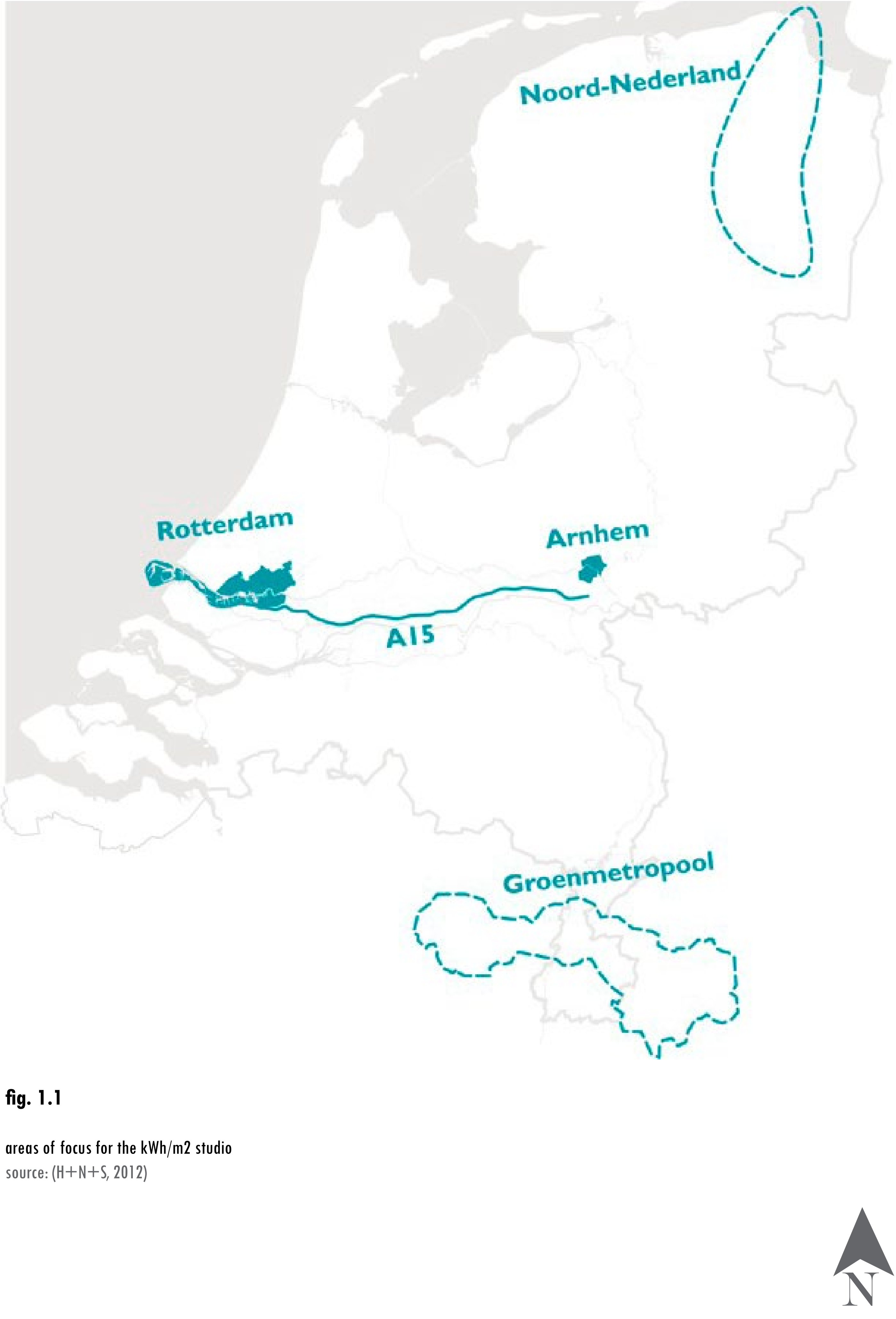



**fig. 1.1**

areas of focus for the kWh/m2 studio
source: (H+N+S, 2012)

# 1.2_ Future Challenges and Motivation

## Introduction

urbanization

By the year 2050, almost 70% of the world population is expected to be living in urban environments, and these numbers are even higher within Europe, where, 82% of the total population is projected to be housed in cities. Moreover for the Netherlands, this percentage is estimated to rise at round 90,5%compared to 56% in the 1950s (United Nations, 2012). This represents not only a staggering growth in the past 50years and in the still to come decades, but also an overwhelming shift in the living dynamics of our society. This phenomenon raises numerous questions and challenges with regards to our future, such as: how will our cities look like? And how will they cope with such an enormous pressure?

Currently the urban environment is housing some 50% of the world population (80% for the Netherlands). This means that from a total of around 7 billion people, 3.5 billion are living in urban settings, and if projections are correct, by 2050, from the total of 9.3 billion people, 7.6 billion will be relying on the city for shelter. Therefore, urban populations will more than double in the coming 40 years.

individualization

At the same time a general trend of individualization can be observed in urban environments around the world. In the Netherlands, the past 100 years have transitioned the density and home size from a average 35 square meter household inhabited by a family of 5 (two parents and three children) to an average 150 square meter household inhabited by two persons (Municpality of Rotterdam, 2012). This trend is not sustainable within our current model of urbanization and considering the projections in population growth for the next 40 years.

The impacts of such a process have implications not just on the spatial footprint of our housing areas, but, perhaps even more importantly and more difficult to identify straight away, are its effects on the urban microclimate.

**fig. 1.2**

artist impression illustrating the "parasitic" nature of humans and human life
source: http://www.seismologik.com

The problems of urban microclimate and the relative low climate robustness of our current cites is becoming more and more pressing as it starts to affect more and more people directly, in a increasingly violent way.

Our cities are having great difficulty in managing water, and providing clean water for its inhabitants. They are more and more susceptible to flooding and overflow of water drainage systems in peak rainfall, and the rainfall dynamics are expected to evolve in unfavorable way. Leading to even more rainfall in peak seasons and even less in drought periods, up to plus 14% in the winter and minus 19% precipitation in the summer  (KNMI, 2006).

urban problems

These issues have allot to do with the way in which our cities are built and designed making them ill-equipped to deal with climate issues. The problems are accentuated by climate change even with the current urban population, which is still 50% lower than projected for 40 from now, when coincidently climate change effects are also projected to intensify. If we imagine this dramatic increase in populations resulting in even more built-up space, even higher constructions and considerable decrease in urban green, and translate that in current impacts of such transformations, the urban environment runs the risk of going from being a shelter and platform for human life and interactions to a hostile environment.

## Global Energy Challenge

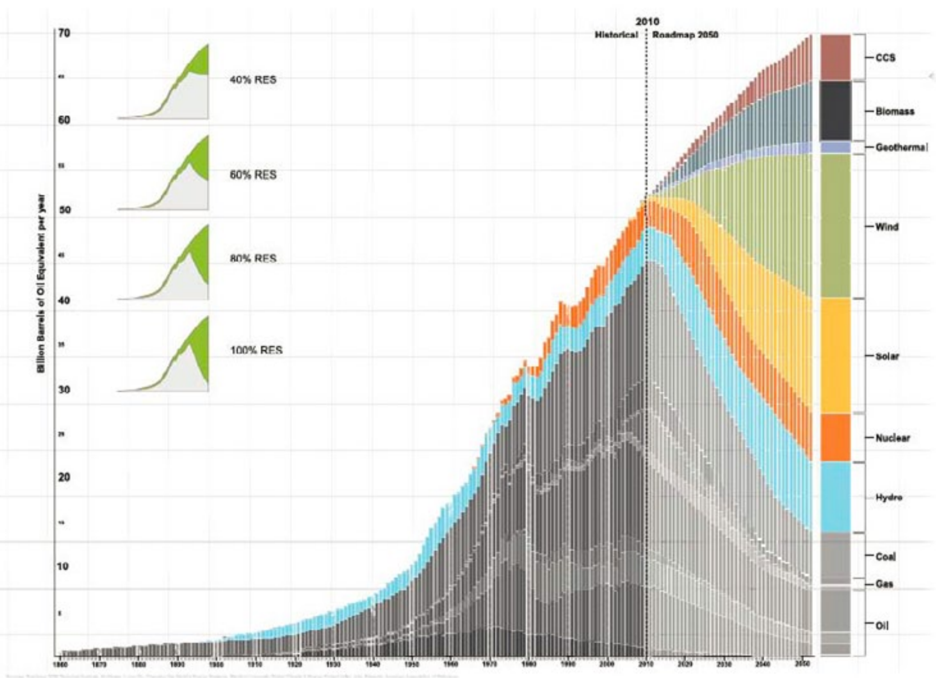
city as a sink of energy

The city, as it is today, is man's greatest sink of energy, consuming overwhelmingly more than it can generate in its current configuration. If we take into account the projected changes, its consumption is expected to skyrocket in the coming decades.

Overall, European energy consumption is estimated to be around 50 billion barrels of oil equivalent in 2010, growing to about 70 billion in 2050 (fig 1.3), with several saving policies implemented  (OMA/AMO, 2010).

**fig. 1.3**

the evolution of energy consumption in Europe and the needed shift in sources visualised
source: OMA/AMO, 2010



This all is growing from consumptions estimated around 3 billion barrels at the beginning of 1900s, which means a 2300% increase in 150 years. Translating that into a more understandable example, with the energy consumed currently in Europe we could send some 18500 rockets to Mars and back, meaning one round-trip every 30 minutes and rising to one round-trip every 20 minutes by 2050. (Citation and info graphics)

depleting resources

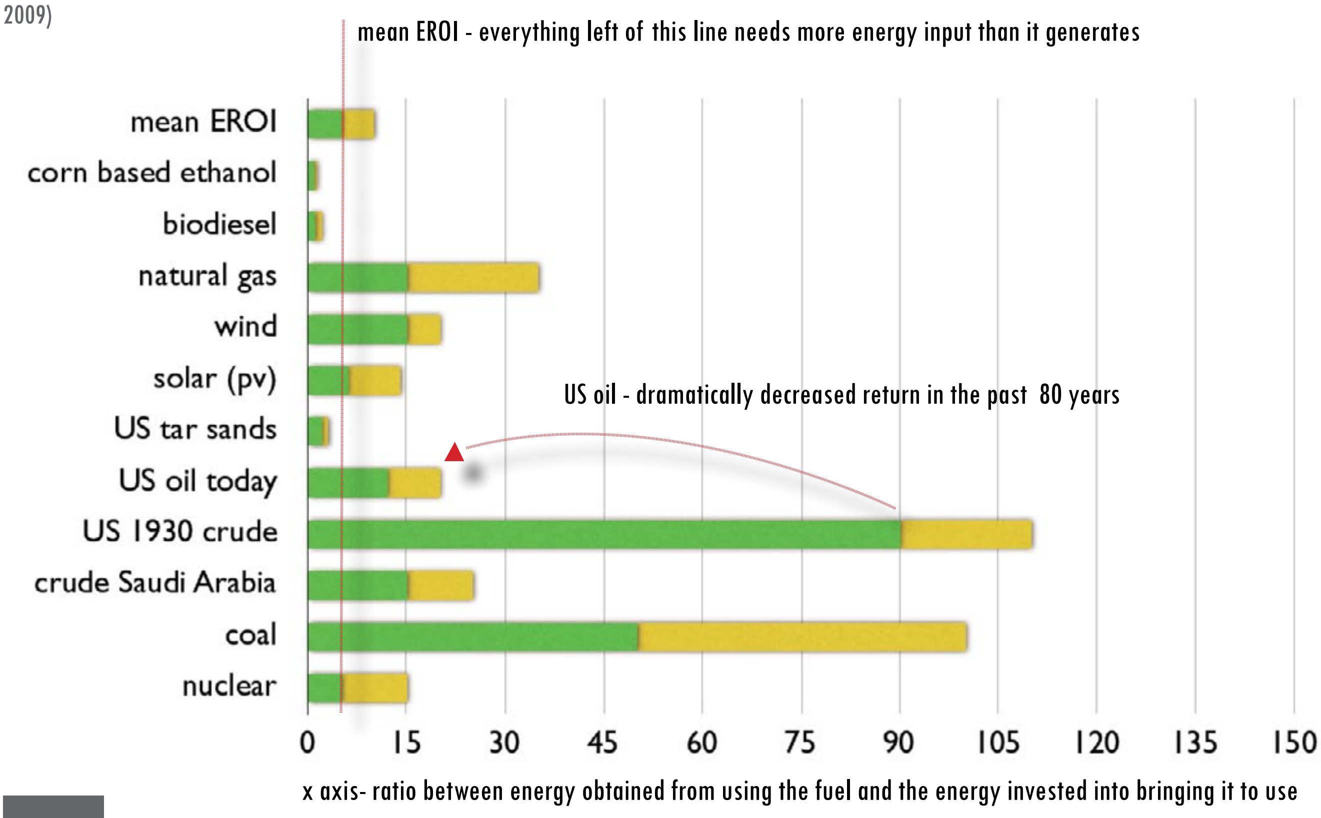
Current energy systems are based on fossil, nonrenewable sources, which are depleting. Some scientists estimate that in roughly 15-20 years the oil supply will not be enough to satisfy the demand  (Moors, 2005). The implications of the depletion of fossils become apparent when looking at the energy return on investment evolution in the past decades as well as projected trends. The necessary investments both in terms of energy and money for obtaining a unit of energy are growing exponentially. More and more money will have to be invested back into energy generation. Oil sources are becoming scarce and rigging became in the past decades an extremely expensive and dangerous endeavor, which has grave implications on human life and nature.

EROI

In 1983, a consortium of oil companies invested huge amounts of energy and around 2 billion dollars and into drilling for oil in a pocket which ultimately turned out to be empty. The investment was based on oil stains found in that area of the Beaufort Sea, and it is one of the strongest examples of the high level on uncertainty surrounding oil extraction, especially since the resource is becoming scarcer. The risks surrounding investment increases considerably, and so do the investments themselves, with drilling needing to go to deeper and deeper pockets and even further offshore. Probably even more relevant, more and more energy is put into extracting it. All these factors contributing to the gradual shift of energy return on investment for the nonrenewable resources(fig 1.4).

According to Andy van den Dobbelsteen (reference presentation -chart) the current financial crisis has saved the world from plummeting into an energy crisis by relieving the demand for oil and therefore prolonging the reaching of peak oil. Either way, the tipping point will be reached and it will happen soon.

**fig. 1.4**
EROI - energy return on investment for different energy sources
green- energy return on investment
yellow - range of uncertainty
source: (by H+N+S landscape architects, 2012 based on data from: Pimentel, 2008 & Heinberg, 2009)



geopolitical impact

There is growing concern that if the remaining sources of energy are not immediately directed towards renewable, alternative conversion techniques we might reach a point of no return, in which scenario we will not have enough resources left to power the transition.

A direct effect of this general state of uncertainty and high dependence on fossils of our economies are raising geopolitical tensions. Oil wars are a term much too familiar to our generation. Nations are fighting over the remaining sources of energy. If we continue to consume at this rate, similar tensions might be generated by clean energy as well.

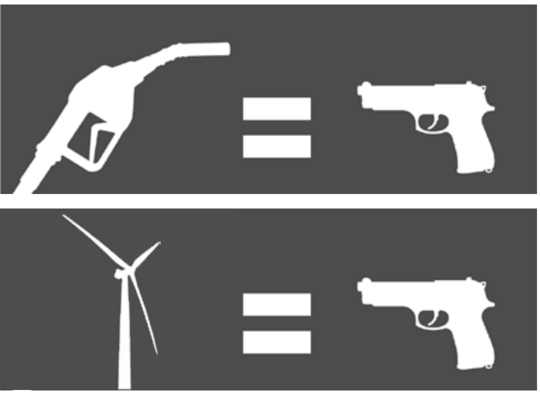


**fig. 1.5**
from oil wars to wars for renewable energy locations?
source: by the author

The potential for solar energy is higher closer to the Equator; therefore those areas will present great interest for P.V. technologies. Wind in countries like Denmark and Norway making them ideal spots for wind turbines. These site specific conditioning can have strong reverberations in our future. Who will control the Sahara desert? The continent which it is a part of, or the strongest most energy grueling nation? We might end up in a future were colonization of other nations is done for harvesting renewable energy, and that is one scenario which is much to similar to today's society if not even more gruesome(fig. 1.5). Following this it becomes clearer and clearer that energy should be first used as efficiently as possible before we go to war for something we waste so carelessly!

## Climate and Microclimate Challenge

climate change

Globally, a second set of challenges are represented by climate change and its effects. The 20th century has seen an overall increase by 0.6 degrees Celsius in global mean temperature (IPCC, 2007). This apparent small variation has enormous implications in the changing of our global climate conditions. These can span from small variations in temperature or precipitation to large scale disastrous hurricanes. In this context human settlements are becoming more and more vulnerable to the forces of nature.

cause and effects

Human activity is considered to be the main factor, causing the global temperature rise and ultimately all side-effects. The increase in percentage in the composition of the atmosphere of gases such as carbon dioxide (CO2), nitrous oxide (N2O) and methane (CH4), considered to be the most important greenhouse gases, is viewed as the major process driving climate change. To the increase in global temperature we can add a decrease in the snow and ice cover and rise of sea levels, all of which are phenomena interlinked and originating in the effects of human activity on the environment (IPCC, 2007).

As we look at the projected trends in population growth we can expect that greenhouse gas emissions could grow at an alarming rate if following the same pattern, and therefore have a dramatic impact on climate, and ultimately on the safety of our habitat. Two thirds of the cities worldwide are settled in delta areas, and with predicted sea level rise coupled with increase in precipitation the effects on urban life can be significant.

## Urban Framing

modernistic approach

The fast urbanization and housing crisis following the Second World War have left a strong imprint on the planet. Modernistic "tabula rassa" approaches to city design have proven disastrous, for the city's capacity to exchange flows with its environment. City as a machine ideologies have transitioned urban tissue from highly complex traditional cities to linear, mechanistic, entities. The interventions inspired by technological progress and innovation were to be the embodiment of man's domination over his environment. Serge Salat writes that "the 20th century could have been the century of the demise of cities" (Salat & Bourdic, 2011, p.1197).

These new and resonant views on the city, championed by highly influential figures of the time, such as Le Corbusier, have dramatically shifted the way cities are designed in way which today proves to be much too inadequately prepared to cope with contextual circumstances. It yielded cities which are "entirely given over to speed and to the ever-growing intensification of transports and energy consumption. This floating city, drifting in a territory that is too big for it, loses all urbanity, all identity, and all definition. It stops being a city" (Salat & Bourdic, 2011, p. 1197).

city as intestine

When looking at flows, one grave foresight of recent designs of cites is their linearity. Similar to a production line, the city consumes flows (of energy, resources etc.) and generate entropy. According to Salat flows and form mutually influence each other, and therefore the manner in which cities are design has strong implications on its flows. By this line of thought there should be something fundamentally wrong embedded in the morphology of most of our cities.

Jane Jacobs first touched upon the issue of urban complexity, referring to modernistic design when stating that "Cities happen to be problems in organizational complexity, like the life sciences. They present situations in which a half-dozen or even several dozen quantities are all varying simultaneously and in subtle interconnected ways" (Jacobs, 1961, p. 433).

morphological issue

This fundamental, problem is elaborated and articulated in morphological terms by Salat when writing that "The major problem of the contemporary city is the disconnection between scales. The 20th-century technicist urban planners who ignored the fractal structure of historical cities divided the city into two spatial scales dedicated to two types of relations and behaviors: the greater metropolitan region traversed and structured by large transit infrastructures dedicated to speed and summarily zoned; and the neighborhood, celebrated as the building block of the sustainable city, when its concept, boundaries and limits remained blurry and ill-defined." (Salat & Bourdic, Power Laws for Energy Efficient and Resilient Cities, 2011, p. 1197). This disregard for scale hierarchy is apparent in modernistic city morphologies and according to Jacobs and Salat it could very well be the route of both socio-cultural issues and energy problems which arise in modern urban settings.

landscape approach on city design

In the late 70s a new, but still fragile view on urban environments started to take shape, which is that of city as an organism. With such an approach the city should follow, or abide by the same rules the natural world around does, in order to thrive in its surroundings. In this context, landscape architecture, or even more so, a landscape approach to design and planning become vital contributors to the future of our cities, if there is to be any at all.

The city should be adaptable to change, if we were to look at Darwin's view on the survival of species. Dr Leon C. Megginson, paraphrased Darwin's writings in Origin of SPecies under the heading:

"According to Darwin's Origin of Species, it is not the most intellectual of the species that survives; it is not the strongest that survives; but the species that survives is the one that is able best to adapt and adjust to the changing environment in which it finds itself." (Megginson, 1963, p 4)

In an ecological landscape based approach, the city is transitioned from a linear (conveyor belt) system to a system in which as many cycles as possible are closed and where pollution and waste are minimized. In this way the city becomes more robust and versatile organism, which benefits from far more energy flows and its overall network is becoming complex rather than linear. Salat compares this eventual versatility of the city with a leaf instead of a tree (Salat & Bourdic, 2011).

# 1.3_ Aim of the Thesis

“Whereas in the past the human preoccupation has been mainly the struggle to carve out a niche in the biosphere, that quest now threatens the very conditions for sustaining human life. We have taken on a lot of responsibility without knowing how to go about it” (Röling, 1997, p. 248)

reflexive modernity

The dynamics of the changes described in previous sections are all crucially influential, not just for the human habitat, or for nature and the environment but for society as a whole. We are essential transitioning trough different states of modernity, in societal terms, from pre modernity to simple modernity and ultimately reflexive modernity, which is defined by reflexive society (Beck, 1992). We are now at a point were the action of the past century, our so called “carving” into the biosphere is proving to have a very different reaction than expect, and therefore as a society we are reacting to there challenges. This new stage in social development “is now faced not with the problem of harnessing or controlling nature for the benefit of humankind but essentially with problems resulting from techno-economic development itself”(Beck, 1992, p. 19).

Within these highly complex circumstances, landscape architecture should aim at investigating possible means by which it can aid society in the transition. The goal should not be at directing or imposing but rather facilitating, and, in order to be able to successfully do that, we must first understand the underlying factors of the dynamics. A comprehensive understanding of fundamental needs and goals as well as of the social and cultural processes which derive particular sets of needs, and the way in which they interact.

This is to say that the urban environment must be understood both in terms of basic provision, regulating needs, as well as social and cultural interactions. In this sense the two categories represent on the one hand chemical interactions and on the other behavioral patterns.
Röling, writes that these two sets of dynamics are strictly inter-conditioned and interconnected to the point were they generate concept referred to as the “soft side of land”(Röling, 1997).

ecosystem services

Ecological or ecosystem services, best describe the human dependence on the biosphere, in a way which is quantifiable. The term is used for all direct and indirect benefits that people derive from the biosphere (Röling, 1997). It encompasses fundamental resources and services such as drinking water, food, space, air, carbon sequestering and even beauty. This concept is important to consider when designing or planning new ways of dealing with current crises in energy or climate, as any outcome will have to address these points if it is to touch upon a fundamental issue of human life on earth; that of its stainability. “One could say that sustainable land management refers to the capacity of land users to maintain the ecological services of the land”(Röling, 1997, p. 248).

Röling also points out that this type of view can have its downfall as it oversimplifies the notion of biosphere up to the point were it can be viewed as “an industry called biosphere” (Röling, 1997), from where people by produce similar to other industry. This simplistic view is not capable of providing adequate solutions.

Human life has grown to the point were it impacts a large part of the biosphere; large enough that it appropriates 40% of the potential terrestrial net productivity (photosynthesis) (Röling, 1997). The question rising from this, is weather the biosphere will be able to still support human life with the current projected trends in population and urban dynamics.

risk society

The focus has now shifted from humans trying to control forces of nature to humans trying to control human activity. In a sense human activity has now evolved into a seemingly unstoppable force which is threatening human life and the planet's ability to sustain it. Beck (Beck, 1992) refers to this contextual situation as "risk society", translated by Rölling as a "society in which a generalized uncertainty, with respect to issues for which the stakes are high, leads to the need for widespread reflection on the future." (Röling, 1997 p 249).

In light of this, Rölling underlines the importance of social sciences, human behavior and human need in the dialog for sustainability and sustainable land use. Ecosystems are "complex, non-linear, chaotic, self-organizing, non-equilibrium and discontinuous" (Röling, 1997, p. 248), while cities have become oversimplified, linear (Salat & Nowacki, 2010), designed, structures based on equilibrium.

land+people

Within this context, the aim of this thesis is to research potential landscape architecture means of negotiating the interaction between man and nature in the sense described above.

Not as an idyllic image of man immersed in the heavenly utopian nature, becoming one with its environment, but in the very pragmatic realization that our built structures are fundamentally colliding with their environment and it is worthwhile to explore weather or not this dream symbiosis with nature will ever be possible, given the current state of human activity impact, and the current modes of interaction with the surrounding.

# 02 THEORETICAL FRAMEWORK

## 2.1_ Ecosystem Services and the City

Millennium Ecosystem Assessment

Ecosystem services are roughly defined as benefits we draw from the biosphere (Röling, 1997). The Millenium ecosystem assessment report, makes a structure of the ecosystem services which have a nexus with life on earth (biodiversity). The report defines three types of services in this sense:

**Provisioning services:**

- Fresh Water
- Food
- Timber, Fiber, and Fuel
- New Products and Industries from Biodiversity

**Regulating and supporting services:**

- Biological Regulation of Ecosystem Services
- Nutrient Cycling
- Climate and Air Quality
- Human Health: Ecosystem Regulation of Infectious Diseases
- Waste Processing and Detoxification
- Regulation of Natural Hazards: Floods and Fires

**Cultural services:**

- Cultural and Amenity Services

One of the remarks put forth by the report is the fact that "human well-being, by several measures and on average across and within many societies, has improved substantially over the past two centuries and continues to do so. The human population in general is becoming better nourished. People live longer, and incomes have risen" (Millennium Ecosystem Assessment, 2005, p 2).

human impact

At the same time, this general well being increase is done at the expense of the ecosystem and there is starting to have repercussions on life. “In part these gains in well-being have been made possible by exploiting certain ecosystem services (the provisioning services, such as timber, grazing, and crop production), sometimes to the detriment of the ecosystem and its underlying capacity to continue to provide these and other services” (Millennium Ecosystem Assessment, 2005, p. 2).

sustainability

The ecosystem capacity to continue to provide the services human life depends upon (weather directly or indirectly - fig 2.1) is a vital part of sustainability. In the context of the previously described reflexive modernity chapter in human evolution and furthermore when discussing risk society and human life’s capacity to alter its surrounding environment dramatically, the concept of ecosystem services becomes of essence.

Therefore when designing for the future, the inclusion of consideration for ecosystem services is a “must have” component of any plan. (if sustainability is considered).

In all the following trials and approaches, the services provided by the ecosystem and its carrying capacity will be addressed. This is done both to explore the maximum potential for sustaining human life of different ecosystems and at the same time to acknowledge the impact our daily lives have on the ecosystem we rely upon.

**fig. 2.1**
ecosystem services and human population interconnected
source: WWF living planet report 2012

# 2.2_ Thermodynamics

## Towards a temporal understanding of urban flows

## Second Law Thinking

Thermodynamics is by and large the science of energy. The term originates from the Greek "therme" and "dynamics" (force), describing the trials of turning heat into power (Dincer & Cengel, 2001). Today naturally the meaning of the term has grown broader and encompasses considerably more than what the ancient Greek understanding of thermodynamics was. The science of thermodynamics is structured by its two fundamental laws:

first law
quantitative

The first law of thermodynamics (FLT) –This law deals with the conservation properties of energy and states that energy is a "thermodynamic property" (Dincer & Cengel, 2001), and it can change from one state to the other in any given moment but, the general quantity remains the same. In this sense we can refer to this as a quantity related law.

second law
qualitative

The second law of thermodynamics (SLT) – While the first deals with quantity the second law deals with the quality of energy, and this difference is paramount for the global energy system of today. It is stating that while energy might by conserved in the quantitative sense it is losing "work capacity" in going from one state to the other.

This understanding has led to the definition of terms such as entropy and exergy which help quantify the work capacity of energy (Dincer & Cengel, 2001).

These laws reveal the fact that energy in a qualitative sense is very vulnerable: "[…]all processes on earth consume 'useful' energy to release 'les useful' energy to the system[…]" (Stremke, Dobblesteen, & Koh, 2011)

### Exergy

The concept of exergy can be defined as the maximum amount of work that can be produced by a steam of mater, heat or work as a medium comes into equilibrium with the reference environment (Dincer & Cengel, 2001).

exergy

The reference environment, is in our case the thermal properties of the surface environment of the earth. Therefore, any resource which is found beneath the earth surface, or in a state which is characterized by a temperature higher or lower than the environment are not in mutual stable equilibrium (Dincer & Cengel, 2001).

When these resources are extracted, their medium comes into equilibrium with the reference environment and thus produce exergy, their work capacity depending on the difference between the state of the carrier and its environment (Stremke, Dobblesteen, & Koh, 2011).

## Entropy

entropy

Entropy is regarded as a measure for the state of disorder of a system. Dincer and Cengel refer to entropy, in the modern context, as being "fundamental for understanding the thermodynamic aspects of self-organization, evolution of order and life that we see in nature." In the case of an isolated system the energy increase is zero, and, entropy increases until reaching "thermodynamic equilibrium" (Dincer & Cengel, 2001).

In this state, all irreversible processes stop. When a system is driven away from thermodynamic equilibrium, by outside factors, and the system begins to exchange entropy with the exterior, then the irreversible processes begin to operate, and entropy is being exchanged due to exchange of heat and matter. A possible example of this is mixing of materials; manure with water, paper with household waste (Stremke, Dobblesteen, & Koh, 2011) etc. The entropy flowing out of a system is always larger than the entropy flowing into the system. (Dincer & Cengel, 2001), so in this sense we can state that the quality of energy is always decreasing within such processes. This is an important conclusion to factor in and is one of the core driving factors of Second Law Thinking in planning and design.

As mentioned before, the first law of thermodynamics states that energy is always conserved, but this is merely from a quantitative standpoint, while from a qualitative view ( second law of thermodynamics) it is being converted from high-grade energy to low-grade energy (Stremke, Dobblesteen, & Koh, 2011). From this Stremke et al. elaborate on the importance of Second Law thinking in the design process, as a set of guiding principles to help generate more energy efficient, sustainable systems.

In this sense they provide a set of exergy-conscious strategies for planning and design, on the basis of innovation areas, that are applying second law thinking such as Engineering Thermodynamics (ET) and Industrial Ecology (IE):

exergy conscious strategies

1. Increase exergy efficiency (heat recovery systems)
2. Decrease exergy demand (building orientation, passive housing)
3. Increase the use of residual exergy (residual heat for room heating)
4. Match quality levels of supply and demand (cascade)
5. Increase assimilation of renewable energy (geothermal)

## SLT and the City

entropy and time

Ricardo Pulselli writes: "the second law is proof of passing time and increasing entropy, like the sand flowing in an hour-glass, an inexorable cosmic clock that drives one-way evolution of the universe. Total universal entropy is greater at any time than it was the instant before. Dissipation due to irreversible propagation of heat is an evolutionary component that not only measures the passing of time but also indicates the irreversible direction of evolution of the universe and of all isolated systems towards a flat, uniform state, devoid of differences and exchanges" (Pulselli & Tiezzi, 2009, p. 12).

He also observes that biological systems have a tendency to apparently go against the fundamental principles of the second law of thermodynamics, developing towards lower entropy and away from equilibrium, "as witnessed by the appearance of biodiversity, distinct ecosystems, organization and information" (Pulselli & Tiezzi, 2009, p. 12).

dissipative structures

In this sense we have two fundamentally different worlds (in what SLT is concerned), merged together. On the one hand there is the human habitat, governed by second law principles, above all high entropy and tendency towards equilibrium, while at the biological world is apparently governed by "chaos". Where these tow systems are able to exchange flows of energy resulting in a matching of the order within a system with disorder of the environment, they generate so called dissipative structures (Pulselli & Tiezzi, 2009; and Stremke, Dobbelsteen &Koh, 2011). This type of structure consumes and assimilates "resources in the form of mater and high quality energy , drawing form external sources and self organizing; at the time it releases wastes and degraded energy into its environment" (Pulselli & Tiezzi, 2009 p. 14).

dissipative cities

In doing so these structures can derive order from chaos and maintain entropy levels constant, around minimum value. Along these lines the city system juxtaposed with nature has the possibility to generate such structures. There is however one importance condition which our cities do not abide by. The entropy produced by its internal process (positive variation) must not exceed the negative variation made possible by the exchange with the outside.

"Our cities physical systems in contact with various sources and sinks" (Pulselli & Tiezzi, 2009 p. 21). The city makes use of the flows of energy coming in to maintain its current structures. Pulselli et al. conclude that if the city was a isolated system with no energy coming in its structures would be abandoned and fall into ruins.

ecosystem grounded

Currently our cities are statements of the current economic model, a model which Nicholas Georgescu-Roegen described in thermodynamic terms. He states that "infinite economic growth contradicts the basic laws of nature" and that "the reversible and circular representation of production and consumption in the economic system needs to be replaced by an evolutionary version of the economic process within biophysical context that supports it". (Georgescu-Roegen, 1976). Put differently the economic system or the city is an open system which receives input (energy , resources etc.) and generates waste (high entropy). The bigger the system the greater the need for absorbing resources and the urgency to part with the waste.

Therefore, as Pulselli et al. observe, the economic system or city must be coherent with the thermodynamic constraints imposed on its environment. It must be grounded in the ecosystem services on which it rests (Pulselli & Tiezzi, 2009). By these factors cities should be highly grounded in their surroundings , and not depend on imported resources. Such a system will most definitely collapse at one point in time as it is not aware of the carrying capacity of its environment.

## Discussion on SLT

When discussing second-law thinking, Stremke et al. write "From the literature research, it became clear that second-law thinking not only offers explicit principles for the exergy-conscious organization of the human environment, but also helps to unravel the complex socio-ecological systems that spatial planners, landscape architects and designers are concerned with" (Stremke, Dobblesteen, & Koh, 2011, p. 167).

In light of energy grades, revealed by SLT, the approach on planning and design becomes paramount, and not just when discussing renewable energy sources, but fossils as well. "A thermodynamically optimized power plant may still run on fossil fuel" (Stremke, Dobblesteen, & Koh, 2011, p. 168), and therefore thermodynamical optimization should frame renewable and fossil energy systems alike. Especially in the context of energy transition, and the difficulties it raises in terms of economy, society, and policy. Thermodynamical optimization should come as a exergy demand reducing action as well as platform for integrating renewables (Stremke, Dobblesteen, & Koh, 2011).

In the context of resource depletion and the overall discussion of energy efficiency Second Law Thinking is without a doubt a crucial component. We could say that we have been living in a world assumed to be guided by First Law Thinking (nothing is lost!). Even going so far as to assume that development weather economical, industrial, technological or societal will be dictated by the rate we consume resources. Second Law Thinking comes as a reality check, in the sense that it reveals energy in terms of quality and frames the concepts of exergy and entropy. Furthermore when discussing the robustness of city wide energy networks energy grade becomes very important and is crucial in optimizing streams, linking waste cycles and pairing up functions in order to achieve efficient and robust structures.

# 2.3_ Constructal Theory

## Constructal Theory and Energy Flows

Second Law thinking and the guidelines formulated by Stremke, Dobblesteen & Koh, are translated into different relevance levels on different scales. For example increasing exergy efficiency is more relevant on a building scale, while increasing assimilation of renewable exergy has as focal scale the region (fig 2.2). Starting from this, the assumption is that, put together they could generate efficient energy system that works its way through scales.

**fig. 2.2**
exergy conscious interventions for planning and design of the built environment
source: Stremke, Dobbelsteen & Koh, 2011

| Exergy-conscious strategy | Building component | Building | Neighbour-hood | City | Region |
|---|---|---|---|---|---|
| 1 Increase exergy efficiency (e.g., heat recovery systems) | *** | ** | * | * | * |
| 2 Decrease exergy demand (e.g., building orientation and passive house) | * | *** | *** | * | * |
| 3 Increase use of residual exergy (e.g., residual heat for room heating) | * | ** | *** | *** | ** |
| 4 Match quality levels of exergy supply and demand (e.g., cascade) | * | ** | *** | *** | ** |
| 5 Increase assimilation of renewable exergy (e.g., geothermal) | ** | ** | *** | *** | *** |

*Less relevant
**Relevant
***Focal scale.

flow configurations

These are still energy related guidelines and have no perceptible translation into physical patterns or shapes. Bejan states that classical thermodynamics are only concerned with their state of equilibrium and not with the "configurations occurring in its non-equilibrium (flow) state[…] the first and second laws (of thermodynamics) speak of a black box. They say nothing about the configurations (the drawings) of the things that flow." (Bejan & Merkx, 2007, p. 2). How would an increased assimilation of renewable energy look like?

In order to try and answer this, principles of Constructal law are used and translated into design and planning terminology. Bejan (Bejan, 2010) remarks that if we look at cities, villages, and any type of human settlement in terms of systems. Complex systems, interrelated, that use energy, on all possible layers; from heating homes, to vehicle transportation and even at an individual level to move trough the landscape. Second law thinking as stated above provides principles of how these systems should deal with energy. But how should they behave? (Bejan, 2010)

constructal law

The Constructal Law deals with systems from a thermodynamic standpoint and analyzes the evolution of systems towards more efficient, mature organisms. Looking at the current global energy system we can drive a set of statements:

- The world is a finite system powered by energy. (different scales and subsystems – continent/state/region/city etc.)
- (Current)Energy resources are finite – and thus must be used efficiently.
- The issues of system survival or risk become more and more relevant.

modern city to fractal city

The constructal law states that for a system (global/continental/regional etc.) to survive it must be allowed to evolve in such a way that it can morph into a state where it can easier access the energy flows within (Bejan & Lorrente, 2004). "For a system with fixed global size and global performance to persist in time (to live), it must evolve in such a way that its flow structure occupies a smaller fraction of the available space." (Bejan & Lorrente, 2004). This, as observed by Serge Salat is a feature that is going against the trend of the past century in urban development.

In short, in order to provide quick access to energy flows cities should evolve towards more complex forms, but the actual phenomenon is that of simplification. (Salat, Bourdic, & Nowacki, 2010).

Modernism has treated the city as free standing objects of architecture, an approach which is reverberating through time and is making its impact felt on many levels but probably none as acute and disastrous as energy efficiency. By segregating functions, increasing distances and up-scaling units, the city essentially makes it harder to access energy flows.

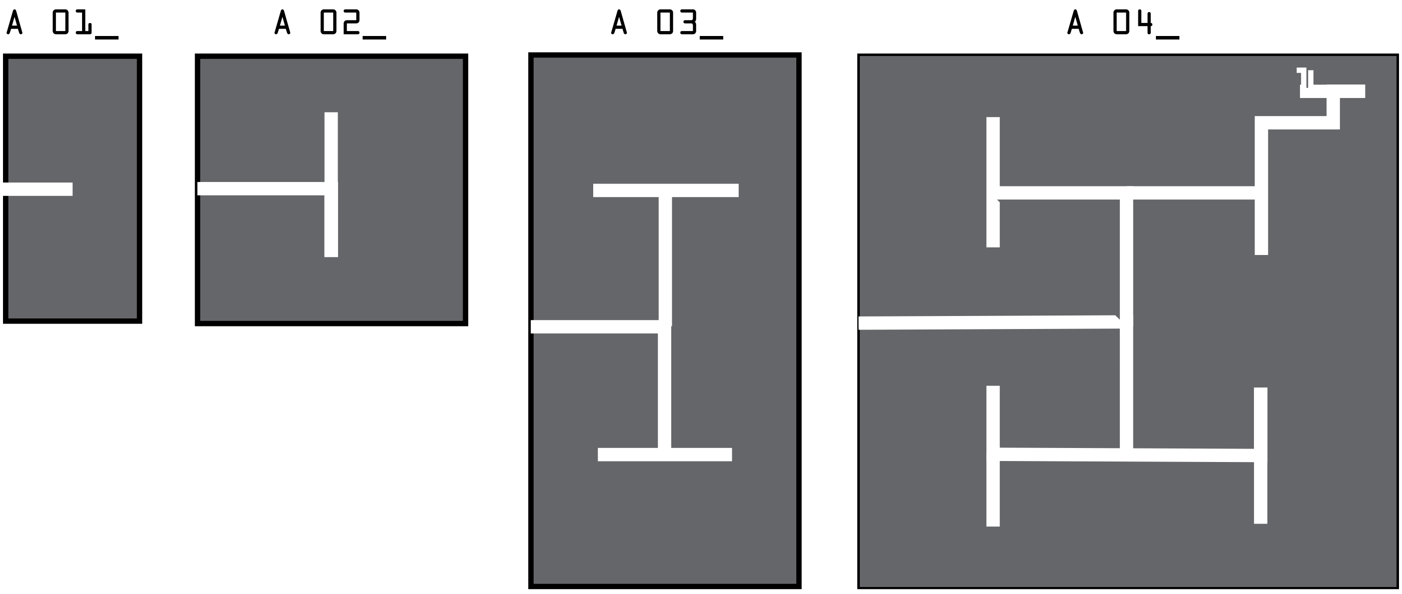



**fig. 2.3**
optimal flow geometry as described by consturctal theory
A01 to A04 describes the optimal evolution of street patterns -growing complexity
source: by the author, based on (Bejan,2010)

Bejan's constructal law states that a thermodynamically mature system should have a flow structure that occupies a smaller fraction of the available space, and according to this statement we can conclude that the current, or modernistic approach to the city has made it impossible for the urban system to survive in time, from a thermodynamic perspective.

The constructal theory approach on urban patters describes a self-organizing system which evolves similarly to a fractal in order to dissipate new functions and units in the landscape. This according to Bejan is the optimal development pattern for robust urban systems. Moreover the pattern described is from the start resembling a fractal structure. Bejan states with regards to transportation that, according to constructal theory, there should be many small slow moving entities and few large fast moving entities. (Bejan, 2010). This statement is closely linked with fractal distribution and moreover with the inverse power law as a mean of quantifying and describing the fractal distribution. In this sense the theory of fractals could add a new dimension to constructal law in the sense of quantifying and verifying. When dealing with energy fractal structures tend to generate intense information fields at any distance, and furthermore presumably also lead to local equilibrium. (Salat, Bourdic & Nowacki, 2010).

fractal city

$$p = \frac{C}{x^m}$$

**fig. 2.4**
inverse power law
There are p units of the size x, while m is the fractal dimension and C is constant

source: based on (Bejan,2010)

These structures are visible in ,any aspects of natural life, such as lungs, blood vessel systems and even river patterns. So if constructal theory states that: "For a finite-size system to persist in time (to live), it must evolve in such a way that it provides easier access to the imposed currents that flow through it." (Bejan & Lorrente, 2004), at the same time fractal distribution of elements within a system "provide an intense information field at any distance" (Salat, Bourdic, & Nowacki, 2010), then we could conclude that, for a finite system to persist in time (energy wise) it must evolve in such a way that it follows scale distribution according to fractal geometry. Thus the elements in the system (be that a urban fabric) should according to this statement evolve according to inverse power law rules (West, Brown & Enquist, 1997)(fig 2.3 and 2.4).

## Constructal Theory and the City

The issues raised above an discussed are focusing on energy, on how systems should develop in order to survive, which can also be understood as making as good use of energy as possible. But how does that relate to the urban structures? How can constructal theory provide a framework for designing for cities?

evolution

Bejan, explains using constructal theory principles, how, this theory can account for the evolution of different living organisms, and to explain how the way in which energy is translated into shapes makes different organisms better suited for different means of movement. This is essentially a thermodynamic approach to form generation and how energy flows shape that form. The theory considers flight, running and swimming as main forms of animal movement, and applies its principles to predict the way in which each animal evolved. Moreover its goes to contradict Stephen Jay Gould, who said that if the clock of evolution would be reset and the process restarted animals would evolve in very different ways (Bejan, 2010). The theory, does not attempt to suggest that evolution would yield the same organisms, mainly due to the high uncertainty and degree of chance surrounding the process, but does however state that it can predict with a high degree of certainty that from a thermodynamic standpoint, some main features would be kept, regardless of how many times the process is repeated (Bejan, 2010).

He writes "One of the basic goals of any design—whether it is an animal, a building, or a machine—is to get maximum output for minimum fuel or food (useful energy, exergy). This design principle can be seen, for example, in the tree-shaped flows of river basins, lung structure or the cracking pattern of drying mud flats, in the tube shape of pipes, or in the height versus depth proportionality in the cross sections of rivers. All of these designs allow for the maximum throughput of material with the least flow resistance." (Bejan, 2010, p. 22). This is touching upon the same issues such as the dissipative structures described in the previous chapter. Mainly it describes ways in which systems or organisms could evolve so that they reach the entropy balance needed with their environment, and therefore becoming dissipative structures, and maintaining inner entropy levels constant (around 0) .

urban morphology

Urban morphology is also a process of form generation, conditioned by a variety of factors. Many of these, especially when talking about modernistic (tabula rassa) city design, have nothing to do with the surrounding environment or landscape, but more to do with the machinists view on the city. They are conditioned by industrial world specific guidelines. (street patterns for car traffic etc.)

microclimate

The urban microclimate climate has many aspects, spanning from wind dynamics, to vegetation, water and so forth. These structural aspects, so much routed in the existing landscape are not major defining elements of urban morphology, although they play an important role in regulating entropy levels. (wind cools off buildings that are using energy to heat up). Bejan makes clear the importance of morphology when discussing energy efficiency and thermodynamics optimization of flows. This can lead us to conclude that city morphology should be structured by many other factors than currently if it is to be grounded in the ecosystem services of the site it occupies. To make clear how urban morphology can be structured by elements of climate and landscape we can take wind dynamics as a example. Wind dynamics are at their core following laws and rules of fluid physics (Bottema, 1993). In this sense we can see the wind dynamics of flow around different objects in the urban geometry, as being the same as if they would be immersed in a fluid.

constructal theory and form

This understanding is very important for the link with constructal theory. In short, fish, have been, historically believed to not be bounded by the same gravitational constraints as terrestrial animals. Regarding this constructal theory says the opposite; meaning that although immersed in fluid, fish, in order to move forward need to dislodge a volume of water equal to their body volume, according to Archimedes' law. So fish are technically lifting water as they move. Along these lines, constructal theory accounts for the way fish evolved with arguments of energy efficiency saying that they developed in such a way as to be able to distribute energy through their body in a way that makes them more efficient in moving forwards.

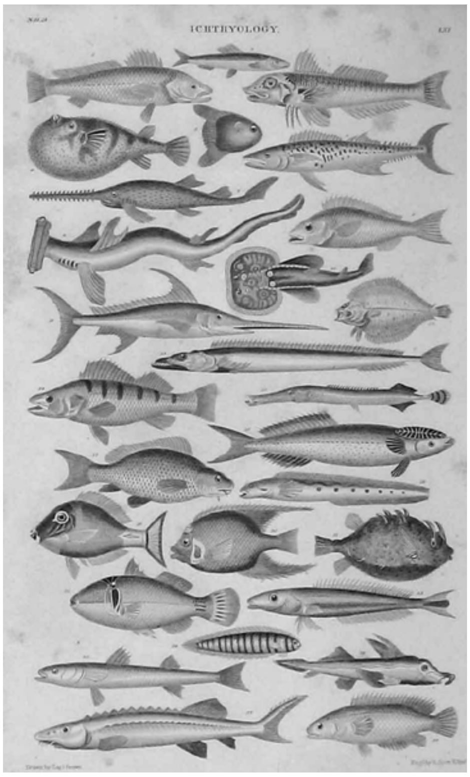



**fig. 2.5**

fish species - illustrating high degree of variation within the same guidelines of flow optimization

source: www.oldprint.com

Now a building could be imagined as an organism, let's say similar as a fish. In this case we can say that the current building shapes largely rectangular represent a primary evolution stage of the organism. If wind dynamics are similar to fluid dynamics, then the movement of the fish trough water, can be compared to the movement of air around the building, so in this sense, if energy is important, according to constructal theory the building should "evolve" in such a way that it makes it easy to distribute energy to all its points. Therefore, areas of the building which are in areas of high wind speeds and thus generally cooler should disappear over time, if heating is an issue.

This of course is just one issue and the process can be repeated when considering cooling or when daylight is important, only then different parameters are used (such as sunshine etc. ). Figure 2.4 illustrates that when additional conditions are included outcomes vary largely although abiding by the same basic principles.

Moreover there are different sizes of buildings in different locations, which ideally should be distributed according to the inverse power-law. Bejan stated related to locomotion that according to constructal theory you should have many small and slow moving entities and few large fast moving (Bejan, 2010). At the same time wind dynamics occur differently around different objects. For example the "small, many and slow" (Bejan, 2010) entities can be viewed as low rise, small sized buildings (residential) around which the wind dynamics are generally relatively slow and confortable, while the "big, few and fast" (Bejan, 2010), could be seen as high rise large buildings (office, industry etc.). Now the principles of constructal theory in the case of urban geometry and wind dynamics are more relevant for the large and few (the high-rise buildings can cause wind turbulence, higher wind speeds etc.), which incidentally consume more energy.

conclusion

The main conclusion that constructal theory could provide when considering urban geometry, is that, if wind dynamics tend to be important, then, perhaps, fish movement, form and fluid dynamics could be a good start to begging mimicking shapes and testing out different approaches. This should according to constructal theory lead to higher energy efficiency within the system (i.e. building), and according to Bottema it should also lead to a better street microclimate (less turbulence, better ventilation etc.) (Bottema, 1993).

## Discussion on Constructal Theory

Constructal theory, similar to biological organisms, is apparently contradicting thermodynamic principles, mainly the second law and understanding of entropy, as it argues that systems can evolve towards more complexity rather than a classical understanding of going towards equilibrium and thus increasing entropy.

criticism

In this sense some of the criticism towards the theory is related to the increasing of complexity and the fact that this does not always generated more flow efficiency (Kuddusi & Egrican, 2008). Concluding their research Kuddusi and Egrican state that "Fourteen different constructal theory applications involving tree shaped flow networks are reviewed with the purpose to check whether an increase in branching (complexity) of tree shaped flow network leads to an increase in flow performance or not? In other words, the review aims to answer the question; does the evolution model of constructal theory in increasing the branching (complexity) of tree shaped flow networks through the sequence of constructal designs, namely, elemental volume, first construct, second construct, . . . , improve the flow performance? The review supported the conclusion of Ghodoossi :"constructal theory will not necessarily improve the flow performance if the internal complexity of the flow area is increased . . . In contrast, the performance will mostly be lowered if the internal complexity of the flow area is increased."" (Kuddusi & Egrican, 2008 p. 1294).

This conclusion is largely following basic thermodynamic principles and therefore could be the obvious critique to consturctal theory. However living organism are also not growing along these lines. As discussed before thermodynamic understanding of decreasing in complexity does not explain how biodiversity and ecosystems come to be in nature and how they can thrive instead of collapsing.

addressing weakness

Another possibly more important point of criticism is that constructal theory is to broad and unclear to constitute a proper theory (Ghodoossi, 2003). Ghodoossi agrues that the general character of constructal theory makes it hard to be equally relevant in all fields it aims for and at the same time maintain its general coherence as a theory. This could be one of the reasons previous criticism regarding increasing complexity and entropy are emerging.

However this could be countered by support from alternative theories or approaches which are dealing with similar issues. Therefore if, it a specific area there are other theories concluding the same things as constructal theory it could be considered valid to state that its arguments in that specific field are correct.

# 03 ROTTERDAM REGION

introduction

Rotterdam, the second largest city in the Netherlands, has a population of roughly 600.000 inhabitants and is one of the largest port cities of the world. Its setting, both landscape wise as well as historical contextual development make is one of the most interesting cities to study, especially in regards to energy, and the current energetic market. The region has been historically closely interlinked with energy form the time of extensive peat workings (Lambert, 1985) to the immense oil refineries of today. Essentially energy generation, conversion and transport is one of the most drastic contributor to the current spatial and morphological configuration of the area.

## 3.1_ Building Rotterdam

### History, energy and agriculture

The initial emergence of Rotterdam as an important trading node came after the fall of Antwerp to Spain in 1585. These circumstances stimulated the growth of both Amsterdam and Rotterdam (Lambert, 1985). "Rotterdam grew as a herring port, and then, with the arrival of refugees, developed an important trade in tobacco. It dealt also in coal and lead from England and about the 1650s began to assume its role as a trans-shipment point for traffic along the Rhine; industries based on imported raw materials. Such as distilling and shipbuilding, began to spread along its waterfront" (Lambert, 1985 p. 201).

peat digging and dredging

The Western Netherlands area, and implicitly the Rotterdam region as well, have, been, historically shaped by energy, in the form of peat digging and dredging.
The great demand of energy in Delft, Gouda or Harleem, for potteries, breweries metal industries and so forth resulted in the emergence of peat extraction techniques to power the economy.

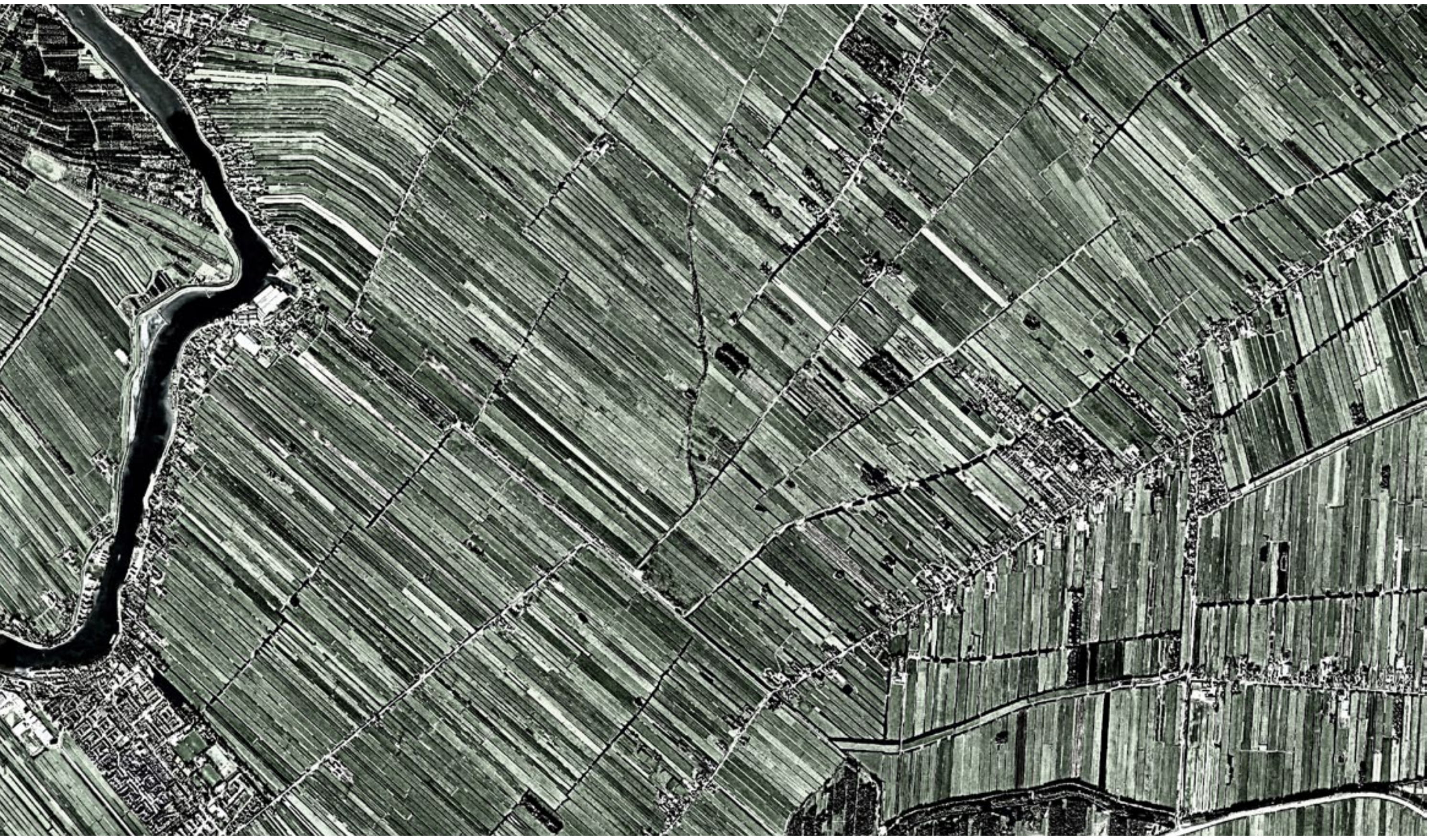


**fig. 3.1**
energy shaped landscape
elongated strips as a result of peat extraction
source: based on satellite image from google

"Originally peat dug from the drainage ditches of reclaimed area sufficed [...] by the fifteenth century new methods were introduced to meet the growing urban demand (i.e. digging) […] Then, c. 1530 peat digging was replaced by the even more destructive peat dredging, slagturven or moeren" (Lambert, 1985, p. 186-187).

impact on the landscape

These techniques had great impact on the landscape, due to their destructive power as well as regulations imposed to counteract their impact. In order to mitigate the effect on the lad pet dredgers were required by regulation to leave long strips of predefined with between workings and then reclaim the dredged areas(Lambert, 1985). Nevertheless this period has vast impact on the landscape. Numerous large water bodies in Utrecht and Holland date to this period and are currently acting as bird sanctuaries or recreation areas (Lambert, 1985). Some of the areas heavily damaged by the dredging practice were later on reclaimed during the droogmakerij. The Oostmeer in Delfland being the first true droogmakerij in 1614 (Lambert, 1985). Currently Rotterdam metropolitan area, and specifically the Port of Rotterdam is housing some of the largest oil refineries in the world, such as Shell in Pernis, it is the most important European gateway for coal, and handles large quantities of crude oil yearly (PortAuthorityRotterdam). This emphasizes as mentioned before the area's strong bond with energy generation technologies in history and their direct impact on the landscape. Peat dredging shaped the landscape in elongated strips (fig 3.1) similar to how oil transport and refining shaped the port itself as well as the area around it.

agriculture

Apart from energy, the area has a strong historical link with agricultural production, and even more so, with innovation in agriculture (Lambert, 1985). The Westland district grew in the 1800s to be the Netherlands's most important area of market gardening.
The historical dredging and its impact on the soil resulting in a mixture of peat, sand an dung (from controlled and regulated workings) made the area suitable for agricultural production. What is even more interesting is its link with invasion.

**fig. 3.2**

agriculture shaped landscape- greenhouse agriculture shapping the landscape in very specific ways - west of Rotterdam

source: based on satellite image from google

The introduction of "lessenaars" ( glass frames placed at angles against brick wall to protect the crops) and later on cold greenhouses and in 1872 the first warmed greenhouses are clear statements of that (Lambert, 1985). These developments shaped the landscape in a very specific and "artificial" manner as well. Densely packed greenhouses with long strips in between for moving goods and fuel are very representatives of the area and generate a very specific landscape, in a way quite resemblent of the peat landscape (fig 3.2).

## A Product of Dutch Industrialization

Although present in the Dutch and somewhat international trading routes, Rotterdam's role and position were note really truly asserted until the 19th century, with modernizations in the transport network of the Netherlands. This included new canals such as Voorne in1822 (Lambert, 1985), connections trough the dunes of the Hoek of Holland, part of the "Niewe Waterweg" (new waterways) projects (Lambert, 1985).

In the year 1857 the city acquired a rail connection to the Ruhr and this combined with the well maintenance of Niewe Waterweg made for a faster growth of the city and increasingly made industry more present in the area (Lambert, 1985).

port development

After 1870 the port was remodeled to fit the bulck shipment requirements (such as grain or Ruhr coal). Previously built, narrow elongated dock of the Maas bank were shifted towards dealing with piece good while completely new docks were being developed for bulk shipments. The Spoorweg, Binnenhavens and Entrepothavens were built around 1874 and in 1894 Rijnhaves was opened for bulk shipment with Maashavens shortly after (Lambert, 1985). "Thus by the 20th century the old quays of the inner town, one focus of overseas trade, were mainly berths for inland shipping" (Lambert, 1985 p 284).
The process amplified and resulted in Park, St. jobs and Schiehavens being opened towards the Ijssel, with Lekhavens to the north and Waalhavens started taking shape, all between 1900 and 1914 (Lambert, 1985). The city of Rotterdam grew and attacked a whole new array of activities while building up on some historical ones as well. By 1914 it was housing some 400.000 inhabitants and was the platform for such industries as ship buildings and repairing, engineering, processing of petroleum, sugar, tobacco, and even chemicals (Lambert, 1985).

Later, in order to enable the 500.000 ton carriers to enter the Niewe waterway, the Euro Chanel (45km) was dredged in the North sea floor. At the same time the Caland Kanaal and Hartel Kanaal were dug parallel to it to disperse bulk carriers, in fear that the Euro-channel will allow to salt water to penetrate to far inland.
Furthermore the development of Maasvlakte allowed for even more petroleum, coal, and natural petroleum gas to be shipped through the harbor.

post war reconstruction

During the second world war, Rotterdam, was the target of a devastating bombing campaign, which left a painful scar on the inhabitants and on the urban fabric. The Rotterdam Blitz, in 14th of May 1940, left the inner city largely destroyed. Heavy rebuilding followed the Second World War, and Rotterdam inner city was revived. Unlike other cities damaged by the war bombings, which restored their previously existent buildings, Rotterdam completely reinvented its urban fabric. Due to contextual limitations such as poverty and pressing need for housing , Rotterdam was rebuilt in largely a very modernistic, manner.

The rebuilding of Rotterdam in this specific manner resulted in it, today , having a very modernistic urban fabric, with a very low density compared to other large cities. Rotterdam, currently has a density 50% lower than Amsterdam, when it comes to the inner city (Rotterdam Municipality , 2007). Moreover the inner city was housing 100.000 inhabitants before the reconstruction and how only roughly around 30.000 (Lambert, 1985). This general outward trend of population with regards to Rotterdam is quite problematic for the city and could even be linked to its energy problems as densely populated ,traditional fabric cities tend to consume less energy than modernistic, over-simplified urban tissues (Salat & Bourdic, 2011).

Post war developments in areas such as the Lijnbaan and Coolsingel, have been following a tendency to replace housing areas with commercial, office buildings, leading to a somewhat de-population of the inner-city. Later attempts like those along Hofplein, Leuve or WIjnhavens have made trials of reintroducing people to the inner city but nonetheless not convincing enough (Lambert, 1985).

**fig. 3.3**
built vs. un-built
urban space(dark grey)
greenhouse space(hatched area)
outer green (light grey)
source: by the author

**fig. 3.4**

Port of Rotterdam evolution
urban space/greenhouse space/outer green

source: based on data from http://www.havenvandetoekomst.nl/

Rotterdam 1340

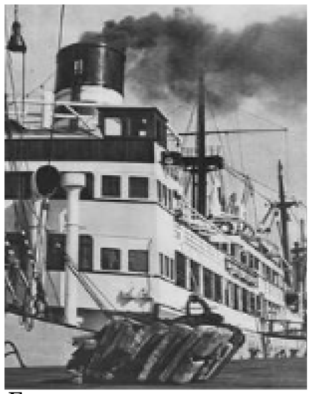
Rotterdam 1600

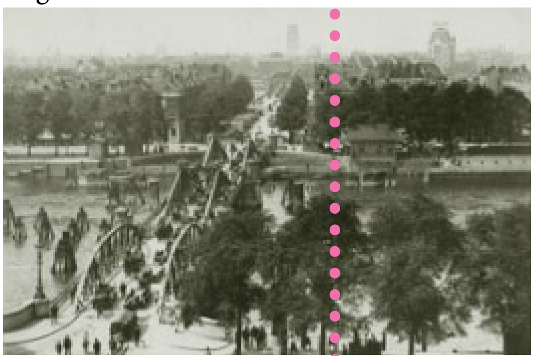
1400-1800 haringhaven

1500

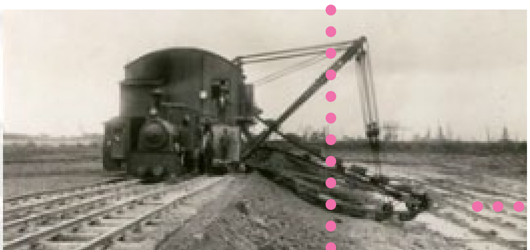
1600


Niewe waterweg 1825

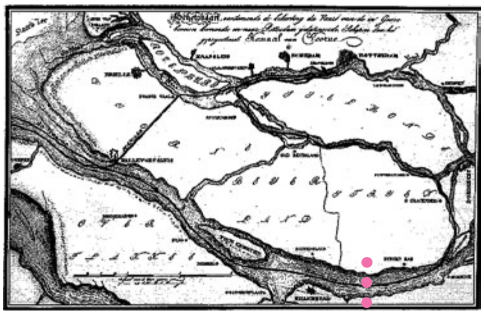

Europoort


Koningshaven 1910


Maasvlakte 1970


waalhaven 1911


Maasvlakte 2



1700

1800-1900 industrial revolution

1900

1920-1940 walhaven mervehaven

1946-1960 reconstruction

1960-1970 europoort

1970 maasvlakte

2000

2012

# 3.2_ Projections for the Future

scenario study

When designing or planning for large, regional scale, territories, and with long term transformations in mind, it is important to acknowledge the great deal of uncertainty follows such a endeavor. There are processes and transformations within a site which are completely beyond the control of the designer (Stremke , 2010), elements which, are influencing the outcome of the transformation process sometimes even more than the design itself. It is however important to plan or strive for desired futures, even with all the uncertainties around such a process, and furthermore, develop plans of action which would facilitate its reaching (Stremke, 2010).

predictive/explorative/normative

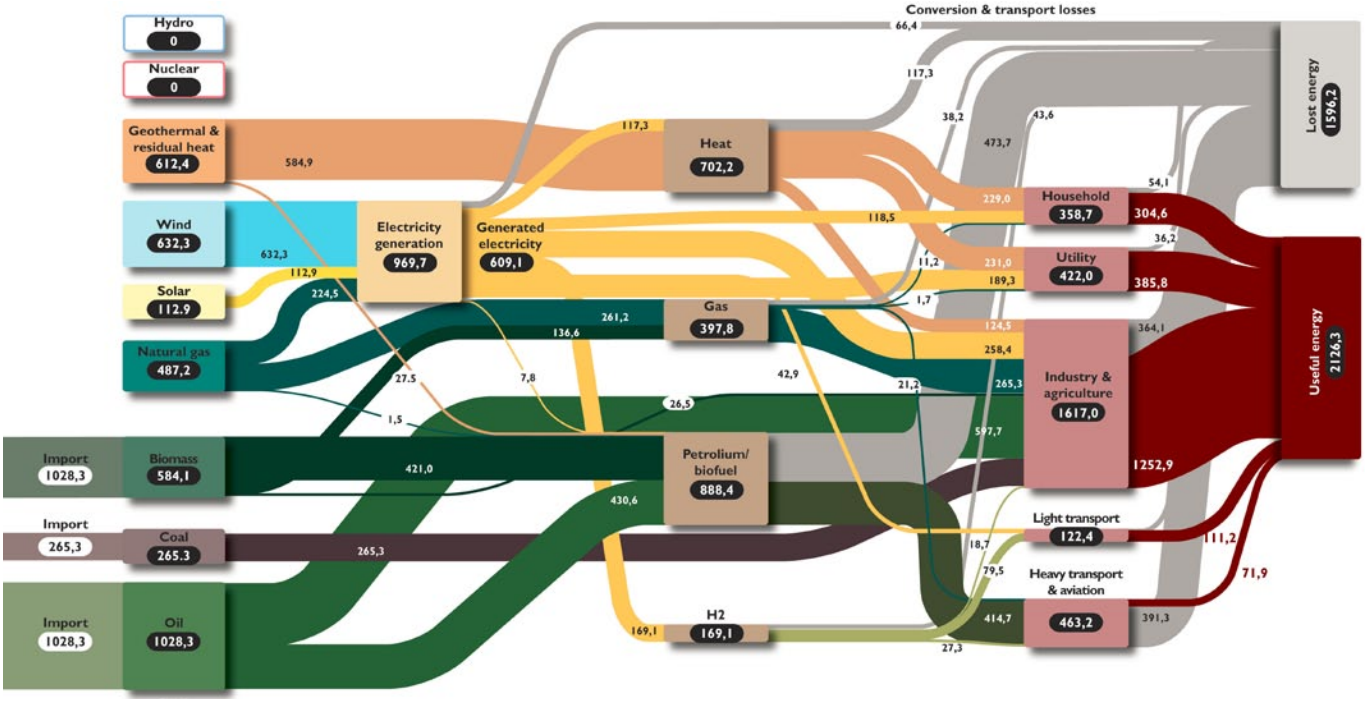
In order to frame the probable, or far futures, in such a way that even with the uncertainties involved they draw their foundation from scientific date and research, scenario studies most often used. This type of study could be split in three different typologies according to the type of future they describe and methods of addressing data. In this sense there are: predictive scenarios (probable futures), explorative scenarios (possible futures), and normative scenarios (desired futures) (Börjeson, 2006).

## kWh/m2 Scenarios

In the current approach two different types of scenario studies were explored. On the one hand, the framework of the kWh/m2 studio provided normative scenarios for the energy systems of each area investigated. These scenarios, developed by H+N+S landschaaparchitekten, are rooted in a general objective of 80% $CO_2$ reduction by 2050. What is also important to address is that, these particular projections, are structured on the basis of a decentralized approach to the problem. In this sense, global scale endeavors in energy production are not to be taken into consideration, as being valid, input factors in the energy generation capacity of the areas.

Furthermore these normative scenarios are structured by national predictions on the matters, and address two very different possibilities in the development of the energy system for the following decades. These are represented by on the one hand an increase of energy use by 15% (fig. 3.6), under the heading “business as usual” in which the energy system evolves along the same trend shown the recent past in terms of consumption, and on the other hand a drastic 30% decrease in energy use (fig 3.6). For each of these scenario approaches a separate energy system was established, which explores exact projected changes in each of the energy sectors and their implication on the system as a whole.

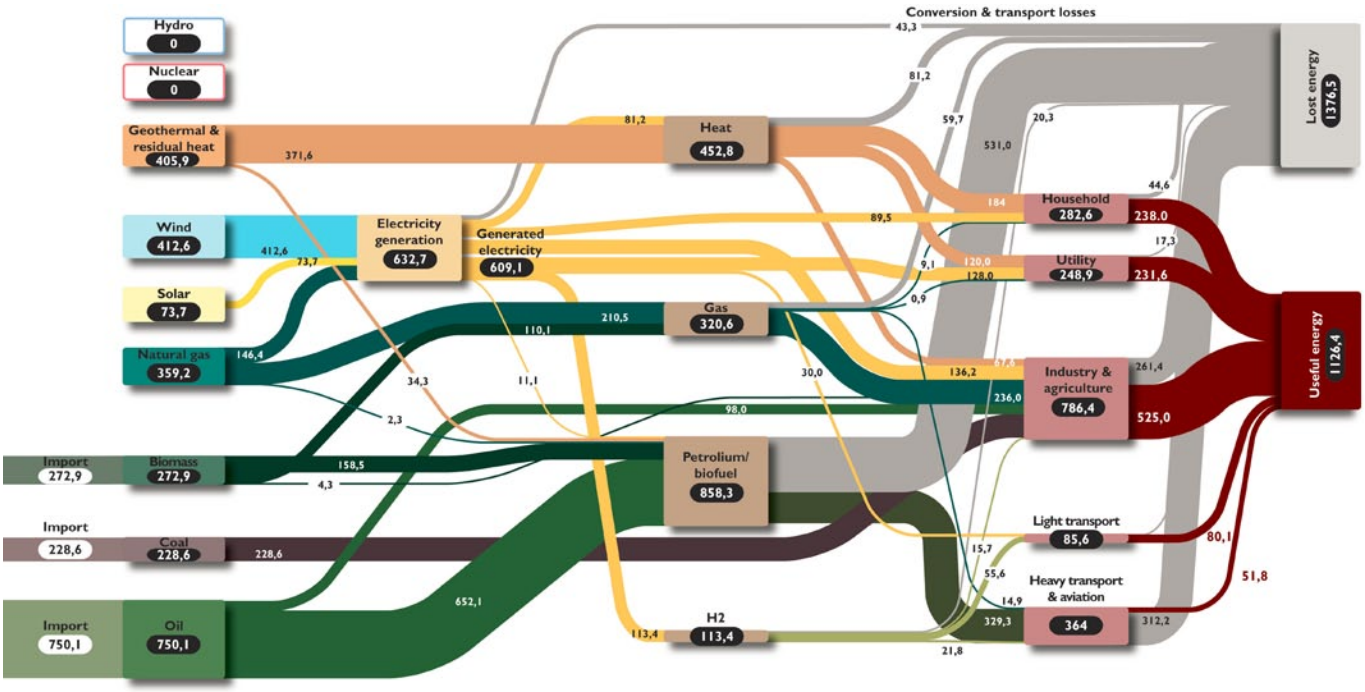
These scenarios represent normative, desired, instances in energy development for the coming decades. However, they address, solely, the issue of energy, without addressing changes, or possible trends which might underline some of the energy changes. In this sense, in order to address the issues in a broader sense, by describing socio economic trends within the energy context. We require explorative scenario approaches which could frame the normative ones.




## fig. 3.5.1

2050 -15% increase scenario energy system (scenario chosen)

source: H+N+S landscape architects, 2012




## fig. 3.5.2

2050 - 30% reduction scenario energy system
general structure maintained, only quantities are decreased

source: H+N+S landscape architects, 2012

# WLO Scenario "Global Economy"

The explorative projections description is based on WLO scenario outlines. These are defined within the framework of two key uncertainties: governance and economy.  In this sense different scenarios can be positioned according to their relation to governance and economy and each of these factors input within the context. Rotterdam, as one of largest  harbor cities in the world, will maintain a strong economical accent, based on a global economy no matter how the analysis is approached.

global economy

The explorative scenarios of WLO are structured in such a way that they provide crucial descriptions and characterizations of each scenarios in several areas considered of importance. For the Rotterdam case, the Global economy scenarios outline was considered, and within this one the characteristics of the Randstad area are explored. In this sense we have "possible future" developments described for: work, housing, regional development, mobility, agriculture, energy, environment and spatial developments.

**Work**

employment

In this category, all economical activities, which lead to production, income and employment,  outside agriculture are included. In the global economy scenario these activities increase prosperity in many ways but, at the same time put a hard strain on the environment.  Growth of the economy means new businesses  or growth of existing ones which mean a high demand for space, either for industrial, commercial  or office usage and on infrastructure equally. This as, pointed in the WLO explorations could affect the safety and appearance of their immediate surroundings as well as the environment. This trend is seen in increasing acreage of numerous businesses and even scaling up of industry and commercial activities. In addition the service sector is changing, transforming itself into an office based activity rather than manufacturing activity. This change could seem that is releases the strain on land demand.

Through this shift, companies need less employees and office work demands less land, but the overall process leads to the "migration" of space need to industrial areas therefore still increasing the net space need.

global free trade

In terms of characterization the global market scenario is translated as being defined by global free trade. This increases the labor market 19% until 2040 compared to 2002, putting immense strain on the space needed. Industry would require an additional 43%, office volume grows by 34%, informal work venues by 46% and seaports by 30%. Of course at the same time employment rate grows, and this particular scenario is the one with the highest employment rate, while the Randstad area is the region with the highest rate within the scenario, 75% of population 15 to 64 years old are employed while the unemployment rate is 4.3% by 2040.

**Housing**

rising demand

All the development and growth within the work layer, have implications on a global scale. For one the scenarios has the highest population growth, the approximate population for the Netherlands in 2040 being 19,7 million inhabitants.

individualization

At the same time, this trend is accompanied by a individualization process in the living habits, meaning that more and more people live alone so there is an increased number of one person households by 54%.
This process puts additional pressure on the housing market making the need for housing reach a number of 10.1 million. Out of this number single family dwellings are increased by 1.9 million compared to 2002 and multifamily dwellings by 1.2 million relative to the same year, Resulting in an increasing of the new housing market by 72%.

**Mobility**

increased mobility

A growing economy with growing income rates, results in a direct growth of population, large percentages of which are represented by immigrants; either form other regions, or other countries. This as we've seen pots a great deal of pressure on the housing market, and space, resulting in its turn in a increasing in mobility. Some areas are more attractive, economically, provide more jobs with a higher salary and higher diversity, making them primary targets for the job market. In this sense the Randstad area and Rotterdam are at the forefront of this process. Without enough space to accommodate all he inflow, mobility grows as a direct effect. This process coupled with better infrastructure and faster modes of transportation made for travel distances over the past decides to increase considerably. The passenger transport sector is expected to grow by 40% until 2040 compared to 2002, while the freight tone-km sector with a dramatic 120%, all this putting immense pressure on infrastructure and emissions. If everything evolves as projected, the congestion hours will be increased by 70% by 2040 while $CO_2$ emissions from the transport sector by 70%. This is highly important in the context of striving to decrease the overall $CO_2$ emissions by 80% in the next decades.

**Agriculture**

60% more greenhouses

The agriculture sector in the Netherlands is becoming more and more specialized and the overall number of farms is rapidly decreasing under a global process of up scaling. For the Rotterdam area the agriculture sector is not determinant in the overall economic and spatial context. The overall agricultural surface is expected to decrease by at least 15%. Within this framework, a process which is expected to yield important implication for Rotterdam is the increase of greenhouse agriculture by 60%.

**Energy**

coal use increases

Between the years 1990 and 2002 domestic energy use has grown with approximately 17%. The large increase in energy use was seen though in the service sector. Within the Global economy scenario ,a well-functioning international energy market is expected, with gas remaining of high importance for the coming decades. The choice of technology within this scenario is determined by costs primarily. Unlike a scenario in which governmental involvement and roles are more important and thus subsidies from governments can regulate prices and can balance priorities. The use of coal is expected to increase in all scenarios, with pulverized coal (or dust coal) plants increasingly important for the Global economy scenario. The scenario as viewed by WLO is expected to see a increase in energy consumption/capita by 30%, with the Netherlands providing 55% of its own energy and the rest being imported. As mentioned the use of coal is expected to increase by 195% by 2040 and oil by 90% while the use of natural gas with only 5% and natural gas stocks plummet with an astonishing 95%. Still the overall $CO_2$ emissions are seen as being increased by 65%, a percentage which similarly to the transport sector one is unacceptable.

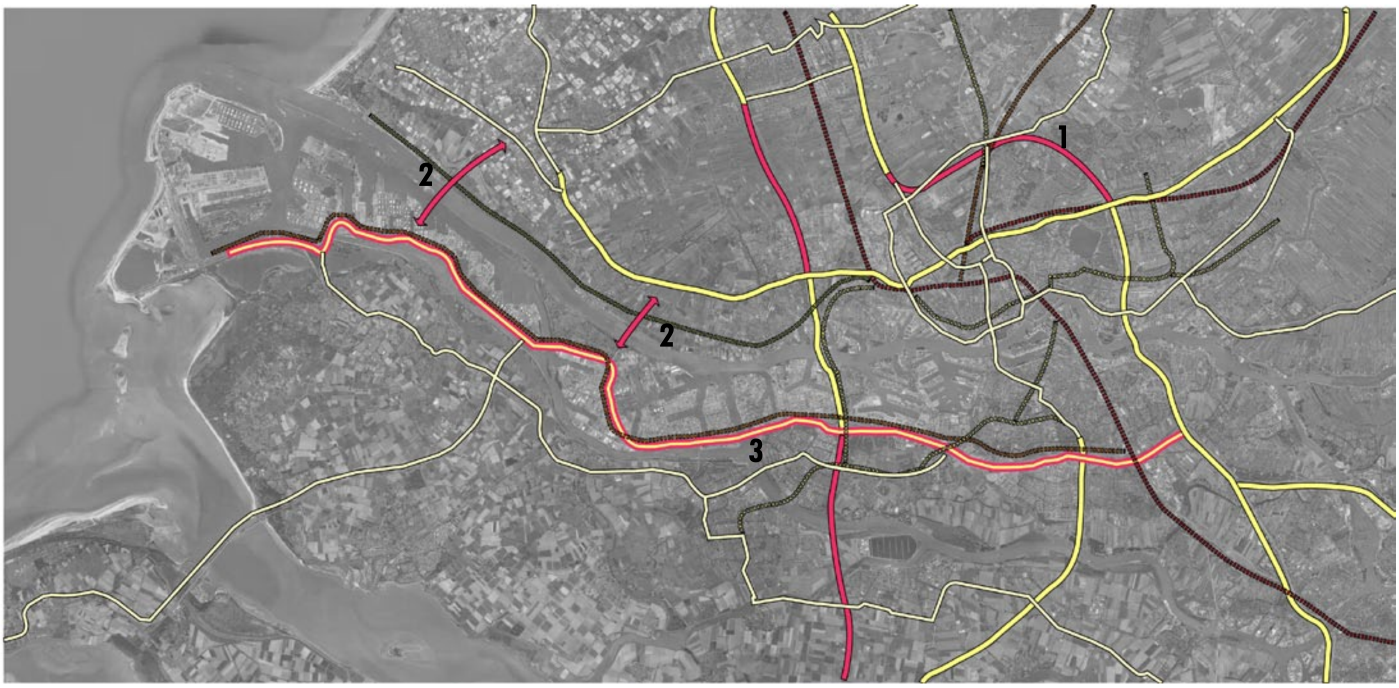



**fig. 3.6.1**
infrastructure developments

1. As the economy grows, improvements on infrastructure are expected.
2. New connections across the harbour could also be expected
3. The A15 is the most important transport axis, being extended as well as adapted to traffic needs

figure based on WLO scenario projections

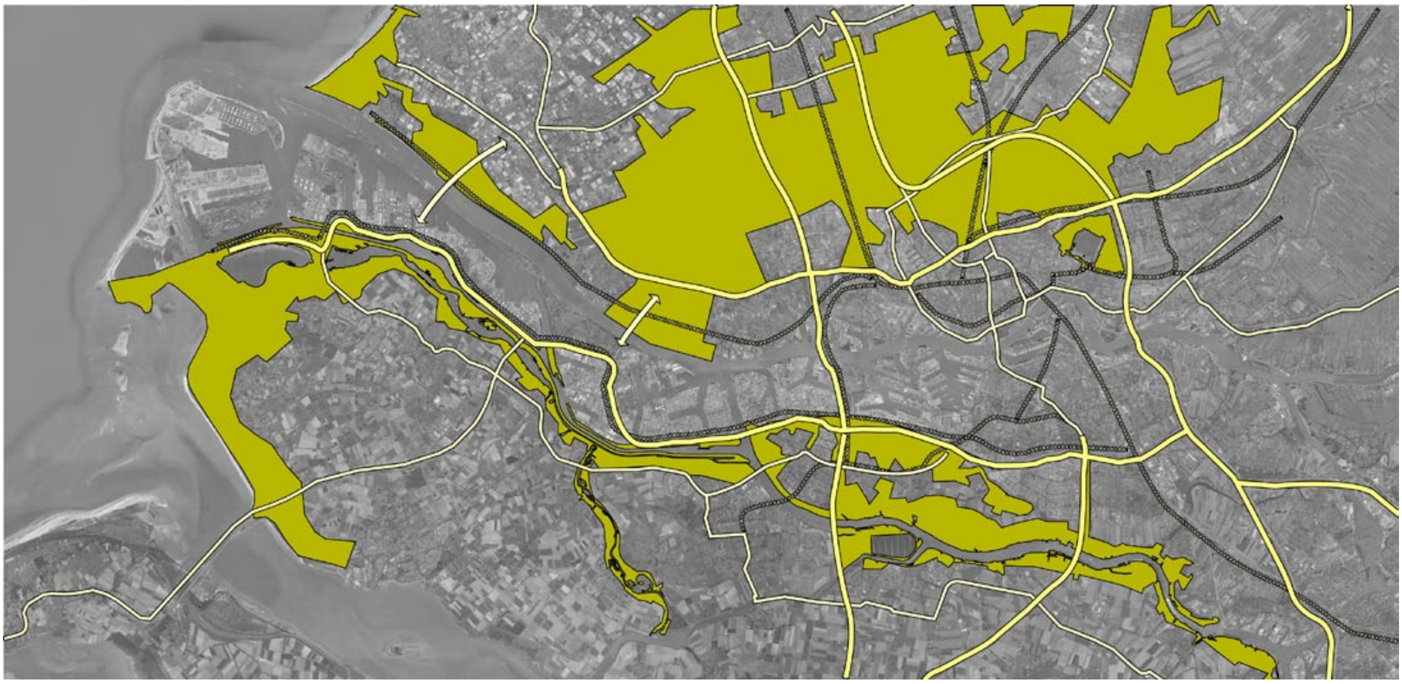


**fig. 3.6.2**
nature and green developments

1. New recreation space is hard to find
2. There are growing attempts to conserve the existing areas for recreation (nature, green, weltands, meadows etc.)

figure based on WLO scenario projections


**fig. 3.6.3**
industry developments

1. The Port and A15 structure the main industrial axis.
2. Residual heat sources in the Port could be exploited
3. Potential need for new industrial space is focused in certain predefined areas
4. The Maasvlakte 2 is completed

figure based on WLO scenario projections


**fig. 3.6.4**
agriculture developments

1. Greenhouse horticulture is expected to grow by a large percentage.
2. Conventional agriculture space could decrease
3. Nature areas and green space outside of the urban environment are expected to be conserved
4. The combination of 1 and 2 and 3 can lead to pressures from greenhouse expansion on other land uses

figure based on WLO scenario projections

# 04 RESEARCH FRAMEWORK

## 4.1_ Context

stakeholder duality

In terms of site characteristics one of the major factors is the duality of stakeholders. On the one hand we have the municipality of Rotterdam which has its strategy in terms of climate and energy under the umbrella of the Rotterdam Climate Initiative, and on the other hand we have the Port of Rotterdam, a private stakeholder with immense power and influence, especially when it comes to the harbor area. Working within the harbour the individual goals of stakeholder will have to be negotiated in such a way that it does not affect the qualitative outcome of the design. The city of Rotterdam is making great efforts in order to prepare itself for the uncertainties of the future and remain competitive on a global scale. In terms of energy and climate change there are numerous initiatives programs and studies.

Rotterdam Climate Initiative

In the next few years, Rotterdam has the ambition to develop into a CO2-free city and a first-rate energy port: 'the world capital of CO2-free energy' (Rotterdam Climate Initiative). This ambition was formulated by the International Advisory Board and is expressed in the target of a 50% reduction in CO2 by 2025, relative to 1990, for the city as well as for the port. This coincides with a period of enormous expansion of the city and the energy port. Rotterdam is thereby addressing not only the supply (at the source as well as within the supply chain), but also the demand (limiting the demand for energy) in order to realize a sustainable energy system. And the solutions can be found in innovation and behavior, with technology as the link. Based on a few assumptions, an interim estimate has been made of the CO 2 reduction potential in Rotterdam. The Rotterdam Climate Initiative aims to reduce CO2 emissions by 50% by 2025 and make Rotterdam 100% climate proof.

The program is divided into 10 specific tasks (Rotterdam Climate Initiative):

10 R.C.I. tasks

1. Leading the way in reducing CO2 emissions.
2. Energy savings.
3. Converting to sustainable energy and biomass raw materials.
4. Stimulating sustainable mobility and transport.
5. Reducing noise pollution and improving the air quality.
6. More trees and green areas in the city.
7. Increasing investments in sustainability and stimulating sustainable products and services.
8. Increasing public support for sustainability and firmly anchoring sustainability in education and research.
9. Preparing for the consequences of climate change.
10. Stimulating sustainable urban and regional development

The city is already taking a integrative approach when it comes to energy transition and climate proof, but this is only visible in terms of tasks, objectives, goals and intercorrelated funding and not in specific integrative strategies men to bring together in cohesive projects these separate processes.

# 4.2_ Problem Definition

## Energy

energy projections

Rotterdam is one of Netherlands's greatest energy consumers. In the Rotterdam metropolitan area a large amount of energy is used in industry and power generation. In total, around 70% of the annual energy consumption of the Rijnmond is down to industrial use and power generation (Milieumonitoring Stadsregio Rotterdam, 2007). This percentage is even higher if we take only Rotterdam in account, as it can account for a large part of the area's industrial activity but only about half of the total population and housing. "At a national level, there is an ambition for sustainable energy provision, comprising policy targets of 2% energy savings per year, sustainable energy growth to reach 20% by 2020 and a 30% reduction in greenhouse gas emissions compared to the year 1990, again by 2020" (Millennium Ecosystem Assessment, 2005, p. 4).

85% less CO2 emissions

Within this context, Rotterdam in aiming even higher, setting its goal for a 50% greenhouse gas emissions reduction by 2025 (Rotterdam Climate Intitiative). This is even more challenging since 85% of the greenhouse gas emissions of Rotterdam come form the industry (Tillie, 2011), and at the same time there is a certain degree of uncertainty when it comes to individual company energy policy in terms of use, re-use and savings. "The figure for energy reuse within and between companies is not known" (Milieumonitoring Stadsregio Rotterdam, 2007, p. 3). At the same time it is important to acknowledge that however large the energy consumption and CO2 emissions of the industrial area or harbors, the products they are providing are directly linked to daily needs of people. "The energy use by the companies in the port is related to that of 'end users outside the port'. After all, the products from the industrial complex are intended for the market and ultimately reach the consumers" (Milieumonitoring Stadsregio Rotterdam, 2007, p. 7).

producing for other regions

However, only a fraction is used within the region, most of the products being destined for export to national or international markets. In this sense we can say that the region is bearing some of the $CO_2$ chaser of markets and cities otherwise unrelated. A big part of the $CO_2$ emissions in the harbor of Rotterdam can be attributed to markets in Germany, or Asia and so forth. (This has been evidenced in the diagram braking down the flow for the Rijnmond are industrial sector.) Similarly, $CO_2$ emissions of other large global energy consumers could be attributed to Rotterdam.

energy consumption

When it comes to energy use Rotterdam has an immense energy consumption figure, totaling about 260PJ (petajoules) (Municipality of Rotterdam). If we project this according to future expectations in terms of energy use and population dynamics we can expect Rotterdam's energy consumption to reach colossal figures in the next decades (fig 4.1).

"The international energy agency (IEA) predicts that by 2030 energy use will have risen by more than 50% compared to the year 2005" (Milieumonitoring Stadsregio Rotterdam, 2007, p. 9). If we are to do the math, on a global scale this is simply not acceptable, nor possible. Andy van den Dobbelsteen stated that "if we are to divide all the known resources (including the untapped ones) by the global consumption, we can last only one human life" (Dobbelsteen, 2012). At a certain point our projection for the future move from the point of being demanding for the economy, or for the resources, to being simply impossible in terms of resources.

2% energy from renewable sources globally

At the same time, a growing number of scientists agree that if we are to make the transition, we need to do it now. Namely that, the remaining fossil fuels should be used to power the energy transition (KEMA, 2012). It should be used to build solar panels, wind turbines, heat collectors and so forth, all of which cost enormous amounts of energy to build and which are still not generating enough in order to be able to power this transition. "In 2002, the energy generated by sun, wind and biomass provided less than one percent of the total primary energy use. If all the energy from waste is counted as sustainable energy, then 2% of the energy came from sustainable sources" (Milieumonitoring Stadsregio Rotterdam, 2007, p. 4).

80% consumed by industry

As stated before Rotterdam is consuming roughly 260PJ yearly, out of which almost 80% (fig 4.2) is accounted for by industry and power generation (Municipality of Rotterdam, 2012). That leaves about 20 percent of energy consumption to be attributed to all other sectors. With the projected 15% increase it can reach roughly around 300 PJ. These calculations do not account for the Westlands area greenhouse horticulture, as that is difficult to attribute to Rotterdam alone, more so that its industry for example. For the scope of this paper, the Westlands energy consumption is considered more as part of the Rijnmond area than Rotterdam.

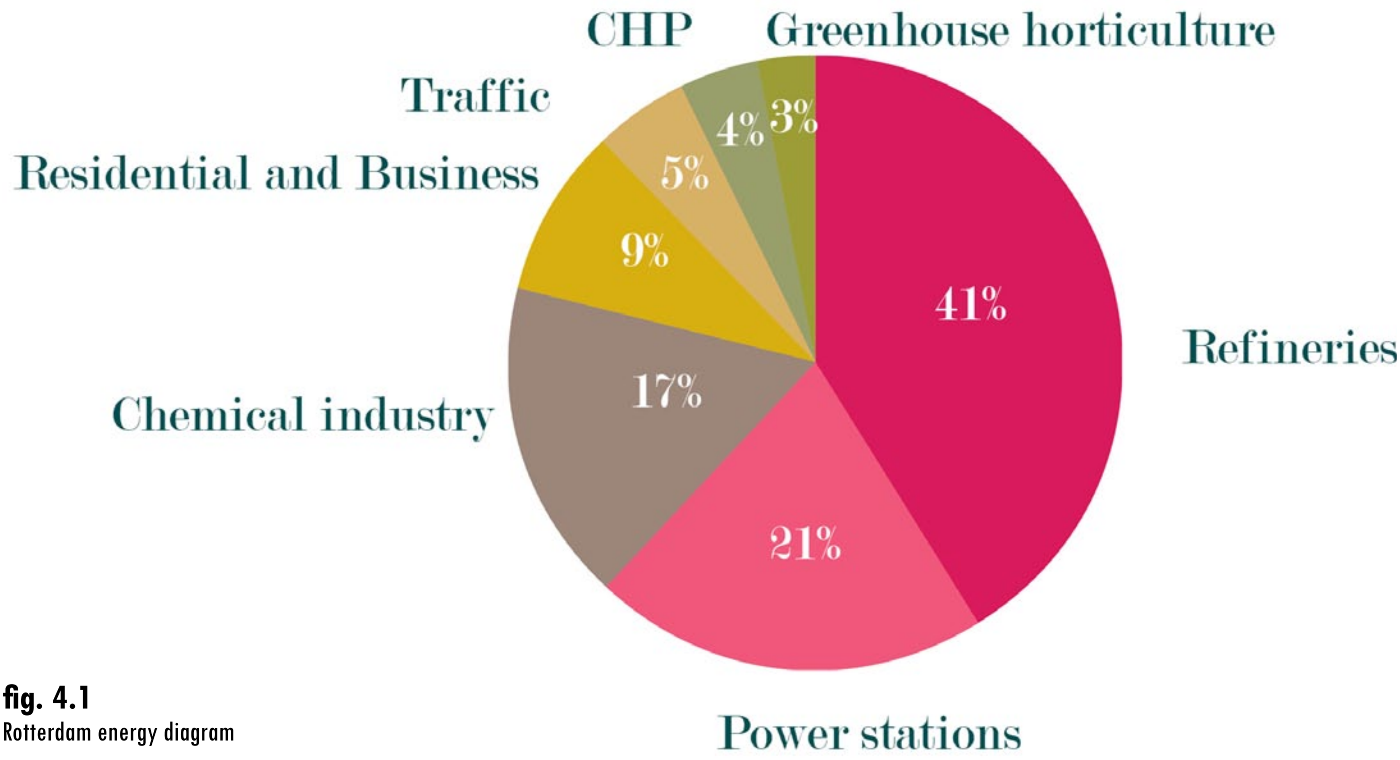



**fig. 4.1**
Rotterdam energy diagram
energy share of different sectors
figure based on data from the Municipality of Rotterdam

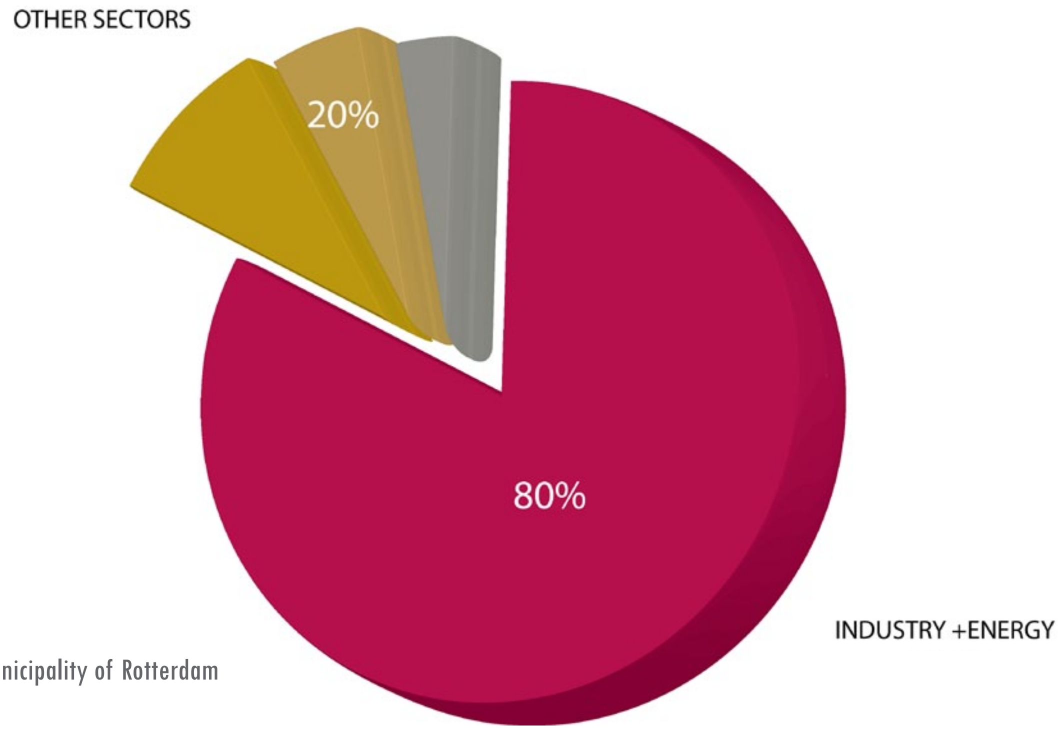
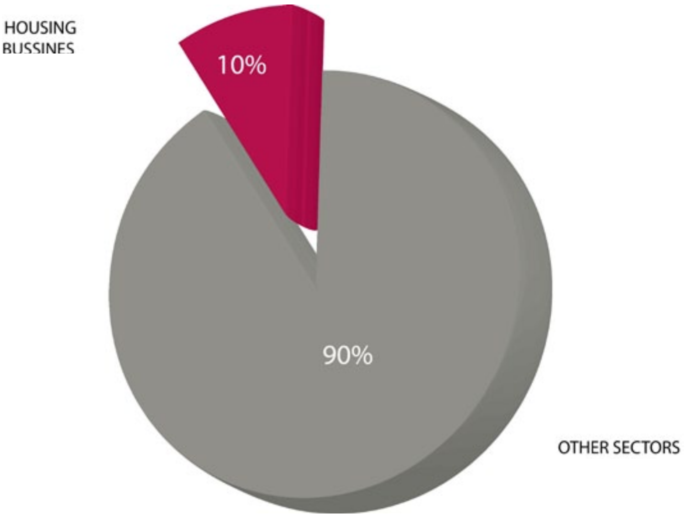



**fig. 4.2**
Rotterdam energy diagram
industry/other
figure based on data from the Municipality of Rotterdam



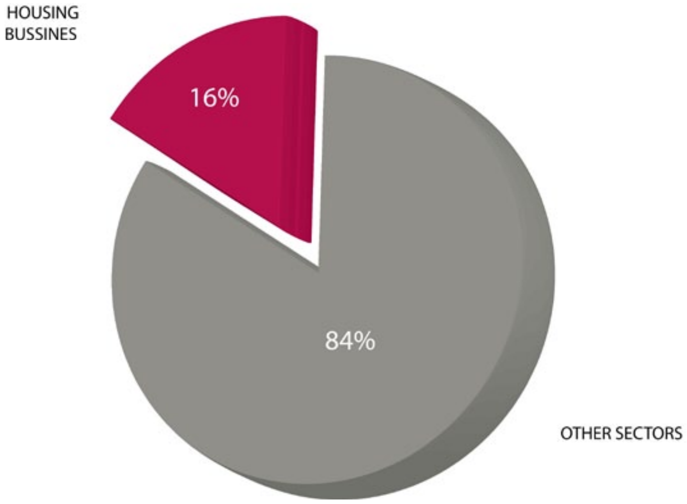




**fig. 4.2**
Rotterdam Energy Diagram
current and projected housing share
figure based on data from Municipality of Rotterdam

Out of this total energy consumed, electricity accounts for about 72PJ this comes from sources such as solar, coal, nuclear and so forth. The heating needs account for some 53 PJ in Rotterdam, while the biggest energy source is represented by oil (based on data from H+N+S landscape Architects, 2012). If we were to switch Rotterdam's current energy system and provide all needed energy from renewable resources, it would have to be supplied in such a way that these basic needs are met. Therefore, electricity, thermal as well as biofuels potentials should be explored.

The power of the sun is 1000 W/m2 (representing square meters facing the sun and not land area) (McKay, 2008). For Rotterdam there is a need to compensate for the angle between the land and the sun, which decreases the intensity during midday with about 40% and also account for sunshine hours which make the sun shine only about 34% of the daylight hours in a typical day for Rotterdam. As a result south facing roofs in Rotterdam have a potential of 180W/m2 and horizontal ones a potential of 160W/m2.

**Solar Thermal** (fig4.4)

This potential is converted differently and a different efficiency levels according to conversion techniques. For thermal energy an average efficiency level of turning sun potential into how water is about 50% (McKay, 2008).
This means that for Rotterdam a technical maximum for solar thermal harvesting is defined by the formula:

50%xS(total surface)x160W/m2 (or180W/m2)

The end result is a total of 212PJ for solar thermal potential. This number is 400% more than the heating needs of Rotterdam, however it also employs 100% of its space (meaning there is not space left for another function) . If we were to generate only what Rotterdam needs, we would need about 20% of its space
.

**Solar P.V.** (fig 4.4)

For P.V. generated electricity the efficiency for conversion is much lower, going from about 10% (some cheaper panels) to around 20% (the more expensive ones) (McKay, 2008). This means that solar technical maximum for Rotterdam is defined by the formula:

10%(20%)xS(total surface)x160W/m2 (or180W/m2)

# Solar technical max

180 W/m2 for south facing surfaces
160 W/m2 for flat ground

## Solar thermal technical max

212PJ = 400%

## Solar P.V. technical max

102PJ = 141%

# Solar thermal space need

25% space = 30Km2

50%xSx160W/m2

53PJ

# Solar P.V. space need

70% space = 79,1 Km2

(10%)20%xSx160W/m2

72PJ

**fig. 4.4**
Solar thermal and PV
technical max and required space
figures based on calculations with data from Municipality of Rotterdam and McKay, 2008

# Wind technical max

load factor 30% (good site, modern turbine)
power/unit area = 2W/m2 (onshore)
wind speeds of 6m/s
power/unit area = 3W/m2 (offshore)
corridors for ships - only 35% of space used

## Wind onshore technical max

42PJ = 60%

## Wind onshore space need

190% space =212 Km2

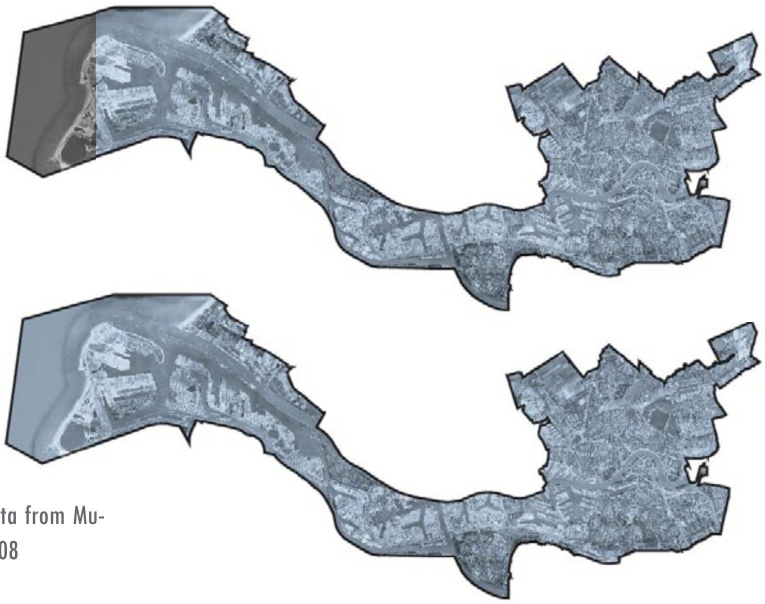


**fig. 4.5**
Wind energy
technical max and required space
figures based on calculations with data from Municipality of Rotterdam and McKay, 2008

72PJ

If we were to use more expensive panels to generate electricity, and use up the entire surface of Rotterdam we could generate about 100PJ of electricity. This is more than needed, and if we only supply what is currently consumed in terms of electricity, the surface employed would take up roughly 70% of Rotterdam.

**Wind energy** (fig 4.5)

For wind potential the theoretical estimate places Rotterdam at around 2W/m2 with an average wind speed at roughly around 6m/s (McKay, 2008). However imputing other limitations wind energy density, based on H+N+S landscape architects calculations, for Rotterdam is around 1000 MWh/ha of land. This means that Rotterdam could generate about 42PJ of electricity if covered with wind turbines, And we would need roughly two times its size to supply the needed electrical power completely with wind turbines. This has largely to do with the great spacing needed for turbines and varying wind speeds. However, wind potential represents a great asses offshore were the potential is greater, but costs of implementation and energy grids need to be worked out first.

**Biomass**

When dealing with biomass it is important to acknowledge its tremendous impact on land use. According to David McKay, if we were to power all traffic with biomass we would need to cover a strip of land 8km wide along all roads (McKay, 2012). This is roughly translated into a strip which is 666 times wider than the average motorway (2 lanes per direction each 3m totaling 12m).

Biomass energy can also be translated as solar energy. Plants turn solar potential into energy at a rate of roughly 2%, which makes the potential for Rotterdam around 0,5 W/m2 (McKay, Sustainable Energy - Without the Hot Air, 2008). The biomass potential makes for a technical maximum of about 2.4 PJ for Rotterdam. This means that if we were to supply ne oil need for Rotterdam with biomass we would need roughly around 60 times the size of Rotterdam.

**Conclusion**

As a general conclusion, these rough calculations make it obvious that, however difficult, the switching from fossil fuels to renewable energy is achievable even in extreme conditions. The main issue with our current energy system is the colossal amount of waste. The Netherlands is currently wasting or losing (in conversion transport or usage) more energy that it is making useful (H+N+S landscape Architects, 2012). Therefore, the primary focus should be on reframing the energy system and flows in such a way that we decrease the losses.

exergetic optimization

According to SLT guidelines defined by Stremke, Koh and Dobbelsteen we should aim for increasing energy efficiency and decrease exergy demand (Stremke, Dobbelsteen & Koh, 2011). The toll on land use of new technologies is obvious, and we need to be as efficient as possible in order to ensure sustainable solutions and not just a few decades worth of patching up the problem. We need to stop trying to provide for a faulty system and work on revolutionizing the flows rather than figuring out ways of providing for a completely un-sustainable system.

trias-energetica

Therefore the main problem with regards to energy is (in line with second law thinking and trias-energetica) decreasing the exergy demand as well as decreasing entropy along the flows.

# Climate

climate change

The Intergovernmental Panel on Climate Change defines climate change as "referring to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity" (IPCC, 2007, p. 6).

impacts

What is important to acknowledge are the impacts that climate change and the predicted developments in climate for the coming decades will, could or are having on Rotterdam. Whenever discussing climate change we tend to refer it to the future, to coming decades, to adaptation or mitigation for the years to come. However, climate change is already impacting our cities in a major way. As stated before the Rotterdam climate initiative is aiming of making Rotterdam 100% climate proof by the year 2025, and therefore climate should be a central topic in discussing plans for the future of Rotterdam.

climate scenarios

The KNMI has developed since 2006 specific climate scenarios for the Netherlands (fig 4.6), which it has later adjusted and fitted to new developments. Framed in order to facilitate dealing with uncertainty, the climate scenarios have certain common points which can be valid, no matter what the specific projections are(KNMI,2006):

- The global mean temperature will continue to rise. Mild winters and hot summers will become more common.
- On average winters will become wetter and extreme precipitation amounts will increase
- The intensity of extreme rain showers in the summer will increase, however the number of rainy days will decrease
- Sea level will continue to rise.

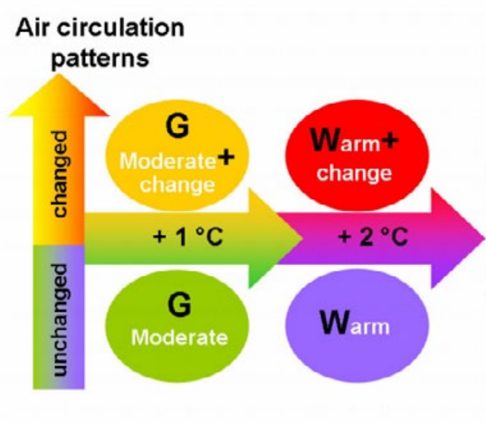



**fig. 4.6**
KNMI climate scenario parameter and table
based on data from KNMI, 2006

| SCENARIO | G | G+ | W | W+ |
|---|---|---|---|---|
| SPECIFIC CHANGES | 1C temp rise<br>No change in air ciculation | 1C temp rise<br>Milder winters<br>Warmer winters<br>Warmer summers<br>Dryer summers | 2C temp sire<br>No change in air circulation | 2C temp rise<br>Milder winters<br>Wetter winters<br>Warmer summers<br>Dryer summers |

temperature projections

In the Netherlands, the past century has seen a overall increase in temperature by 1.2°C. The direct result of this being an increase in number of summer days. The ten warmest days are almoust entirely found after 1988 (KNMI, 2006). Overall climate scenarios estimate changes in global mean temperature of 1 to 6 °C by the year 2100 (KNMI, 2006). Due to its positioning close to the sea and in the northern hemisphere, the Netherlands expects milder temperature growth, spanning from 0.5 to 2.7°C by the year 2050.

precipitation projections

Within Europe a general increase in precipitation of 5 to 10% has been observed in the past century (KNMI, 2006). For the Netherlands the past century can be translated in increases up to 18% with highest increases in winter, autumn, and spring (from 21 to 26%) and with summer precipitation hardly changes (about 3%). "In the G and W scenarios (those without significant change in air circulation patterns) precipitation increases both in summer and winter with approximately 3% per degree global temperature increase. In the G+ and W+ scenarios (those with significant change in air circulation patterns) precipitation increases more in winter (about +7% per degree C) and decreases in summer (about –10% per degree C). The decrease in summer precipitation can be attributed mainly to the decrease in the number of rainy days." (KNMI, 2006, p.10). This means that both extreme and mild changes are accounted for and their impact on the landscape quantified. This is mainly due to the fact that there is a wide variety of estimations when it comes to precipitance dynamics in the future and the numbers vary between themselves.

sea level

On average, globally, sea level has risen by 1-2mm every year since 1900. Furthermore, this increasing has been greater since 1993, having a yearly increase of 3mm with high variations (KNMI, 2006).
For the North sea the increase has been 2mm per year which means 20cm in the 20th century. For the Netherlands specifically, this is even greater as we have to account for soil subsidence, which has been 4cm in the past century (KNMI, 2006). Sea-level reacts slow to global temperature changes, therefore making sea-level variation more important only after 2050. We can expect an average rise by a few meters in the coming centuries (KNMI, 2006). For the Netherlands, the difference in global mean temperature for each scenarios make sea-level vary as well. By 2100 the sea-level is expected to increase by 35 to 85cm and with 1 to 2.5 m from 2100 to 2300.

direct impacts of climate change

Some of the direct impacts of these changes, which could be expected to the Netherlands and therefore for Rotterdam as well are:
-Increased peak discharge for the Rhine and the Meuse due to precipitation increase in the winter, intensifying the number of floods.
-Decreased levels of precipitation in the summer can cause navigation problems in the future
-The energy need for heating houses in the winter can decrease in some scenarios due to warming in the winter (on average by 10%), however, summer temperature increasing will make costs for cooling down buildings increase (KNMI, 2006).
-The temperature variations can have a positive impact of agricultural production (especially grassland), however this can be canceled out by water shortages in the summer.
-Air quality is also expect to be affected "Weather conditions, such as wind direction and solar radiation intensity largely affect air quality, since they affect the supply and formation of polluting substances. Periods of smog in summer (high ozone concentrations) frequently coincide with heat waves (high radiation intensity). In case emissions remain the same, an increase of the number of tropical days (maximum temperature ≥ 30°C) will increase the chance of summer smog, especially in the W+ scenario" (KNMI, 2006, p. 13)

# 4.3_ Research Question

The main research question guiding the process is (fig 4.7) :

Can **exergetic optimization** of energy and matter cycles yield an **attractive** urban structure that provides **ecosystem services** and supports human **life**, activity and growth?

thermodynamics

Thermodynamics is the science of energy, structured by its two fundamental laws (Dincer & Cengel, 2001)

exergetical optimization

exergetical optimization : increase exergy efficiency /decrease exergy demand / increase use of residual exergy /match quality levels of supply and demand /increase assimilation of renewable exergy.

FLT

The first law of thermodynamics (FLT): This law deals with the conservation properties of energy and states that energy is a "thermodynamic property" (Dincer & Cengel, 2001), and it can change from one state to the other in any given moment but, the general quantity remains the same. In this sense we can refer to this as a quantity related law.

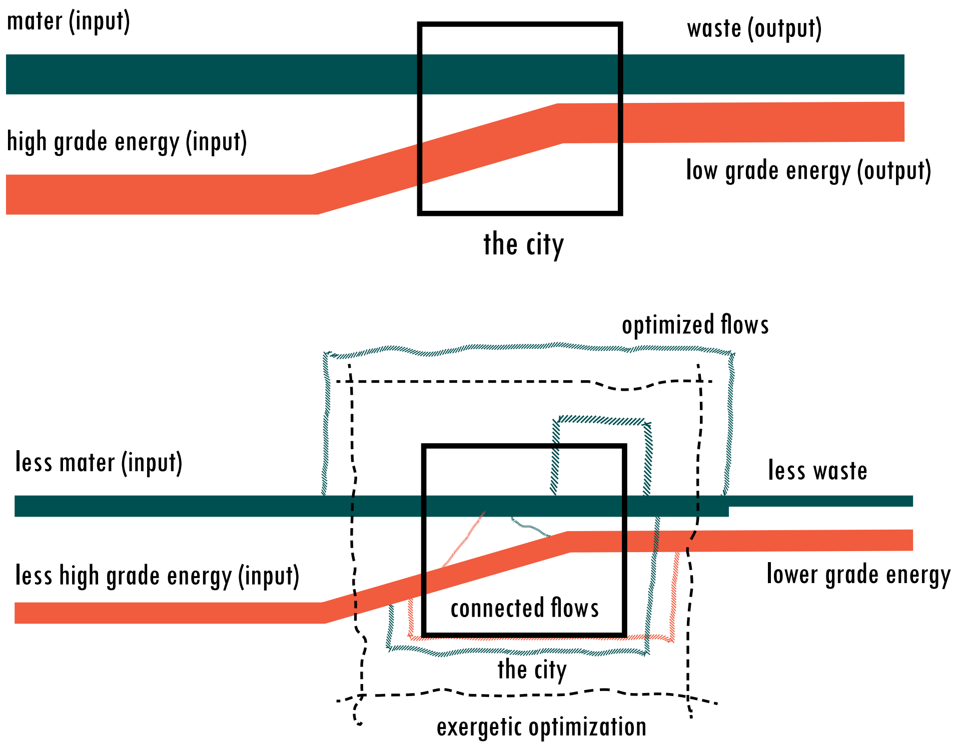
SLT

The second law of thermodynamics (SLT): While the first deals with quantity the second law deals with the quality of energy, and this difference is paramount for the global energy system of today. It is stating that while energy might by conserved in the quantitative sense it is losing "work capacity" in going from one state to the other.

**fig. 4.7**
Research question schematic approach

**contemporary city**

**exergetically optimized attractive city**



# 4.5_ Methodological Approach

philosophical world view

The issue of the philosophical worldview is addressed as it is influencing the way research is executed (Creswell, 2009). The approach on worldviews chosen is the pragmatic one. The reasons for that are numerous and have to do with the nature of the research and its goals. The need for mixed method research strategies is at the basis of the choice, and this need is generated by the topic itself. First of all the need for quantitative date and research when it comes to energy is obvious, and then, when dealing with social integration a qualitative approach would be more fitting. There also the uncertainty of the subject, there is not yet a clear way of how to develop design principles for energy integration therefore truth is what works at the time (Creswell, 2009). Moreover there is the integrative multi-criteria approach which focuses on different contextual situations; an aspect of pragmatic approach.

pragmatic approach

By using the pragmatic approach the assumption is that the result generation will come step by step and each one being derived from the previous one, in a manner that is found more suitable, be that quantitative or qualitative.

The following paragraphs will detail on the exact strategy chosen for the research, making clear the relation between research and design, in what manner will research be conducted and how design will be integrated.

complex intellectual model

As a starting point, in terms of placing design and research instances in the process the complex intellectual model (Milburn & Brown, 2003)acts as a base. This approach is considered best suited as it entails the examination of the design problem through a series of complex interrelated components (Milburn & Brown, 2003). The key factor in this approach is the possibility of reframing the problem, which in the context of the topic chosen can prove crucial. At the same time it describes ways in which testing and evaluation of proposals can reframe new solutions, looping the design until goals are achieved.

The model is further elaborated and adapted into a flowchart of the process as expected in a preliminary stage.
The flowchart describes the way the process will develop in stages and how it relates to Milburn's model. The steps of the model are framed by 5 phases in the process.

These phases refer to preliminary assessment: (in terms of literature studies); present study: in terms of analysis of the site and acquisition of site specific knowledge; future projections: as an extension of the site specific knowledge acquisition, and referring to projection studies for the future; design: marking the beginning of actual implementation into spatial configurations of the concepts; and evaluation referring to constant testing of solutions adjusting and returning to design as many times as necessary to reach goals (fig 4.8).

step by step description

**1. Preliminary assessment**
This stage is integrated in addition to the complex intellectual model in order to provide a first opportunity to frame the problem according to literature research on the topic at hand as well as generate first sketches in an intuitive manner, revealing "dream images" based on theoretical studies. In includes literature studies on all the theoretical views described in the theoretical framework chapter.

Acquisition and Assessment of Knowledge the first research step in Millburn's model is actually split into 2 sub-steps(on the topic and site specific). They are referring to Acquisition of knowledge, and in this case they are approached from a subject (topic) view point, and from the site specific viewpoint. They refer to gathering knowledge related to the subject in general and gathering knowledge on the site chosen for study. Step number 2 leads to formulation of a set of preliminary research questions and a set of preliminary sketches.

**2. Present**
This phase comes as the acquisition of knowledge moves form on the topic to site specific and refers to analyzing existent condition's according to the theoretical lens. It is largely based on existent studies in the, referring both to climate and energy and making sure the future design takes them into account. The existent studies are then processed and the most suitable ones are used in the design process.

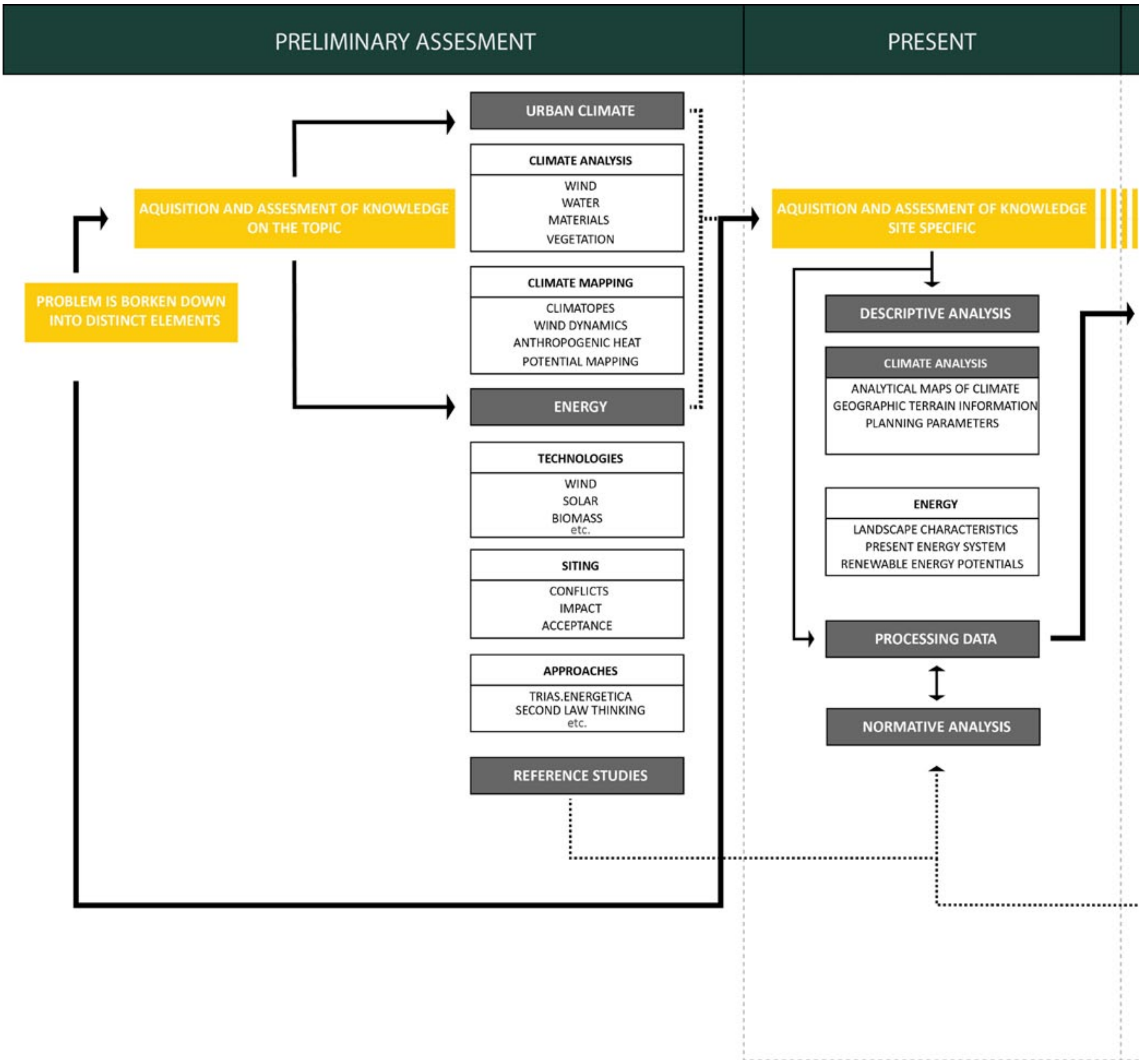
**3 Future projections**
This step then transitions the process into the future projections phase, where, site specific knowledge is analyzed according to studies, scenarios, goals and predicted or planed trends. Although not representing a proper scenario study with comparisons and evaluations of all scenarios, this step is aiming to offer consideration to important projections for the future, both in terms of normative and explorative projections as well as near and far futures. This step takes into account major plans by the municipality as well as scenarios offered by the kWh/m2 studio and WLO scenario study. They are then framed into a set of coherent major projections for the future of Rotterdam.

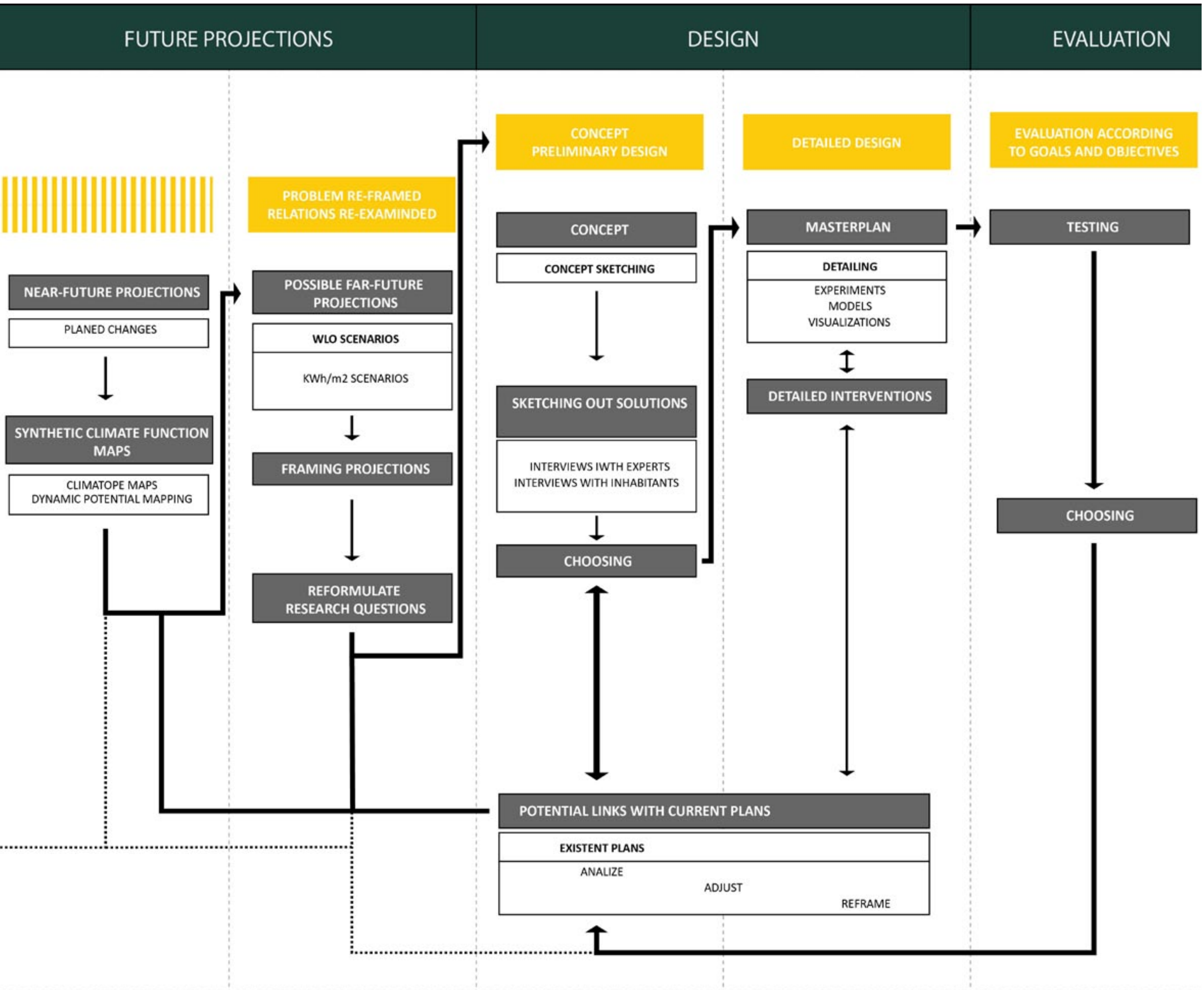
**4. Design**
After the reframing of the research question the concept is slowly implemented by gradual intuitive and theoretically informed sketching and choosing. Also important strategies identified in the previous phase are adjusted according to formulated guidelines. Concept and Preliminary design is the step in which the elements analyzed before come together in two different manners. Producing a preliminary design and the sets of principles. This step is then dedicated to detailing the ideas in the previous step.

**5. Evaluation**
After a satisfactory detailing level is achieved (in order to assure proper testing conditions), the design is tested and evaluated. The process then loops back to the reframing of the research question and the design is adjusted according to theoretical input and conclusions of testing. It refers to evaluating the results based on previously identified criteria, testing and choosing problem areas and turning back in the process in order to get more knowledge and repair the design. This is repeated until the objectives are reached. If some designs prove to be following a wrong path the research question and approach is reframed to accommodate the findings and explore alternatives.

What is important to specify is that the model, is offering a general structure of the moments of research and design, and within the research part of the framework, there are always two types of research being conducted, both quantitative and qualitative, which at the end of the step get mixed in either sequential, concurrent, transformative and triangulation manners. In this manner the aim is to produce a framework which allows for constant adjusting and frames a proper research by design approach.

**fig. 4.8**
Methodological flowchart
figure by the author




FUTURE PROJECTIONS
DESIGN
EVALUATION
CONCEPT
PRELIMINARY DESIGN
DETAILED DESIGN
EVALUATION ACCORDING
TO GOALS AND OBJECTIVES
PROBLEM RE-FRAMED
RELATIONS RE-EXAMINDED
CONCEPT
CONCEPT SKETCHING
MASTERPLAN
DETAILING
EXPERIMENTS
MODELS
VISUALIZATIONS
TESTING
NEAR-FUTURE PROJECTIONS
PLANED CHANGES
POSSIBLE FAR-FUTURE PROJECTIONS
WLO SCENARIOS
KWh/m2 SCENARIOS
DETAILED INTERVENTIONS
SKETCHING OUT SOLUTIONS
SYNTHETIC CLIMATE FUNCTION MAPS
CLIMATOPE MAPS
DYNAMIC POTENTIAL MAPPING
FRAMING PROJECTIONS
INTERVIEWS IWTH EXPERTS
INTERVIEWS WITH INHABITANTS
CHOOSING
CHOOSING
REFORMULATE
RESEARCH QUESTIONS
POTENTIAL LINKS WITH CURRENT PLANS
EXISTENT PLANS
ANALIZE
ADJUST
REFRAME

# PART II

# EXPLORING DESIGN SOLUTIONS

# 05 REGIONAL ANALYSIS

introduction

As part of the analysis of the site, energy and climate are regarded as important determinants. This chapter will explore some energy potentials for the Netherlands and analyze the rough potentials for Rotterdam. The results of the brief analysis will determine which areas are most suitable for Rotterdam to focus on. Also urban microclimate analysis results will be inputted in order to better understand the specific challenges and how those challenges can be approached.

## 5.1_ Energy Potentials

### Introduction and Method

Although mainly focused on energy efficiency and reducing exergy demand, the research must also explore rough energy potentials for Rotterdam. This is done mainly because of assuring a realistic grounding of the proposal in the ecosystem services of the site it is placed on (Pulselli & Tiezzi, 2009). By doing that, the end design should provide a good balance between supply and demand and ensure that the conversion techniques chosen for provision are actually sustainably grounded in the specific nature of the site.

energy potentials

Energy potentials addressed are focused on different scales and address major conversion techniques and sources of energy, guided by Energy Potential Mapping methodology(fig 5.1) (Dobbelsteen, Broersma, & Stremke, 2011).

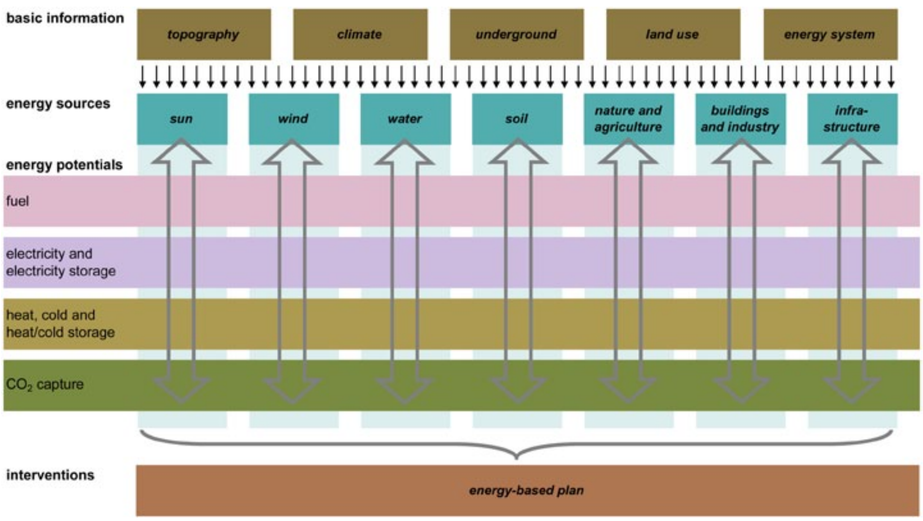
sustainability

When designing with energy, in a fragile fossil dependent society, sustainability tends to be very important. In this sense taking advantage of the local resources or opportunities becomes a crucial issue and step in the design process. The Energy Potential Mapping method, is designed to do just that; to chart, quantify and inventory all different local energy potential on different scales (Dobbelsteen, Broersma, & Stremke, 2011). The maps generating with this method are intended to help guide the design process, from early stages and help decision making with regards to locating new functions and integrating them within a robust energy system.

EPM

Energy potential mapping is providing the backbone for this analysis, although not explored to the fullest. The reasons determining a partial exploration rather than detailed full potential studies have to do with the main focus of the research, which is reducing demand rather than generating for current demands. Further exploration is needed in order to cement the described potentials, and therefore other studies are also explored and results compared for verification purposes.

**fig. 5.1**
Energy potential method visualized
source: van den Dobbelsteen, Broersma, & Stremke, 2011




The method is split in several distinct steps, from inventory of basic information such as (topography, climate, land use, underground and energy system), to an inventory of energy sources which then are combined into energy potentials for fuels, heat and cold, electricity and CO2 capture (Dobbelsteen, Broersma, & Stremke, 2011). The final step is a synthesis map of the energy potentials of a certain area which forms the platform on which the design evolves.

## Sun

sun potential

The solar energy density for The Netherlands is worked out and reveals several areas within the country, separated according to their potential for PV conversion of solar energy. Rotterdam has a relatively constant potential along its region, revolving around 1000 kWh/m2 (fig 5.2.1)(H+N+S landscape Architects, 2012).

Previously we explored technical maximums of several conversion technologies for Rotterdam. Of course not all land area can be used to generate energy, and power conversion is subject to numerous limitations (Dobbelsteen, Broersma, & Stremke, 2011). Building density, different land-uses and so forth, all can provide either platforms or limitation for implementation of technologies (fig 5.2.3; fig 5.2.3.1). For example the built environment can act as a platform for solar P.V. conversion but as a limitation for wind turbine placement(fig 5.2.4 and fig 5.2.5).

limitations

When overlapping data of built density with the energy density of the area, we can determine areas which represent potential for PV conversion in Rotterdam. Generally these areas are represented by built environments or industrial roofs, which are not shaded. Relative to the Netherlands Rotterdam presents a high potential for solar power. The city is sited in one of Netherlands's most sunny area (in terms of sunshine hours per year), and is also one of the most built up areas without being too dense so that buildings shade one other.

## Wind

wind potentials

For wind energy, Rotterdam is split in at least 2 potential zones in terms of energy density. The area representing the inner city and most of the urban built-up area has a relative energy density of about 60kWh/m2 (HNS landscape Architects, 2012); the Westlands, and Europoort roughly 80 kWh/m2 ; Hoek van Holland and Maasvlakte 100 kWh/m2 and finally Maasvlakte 2 120 kWh/m2 (HNS landscape Architects, 2012)(fig 5.2.2). Overlapping this with built-up densities reveals the relative low potential for wind turbine placement in the area, leaving little room for implementation (fig 5.2.4).

**fig. 5.2.1**
Solar power density
source: H+N+S landscape architects, 2012

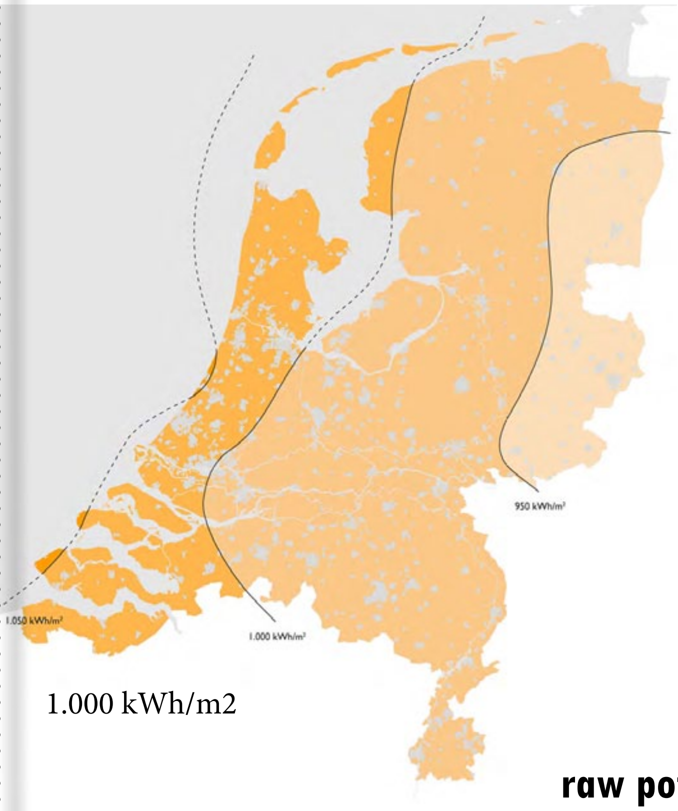
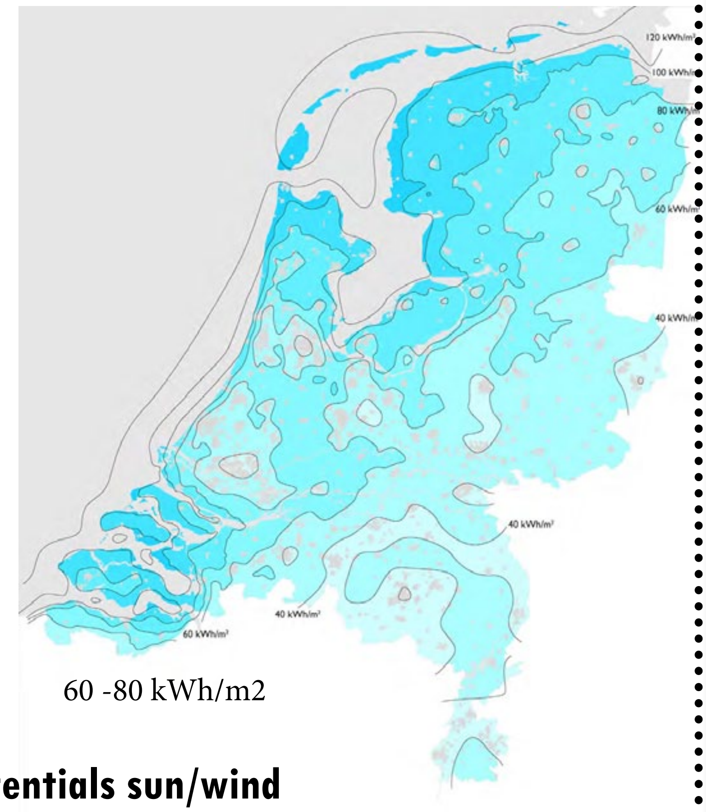



**fig. 5.2.2**
Wind power density
source: H+N+S landscape architects, 2012



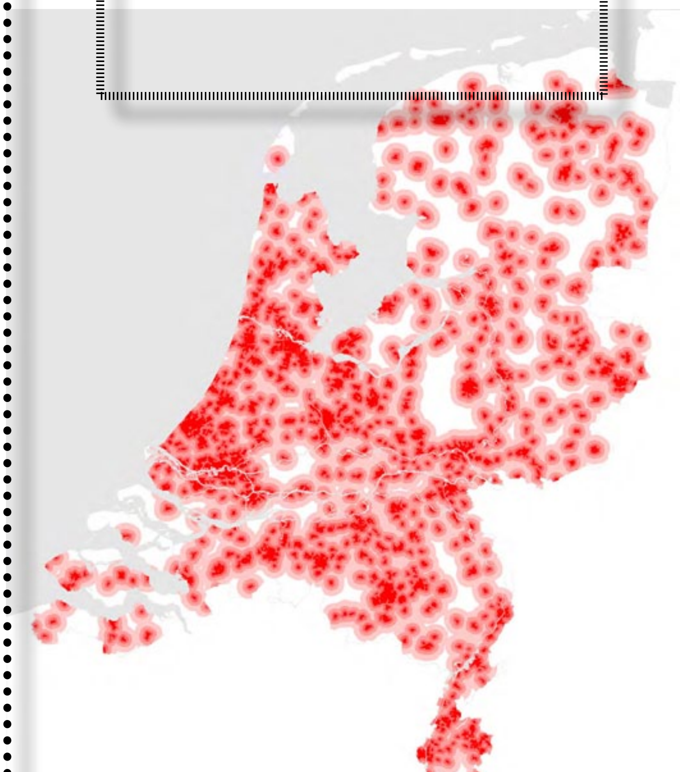

**raw potentials sun/wind**

**fig. 5.2.3.1**
detailed built space for Rotterdam
source: by the author

**fig. 5.2.5**
PV panel potential - facilitated by density
source: H+N+S landscape architects, 2012

**fig. 5.2.3**
built density
source: H+N+S landscape architects, 2012

**fig. 5.2.4**
wind turbine potential -limited by density
source: H+N+S landscape architects, 2012



**limitations/opportunities filter**

**actual site potential**

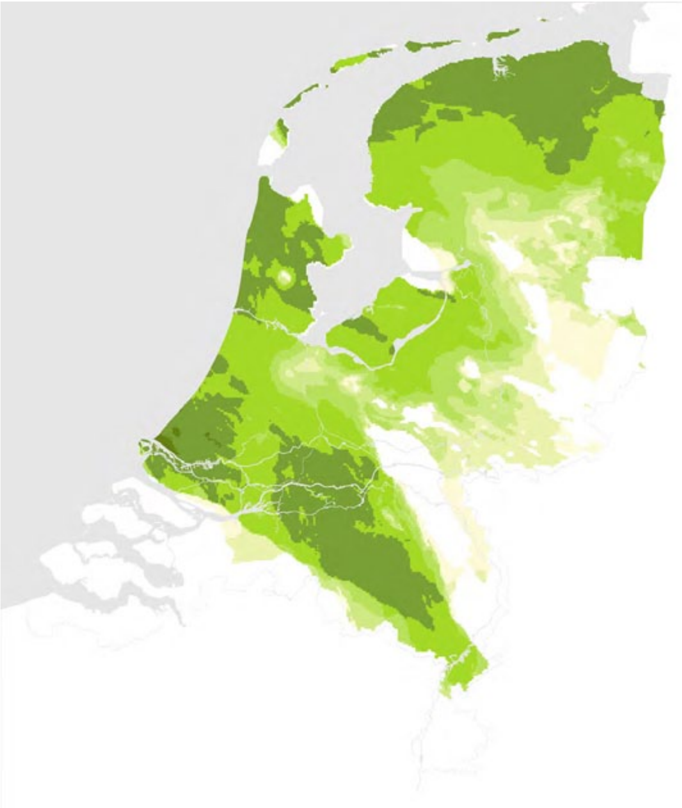
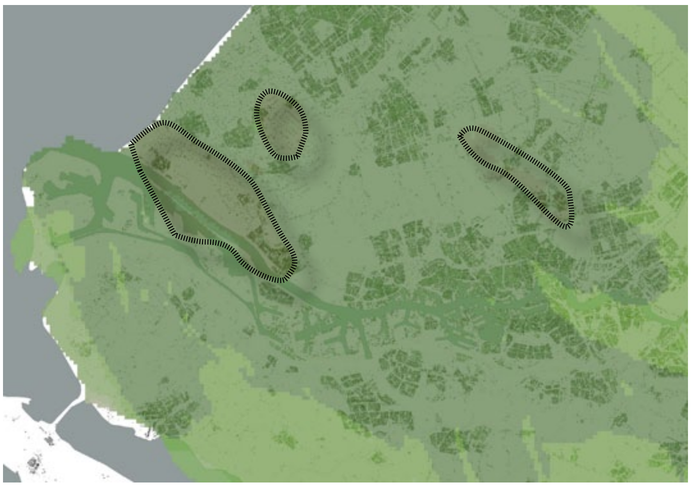


**fig. 5.3**
geothermal potential areas mapped for the neth-
erlands
Rotterdam in the highest potential zone
source: H+N+S landscape architects, 2012

**fig. 5.3.1**
25C return potential
geothermal potential areas mapped for Rotterdam
figure based on TNO, 2012

**fig. 5.3.2**
40C return potential
deep geothermal potential areas mapped for Rotterdam
figure based based on TNO, 2012



# Soil

geothermal

In terms of geothermal potential, the Rotterdam region is one of the most favorable site in the Netherlands (TNO)(fig 5.3). There are several types of potentials in the area according to TNO, and they can be differentiated by depth and temperature return. In this section we will be referring to aquifers of 1400-5000m depth. For higher temperature returns (40C) most of the areas is situated in a potential zone (fig 5.3.1), revolving around 1000-5000 GJ/ha/year (TNO, ThermoGIS, 2012). Some few idea places have potentials of over 5000 GJ/ha/year and the south easterly area under 1000 GJ/ha/year (TNO, ThermoGIS, 2012).

For a return temperature of 25C (fig 5.3.2) the search areas are approximately the same, with some variations in size. Majority of the region is under the same energetic potential of 1000-5000 GJ/ha/year, with some extra zones of over 5000 GJ and areas under 1000GJ/ha/year being smaller.

All of these potentials are quite high for the Netherlands, making Rotterdam ideal for exploiting geothermal aquifers.

# Nature and Agriculture

animal /farming biomass

In terms of animal manure the area has a relatively low potential (fig 5.4), especially when comparing it to other site in the Netherlands (Ministerie van Economische Zaken, Landbouw en Innovatie, 2012 ). This is mainly due to the relatively low number of animal farms in the immediate region, with the exception of Hoeksche Waard, this however does not have the potential of being relevant on a regional level, but mainly only for the area itself.

Plant biomass, either from agricultural or nature pruning has some potential in the area, although not particularly interesting, but it can however be used as an added bonus, supporting other energy plans. The obvious areas suitable for this are nature, meadows and so forth and have a capacity of generating roughly 50GJ/ha/year (Ministerie van Economische Zaken, Landbouw en Innovatie, 2012 ).

**fig. 5.4**
animal manure potential evenly distributed but low
figure based on TNO, 2012

**Buildings, industry and infrastructure**

residual heat

This section is mainly represented by residual heat from different functions in the city, and by the potential for harvesting the solar thermal energy by means of roads for example (Dobbelsteen, Broersma, & Stremke, 2011).
Having the strong industrial sector Rotterdam, has immense potential in terms of residual heat from these functions. These however are often situated far from residential uses or greenhouses, which represent functions that could benefit directly from the residual heat. In order for the cascading of this heat to work, a distance of no more than 2-2.5 km should be followed along the network. Therefore creative ways in which to close the links should be sought (Dobelsteen & Tillie, 2009). The extensive road network, especially motorways, also represent a high potential for harvesting thermal energy and cascading it in the built environment.

Overall Rotterdam has a high potential for making use of this type of energy, and by implementing networks according to REAP (Rotterdam Energy Approach and Planning), sustainable solutions can be generated, which not only reduce the amount of entropy but decrease the amounts of heat released in the city in the summer time, therefore potentially reducing the urban heat island effect.

## Conclusions

Water as a source of energy has not been detailed. This is mainly because of the limitations imposed of the harbor area and sailing routes. Water generated power is more feasible in the nearby areas (Goerre-Overflakkee or Schouwen Duiveland.)

suitability

As a general conclusion of the brief energy potential inventory, Rotterdam is revealed as having a relatively low potential for wind energy (at least in the conventional way of wind turbine conversion). This is mainly due to the conflict of living areas with this type of energy, and possible conflicts in the harbor. Therefore future plans should not rely heavily on wind energy, especially not onshore. The region has a somewhat high potential for sun energy (relative to the Netherlands) and due to its compatibility with living, this type of electrical conversion technique should be preferred. Also creative ways in which residual heat is used to its potential should be sought out. Biomass should be used as an added value and not form the basis of future energy plans.

In terms of geothermal energy Rotterdam has one of the highest potentials in the Netherlands and this together with the high amounts of residual heat and potentials for harvesting solar thermal energy, could generate interesting opportunities for the city. Heat collecting and storage in the underground is more feasible in Rotterdam than almost anywhere else in the Netherlands.

**fig. 5.5**
heating demand mapped out
source: by the author based on TNO, 2012

# 5.2_ Microclimate Analysis

## Introduction and Method

It is equally important to project the effects of climate change on Rotterdam's microclimate and reveal potential problems, focus areas as well as ring forth potential links between solutions for microclimate and solutions for energy. The projected changes in global, national and regional climate will be detailed for Rotterdam in the following chapter.

mitigation and adaptation

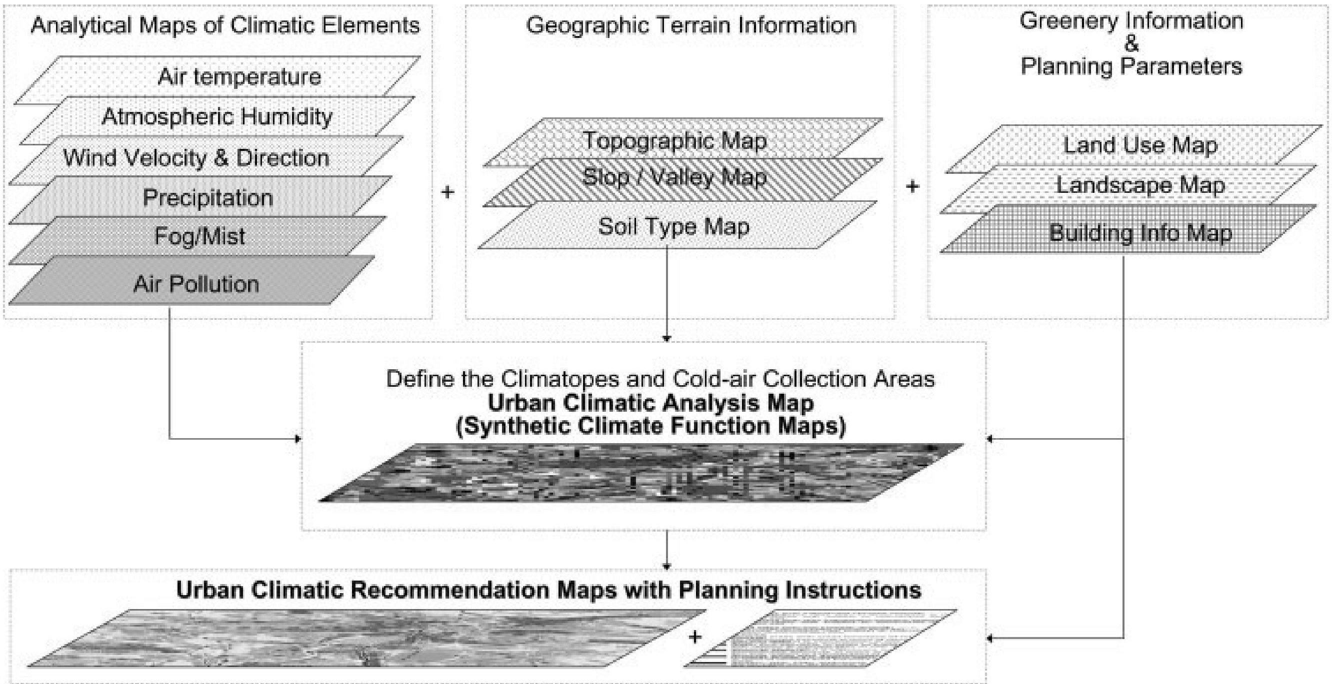
Human response to climate change is twofold. One response is defined by mitigation; which refers to attempts to slow down the process of climate change by lowering the greenhouse gas emissions in the atmosphere (Haitsma, 2011).

Another response is represented by adaptation; which can occur in two ways. One way is earth's natural adaptation to the new climatic conditions and another is human adaptation. Natural adaptation of the environment comes in direct contact with the fundamental notion of the city which requires environmental stability. In this way adaptation response by the environment becomes a hazard to the urban form and fabric (Florescu, 2004 ; Haitsma, 2011).

adaptation

Human adaptation is defined in several way, the comon points of reference being ". . . the term adaptation means any adjustment, whether passive, reactive or anticipatory, that is proposed as a means for ameliorating the anticipated adverse consequences associated with climate change" (Stakhiv, 1993 in: Feenstra et al., 1998, p. 120). In the following paragraphs the adverse effects of climate change on the urban fabric will be explored. As a general methodological underlining factor of the coming studies we can identify Urban climate analysis mapping (fig 5.6). This methodology will not be entirely explored as the purpose of the study is not to generate climate recommendations and climatope mapping of Rotterdam.

**fig. 5.6**
Urban climateanalysis mapping method
source: Ren et al. 2010



The focus will be on the first part of the methodology which is describing ways of gathering climate, geographical and spatial data and combining them in order to generate climate function maps which reveal potential problems. This would then form the basis of the climatope maps and would be further translated into recommendations, but as said it would require further research.
The Urban Climate Analysis Map (UC-AnMap), also refered to as "Synthetic Climatic Function Map" is a methods which provides the basis for integrating and working with climate information in such a way that it generates climatically robust solutions. (Ren, Yan-yung, & Katzschnerb, 2010). The approach is similar to EPM in the sense that it makes use of objective and specific data I order to generate a synthetic map.

Urban climate analysis mapping

The UC-AnMap is informed by three types of information, from analytical maps of climatic elements (air temperature, humidity, precipitation etc.), to geographic terrain information (topography, soil etc.) and greenery and planning information such as land use maps, landscape maps and so forth. There three data typologies are combined to generate the synthetic climate function maps which essentially are defining climatopes* and air dynamics in the site. These maps are furthermore translated into urban climate recommendation maps by overlaying the human activities, identifying problem areas and articulating a specific approach and strategy for each type or subzone identified (Ren, Yan-yung, & Katzschnerb, 2010).

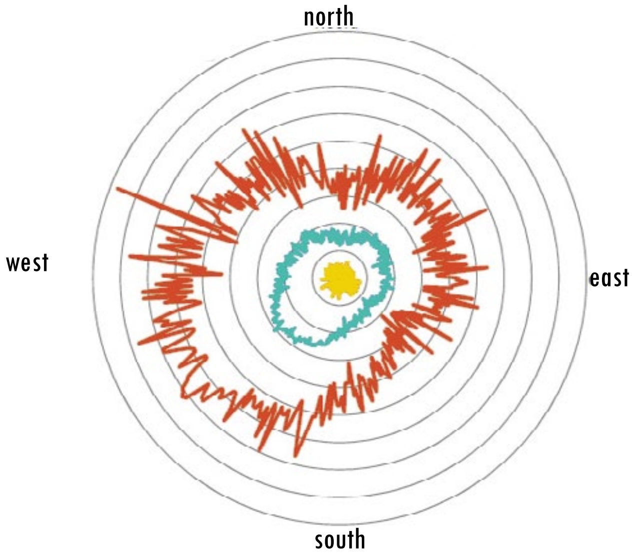


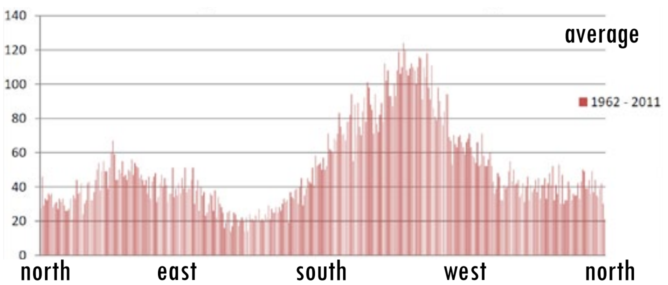

**fig. 5.7**
wind rose for Rotterdam -
minimum wind speeds (yellow)
medium speeds (blue)
maximum wind speeds (red)
figure based on KNMI data

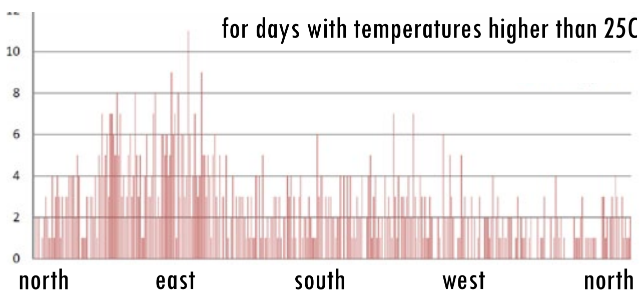
## Wind Dynamics

**fig. 5.8**
wind direction frequency

yearly average and for days with temperatures higher than 25C
graphs based on KNMI data

Wind dynamics are a crucial part of the urban microclimate. The can attenuate some effects of climate change is managed properly or they can multiply its negative impact on the urban environment. Urban geometry is vital in wind dynamic manifestation within the urban fabric (Bottema, 1993). Streets and buildings can intensify wind speeds in the winter or they can block convective cooling winds breezes in the summer, depending on their placement and general geometry (Bottema, 1993).



winter problems

For Rotterdam, an analysis of the wind patterns in the past decades reveals the main wind direction as being south-westerly (fig 5.7), with the strongest winds in the winter coming from that direction. Therefore, areas exposed to this direction should be protected in order to attenuate the wind chill factor, decrease turbulence and improve the urban microclimate (Bottema, 1993).

summer problems

In the hottest summer days the main direction for wind is north-east; south west. Along this axis cooling and ventilation channels should be provided, without of course, intensifying the wind problems in the winter.

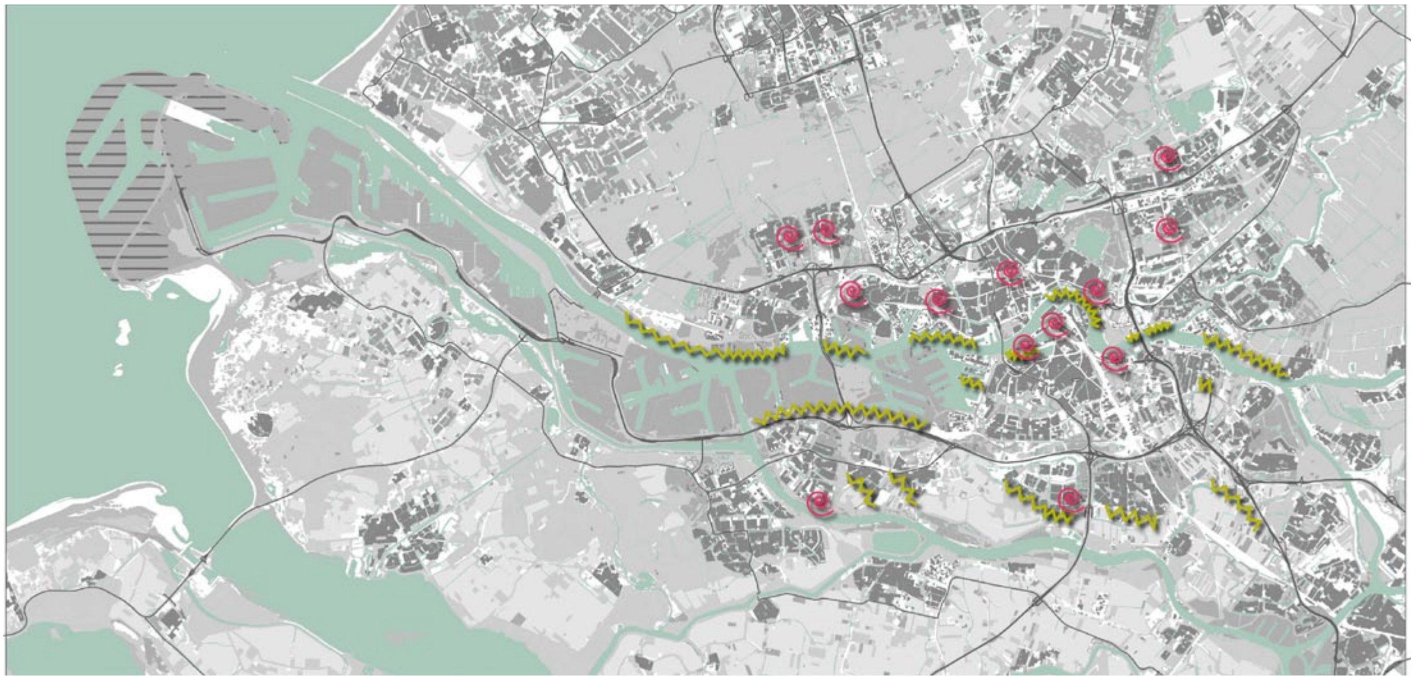
In the below figure, wind dynamics potential problems are revealed at a city level.

conclusions

Mostly the issues facing Rotterdam have to do with turbulence which is present in the areas of high rise buildings and where certain constructions are 50% higher than their surrounding(fig 5.10).

Other important issues have to do with barriers for cool convective breezes, especially in area where there is a high temperature difference between them and their immediate surroundings. Generally these areas are situated along the port of Rotterdam, where hot industrial or the inner city, are directly adjacent to good water bodies or green areas(fig 5.10).

**fig. 5.10**
wind dynamics problems
showing turbulence (pink) and convective wind barriers (green)
figure based on van der Harst, 2011



# Urban Heat Island Effect

The combined circumstances of buildings geometry, improper greening, and material usage in Rotterdam, leads to intensification of the urban heat island effect.

measurements

Measurements done with a mobile station across Rotterdam reveal the dynamics of the process in hot summer days. During the day time, the differences between the inner city and green areas outside. Actually in some instances temperatures outside might even be somewhat higher than in the shaded centre.

heat island effect described

The problem is, in this time, buildings in the inner city absorb radiation from the sun and release long wave radiation during the night. This radiation is kept inside the urban fabric due to built density (low skyview factor) and therefore makes temperatures stay high.

In the measurements done during the night time, this process is visible as outer green areas have cooled down while the inner city is even hotter than during the day time (fig 5.11).

**fig. 5.11**

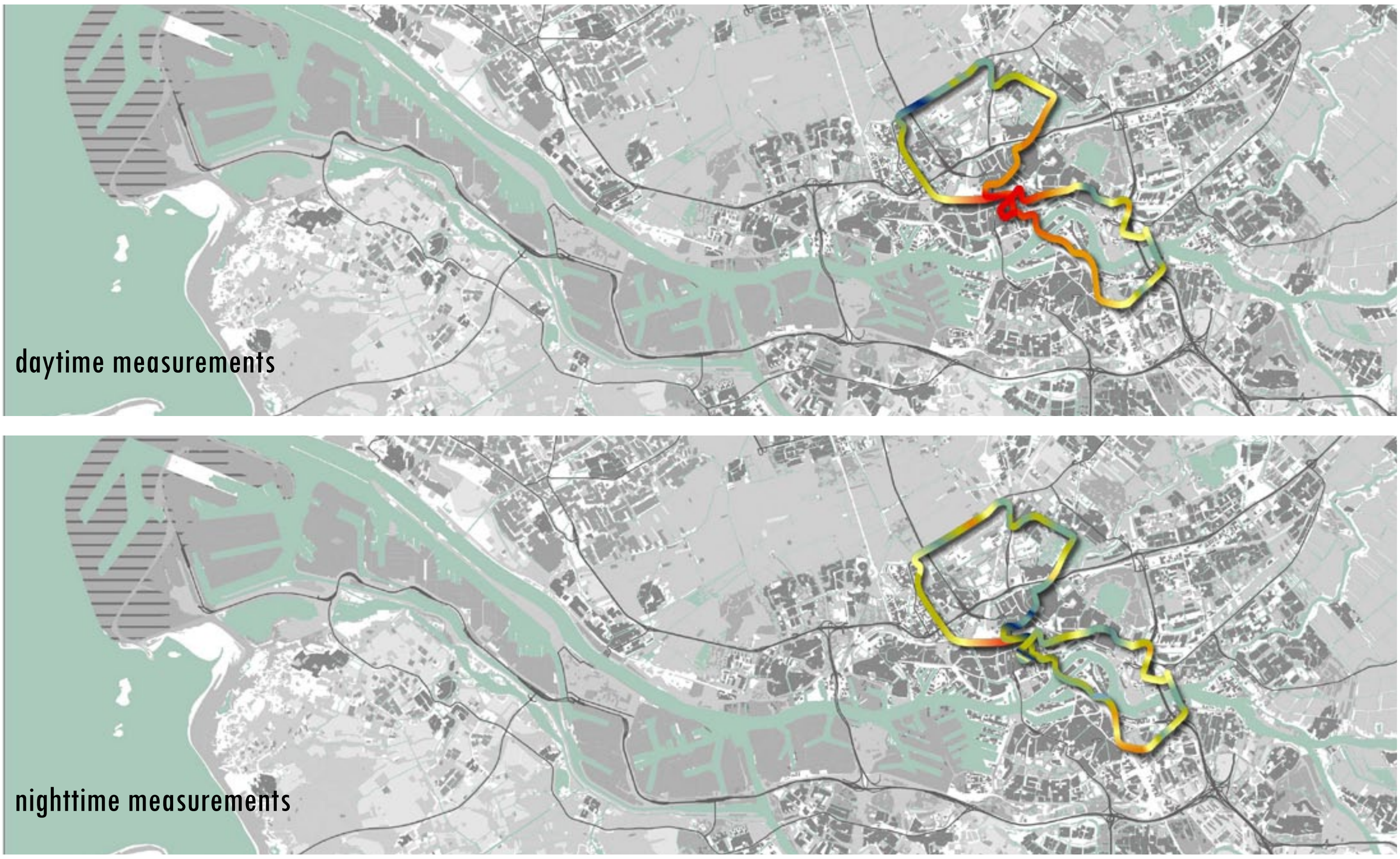
inner city heat island effect

daytime measurements on 6th of August 2009 at 14:00-16:00 - temperatures from 28C(blue) to 40C (red)

nighttime measurements on 6th of August 2009 at 22:00-24:00 - temperatures from 17C(blue) to 27C (red)

measurement with mobile station

figure based on Heusinkveld, 2010



# Water

KNMI scenario rainfall

The KMNI climate scenarios are explored in terms of rainfall. Two scenarios are taken as reference (W and W+). The projections for each of the scenarios are compared in order to make estimates on potential water problems in the future and work out what measures are to be taken, and most importantly what is the water assignment for Rotterdam inner city.

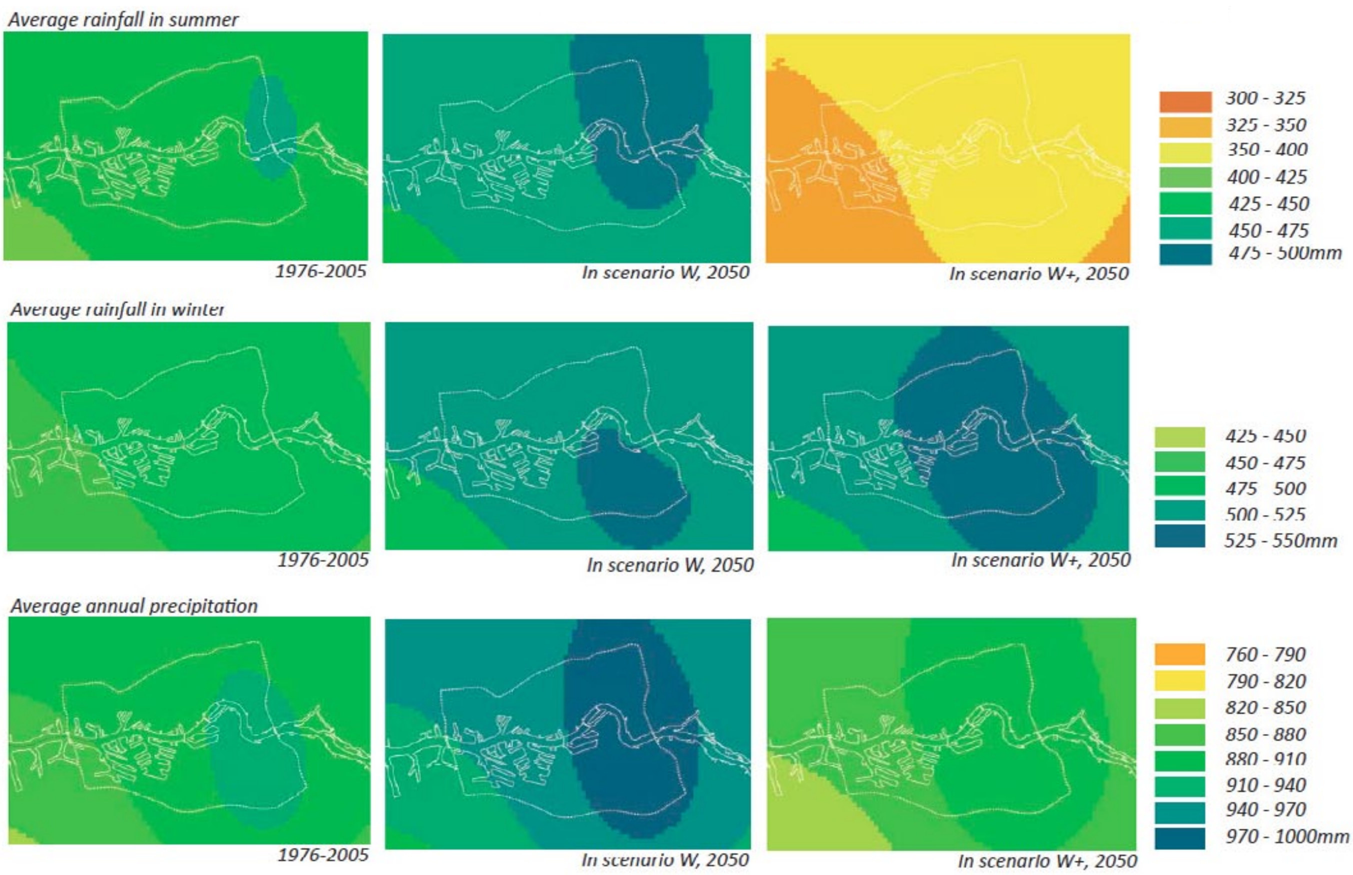
The scenarios have in common an increasing of rainfall in the winter but differ in terms of expectations for summer rainfall. Scenario W is estimating an increase in precipitation while W+ is estimating shortages in terms of rainfall (KNMI, 2006).

worst case scenario

The strategy adopted is to try and prepare Rotterdam for the worst case scenario, which would be a decrease in precipitation in the summer and highest increase in the winter. Therefore, what is needed is storage space for draught periods and retention for peak rainfall(fig 5.12).

Due to the high amounts of hard paved surfaces in Rotterdam the challenge for managing future rainfall is an  important one, and one which will be difficult to coordinate properly  (Qian, 2011).

**fig. 5.12**
rainfall projections
source: KNMI, 2006



## Conclusions

The predicted changes in climate for the coming decades will impact and are already impacting Rotterdam in a major way.

The aspects considered important in this research, and need addressing are related to improving wind and temperature conditions in the city, at the same time adapting to predicted changes in rainfall. By doing this the expected result are a reduced urban heat island effect and comfortable wind microclimate at the same time waterproofing the city.

# 5.3_ The Need for a Systemic Approach

need for connections

The relation between energy and climate proofing becomes evident when looking at issues such as the urban heat island effect and its influence on energy consumption the summer (for cooling) or in the winter when looking at energy used for warming. In light of this the need for a more comprehensive approach is apparent. The main issue at the foundation of this relative confusion in terms of approach is the unclear nature of the problem. This becomes apparent when trying to define it from climatic and energetic stand points.

systemic design

Their interconnectedness is such that it is difficult to pinpoint the precise origin. Alan Berger (Berger, 2009) put forth systemic design as being not about the problem but about the scale. A process of investigation based on generalist knowledge rather than specialist knowledge is slowly uncovering the problem using both top down and bottom up approaches.

In this sense systemic design is a means of uncovering connections and revealing solutions that are not apparent when defining the problem to narrowly. The systemic approach is therefore regarded as means of dealing with the interlinking.

A literature research reveals that systemic design is not something entirely specific to the design or planning profession and it is in fact as an approach present for quite some time especially in professions dealing with artificial intelligence IT and computer sciences.

It is defined by four key components.

1. A design based approach
2. A organismic phylogenetic consideration
3. A holistic approach to design
4. A consideration for resource limitation

design based approach

Design based approach – “This approach to solving a problem is based around performing a requirements analysis of the problem in hand, followed by an exploration of the possible mechanisms to meet these requirements (the exploration helps to clarify the requirements). Finally a design is produced for mechanisms that best meet all the requirements. A key fact about this technique is that there is not a unique way of solving any problem” (Read, 1993, p. 2).

organismic phylogenetic consideration

Organismic phylogenetic consideration – “It may well be the case that a problem that caused some feature of an organism’s architecture to come into existence is no longer around.
Hence the design-based approach, used to solve the organism’s current

problem set, will not produce the same type of architecture as would a design strategy that incorporates phylogenetic considerations […]the importance of understanding the types of problems that our ancestors would have had to solve, and how the solutions that they evolved might have influenced the mechanisms we have today.
This does not require a very detailed understanding of every evolutionary step. Instead it requires judicious consideration of key types of problems and their solutions, in the context of the likely levels of architectural sophistication that would have been present at the time." (Read, 1993, p. 2).

The organismic phylogenetic consideration is important when regarding the energy or climate issues as morphological problems of the urban structures, and when re-examining their evolution and structuring components.

holistic approach to design

Holistic approach to design- "By pulling together data taken from different fields of expertise the scope for mistakes in the generation of theoretical models is limited.
This combined top down and bottom up mutual support technique can be called a holistic design strategy, as it places emphasis on the importance of studying a system from as many directions as possible" (Read, 1993, p. 4).

This approach means to intersect problems and challenges in energy and climate; to investigate the nature of the city and how a drastic reinterpretation could solve today's problems with today's tools. As stated by organismic phylogenetic consideration principles, problems solved in the past are likely to have very different solutions today, and therefore should be investigated perhaps even with tomorrow's technology in mind.

From this, a set of focus points are set in place for future designs. All of the points are interrelated and managed in such a way that they generate sustainable solutions which are adapted to people.

1. The most important goal is energy efficiency as understood by SLT (second law thinking).

2. The solution revealed by a thermodynamic approach is molded in order to improve microclimate and address the goals of climate proofing

3. Potentials for added value are explored: renewable energy supply or even energy self-sufficiency; potentials for food provision or even food self-sufficiency.

# 06 TESTING THE SYSTEMIC APPROACH

As mentioned in previous chapters, consideration for future projections in a important aspect of this research. Therefore investigations are done in this sense, both in terms of far and near future, but also in terms of plans and programs put forth by the municipality.

Out of all the planed actions one stands out with reference to the inner city. That is the plan to density the center of Rotterdam. Rotterdam is, as stated before, inhabited by 50% less people in the inner city than the same area in Amsterdam for example. This is believed to have impact on energy and climate as well as the livability of the inner city (Municpality of Rotterdam, 2012). In order to creatively density the inner city a strategy is put in place called "Rotterdam – people make the inner city". This strategy developed by the Municipality of Rotterdam in collaboration with Doepel Strijker architects and TNO is exploring potentials for densification while at the same time maintaining livability, accessibility to urban green and so forth.

In order to investigate the potential of a systemic approach to design, the starting point chosen is a brief testing on current initiatives. In this sense the densification strategy is studied and looked through with the systemic guidelines formulated in the previous chapter. This way, the goals is to see how the strategy could benefit from the approach and whether its initial goals (of obtaining both green and inhabitant density) are affected.

**fig. 6.1**
inner-city densification

source: Municipality of Rotterdam, TNO, DSA, 2012

# 6.1_ Thermodynamic and climatic optimization

## Making inner- city strategy proposal

The strategy developed proposes 7 typologies for densification and for greenification of the inner city(fig 6.1). The strategies or guidelines are developed with the goal of doubling the density within the center of Rotterdam and at the same time add new green space. The hope is that by going hand in hand with greenification the strategy for densifying the inner city will also improve the micro-climate and perhaps save energy.

densification

"If we consider the notion of doubling the number of inner-city dwellers in Rotterdam, the question that arises is a two-fold one: is there enough physical space for 20.000 new dwellings without destroying the existing qualities of the urban fabric; and how can the municipality help create "mental space" needed to help potential home owners identify these chances and capitalize on them? "(Municipality of Rotterdam, 2012, p 11). The aim of the research is claiming of going beyond densification and adding more green and citing "smart densification".

The goal of this brief investigation s to see whether the guidelines proposed are all doing so and what are additional, unexplored potentials.

In paragraphs to come, each of the guidelines presented in the strategy will be described, then analyzed from an energy efficiency standpoint and from micro-climatic consideration, and in the end further potentials will be explored.

# 7 strategies for densification viewed through systemic and holistic design lens.

**fig. 6.2.1**
groundbased densification potential mapped
source: Municipality of Rotterdam, TNO, DSA, 2012

## Ground-based dwellings

“access at ground level makes a street featuring ground-based housing particularly attractive” (Municipality of Rotterdam, TNO, & DSA, 2012, p. 13)
I refers to inserting new housing were space permits it. Without specifying limitations what height or consideration to street patterns, it is difficult to make a proper assessment of the typology with regards to its surroundings. What we can do is asses ground-based housing typologies form a theoretical stand point in terms of energy, and climate (fig 6.2.1).

### Thermodynamics and microclimatic optimization

In what energy demand is concerned, ground based housing can be the most energy efficient, as long as it is not detached housing (Energy Australia, 2005). If ground based housing is developed as townhouse, terraced, and row typologies then energy efficiency is quite high (Energy Australia, 2005), therefore making then strategy thermodynamically valid. In terms of microclimate generally low rise housing is not as the source of wind issues such as turbulence of improper ventilation (Bottema, 1993). At the same time this typology does not cast large shadows or impact the skyview factor of the city dramatically and as it generally has green space adjacent, it does not contribute to the urban heat island effect (Wilmers, 1990).
Concluding, this type of strategy seems to have all the potentials to be a beneficial addition to the urban fabric in Rotterdam, provided architectural design and implementation keep energy and climate as central.

**fig. 6.2.2**
water-dwellings densification potential mapped
source: Municipality of Rotterdam, TNO, DSA, 2012

## Water-dwelings

“Situated away from the hustle and bustle of traffic, these housing areas benefit from the proximity of top-quality urban amenities[…]living on a grand landscape structure allows for a new perception of the River and its old harbors“(Municipality of Rotterdam, TNO, & DSA, 2012, p. 21).

### Thermodynamics and microclimatic optimization

To these typologies of housing, energy and climate guidelines similar to ground based housing apply. Therefore these can be a welcomed addition to the city. One microclimatic aspect standout though. The insertion of these housing areas has the potential to repair or aggravate some wind dynamics issues of the city. Previously we have identified much of the waterfront of Rotterdam as being a barrier for cool convective breezes coming from the water body, which could potentially cool down the inner city. These new insertions on the waterfront could be developed in such a way that they try to positively influence and guide the breezes towards the center. They have the potential of reconnecting the inner-city with the water in terms of airflow. For this to be achieved, the sloping of the areas needs to be thought of in such a way that the heavy cool air can pass them, and at the same time its materials must provide an environment which does not heat up the air before it arrives in the problem areas.
In short, with prosper sloping of the terrain, corridors for air and less paved surface these areas can be a perfect addition to the waterfront. If not they can make it even more difficult for the city to cool off.

## High-rise dwellings

**fig. 6.2.3**
high-rise densification potential mapped
source: Municipality of Rotterdam, TNO, DSA, 2012

"City densification by means of high-rise is consistent with the Rotterdam famous skyline[…] as they are naturally situated in the most urban areas (high-rise zones) the inhabitants of such dwellings benefit from proximity to amenities" (Municipality of Rotterdam,TNO, & DSA, 2012, p. 22).
In Rotterdam the high-rise typology is defined as referring to buildings with a height of 70m or more. (Municipality of Rotterdam, TNO, & DSA, 2012). Therefore this is one of the most impacting change for the city (fig 6.2.3).

### Thermodynamics and microclimatic optimization

From an energetic standpoint, high-rise buildings are the most inefficient out of all the housing typologies. An average household in a high-rise complex consumes roughly 2 times more energy yearly than a same size household situated in a townhouse or row house (Energy Australia, 2005). From the start this typology is not very promising in terms of energy efficiency, especially in the current environment, when people are now paying half of what they pay for mortgages , for energy. This percentage being only half of that it is just 10 years ago (Tillie, 2011). Even if factoring in space saving and arguments of proximity this is still not a sustainable investment for the future.
Furthermore from a microclimatic perspective, high-rise buildings are the main source of turbulence in urban environments, and they can generate very uncomfortable public spaces for inhabitants (Bottema, 1993). Moreover increasing the height of the buildings greatly decreases the sky view factor and even though they could provide shade in the daytime, they release great amounts of long wave radiation during nighttime and block the ventilation of the city, being major contributors to the urban heat island effect (Oke, 1973).
Therefore the aim should be to considerably reduce the size of the proposed high-rise buildings. The energy Australia report mentions that up until a height of 10-15 stories there is not a major difference between low rise mid rise and high-rise energy consumption, therefore the 70 m height threshold proposed, is recommended to be lowered to 35m in order to improve energy efficiency and mitigate the adverse effect on urban microclimate. Also considerable attention should be given to materials.

## Transformation dwellings

**fig. 6.2.4**
transformation densification potential mapped
source: Municipality of Rotterdam, TNO, DSA, 2012

The current vacancies were mapped out. These consist mostly of the post-war reconstruction office and industrial buildings, mentioned in previous chapters. "Situated in the most attractive parts of town, and equipped with spacious parking facilities, these buildings provide optimal opportunities for high-quality living" (Municipality of Rotterdam, TNO, & DSA, 2012, p. 27).

### Thermodynamics and microclimatic optimization

From an energetic perspective, as well as microclimatic benefits it is hard to generalize assessment of these constructions due to their wide variety of architectural manifestation, form, and so forth. The benefits of recycling the built stock are obvious however with regards to this case. One observation that come to mind is the general character with regards to size of buildings, which are larger than the average housing block in Rotterdam. This aspect needs to be taken into account when redesigning the block, with regards to green space, materials and so forth.

**fig. 6.2.5**
skyborn densification potential mapped
source: Municipality of Rotterdam, TNO, DSA, 2012

## Skyborn dwellings

“Existing buildings with a solid construction are suitable for densification by “topping-up”. This is mostly done with houses after 1950 with their concrete or steel structure and flat roofs. For the greater part, buildings suitable for this form of densification are owned by corporations and developers which often makes their developments by market easier that with privately owned property” (Municipality of Rotterdam, 2012, TNO, & DSA, p, 31).

### Thermodynamics and microclimatic optimization

This typology is very promising for several reasons. On the one hand it offers the opportunity for extra insulation of the existing buildings, and also improving materials of buildings and affect the microclimate positively; adding green roofs, green facades, etc.

**fig. 6.2.6**
infill densification potential mapped
source: Municipality of Rotterdam, TNO, DSA, 2012

## Infill dwellings

“The urban fabric of terraced houses, corner houses and flats can be completed by dwellings that fit in with surgical precision – infill housing. Gaps above narrow delivery streets, in developed plots of land and large courtyards can be filled in with dwellings that cross the street like a bridge” (Municipality of Rotterdam, 2012, TNO, & DSA, p. 33)

### Thermodynamics and microclimatic optimization

This particular strategy is another interesting addition from an energetic stand point. Mostly due to the opportunities mentioned for skyborn guidelines. However when it comes to the urban microclimate apart form close attention to materials and volumes, one particular danger stands out. The infill strategy of generating “gaps” in the hosing blocks can be quite dangerous for wind microclimate. Buildings gaps usually have a speeding up effect on wind. Air flow going through buildings gaps is roughly double in speed by the “Venturi Effect” (Bottema, 1993). This phenomenon can be advantageous when, in summer days ventilation and cooling off as well as removing of pollutants is important, but it can be equally harmful in the winter when strong freezing winds are transformed into even faster air flows (Bottema, 1993).

**fig. 6.2.7**
do it yourself densification potential mapped
source: Municipality of Rotterdam, TNO, DSA, 2012

## Do it yourself dwellings

“With their characteristic facades, nineteenth century housing stock appeals to a large group of home buyers. Often in poor state of repair and way too small to meet current spatial demands, houses of this type can be adapted to suit the lifestyles of young professionals and families” (Municipality of Rotterdam, TNO, & DSA, 2012 p. 36).

### Thermodynamics and microclimatic optimization

This particular strategy is quite distant in approach from all the other, referring mostly to inner redesign of houses. Furthermore only a very small number of potential houses in found. Therefore this type of strategy, is considered to insignificant to have any impact on the microclimate or to individual to real be evaluated in terms of energy. Moreover because of its small contribution to the total number of houses (110 out of approx. 20.000 proposed) it will be disregarded in future calculations.

# Adjusted densification potential

After looking at the strategy trough the systemic, holistic approach lens, and making the adjustments, some typologies have been drastically reduced (high-rise by 50%, and do it yourself removed). This can be however compensated trough unexplored potentials of other strategies. The sky born strategy can be as it is proposed further densified (even doubled). This is proposed as it would make much more sense form an energy standpoint then building high-rise towers, and they can also be maintained within acceptable levels in order to contribute beneficially to urban microclimate. Even with the additional costs and challenges of strengthening the structures of existent buildings it would not compare to constructing 100m towers. Both in terms of energy and materials. Moreover the existent buildings would benefit from this retrofit action and therefore further energy and investment is saved on future potential interventions.

adjusted potential

Finally the recommendation, form a thermodynamically and climate perspective would be as mentioned to reduce the height of high-rise buildings (turning them into midrise essentially), and intensify the sky-born strategy. The final figures are calculated according to this proposition and the end result is quite promising. From a initial number of 20250 potential households in the original strategy, we can achieve 19.430 potential households in a more energy efficient and microclimate responsible way. This is a first step in validating the potential of a systemic approach, and its potential of obtaining good results in a more responsible way, without damaging the original goals (fig. 6.2.7).

**fig. 6.2.7**
total adjusted densification potential
by the author based on :Municipality of Rotterdam, TNO, DSA, 2012

| | GROUNDBASED | WATER DWELINGS | MID/RISE DWELINGS | TRANSFORMATION | ROOF | INFILL |
|---|---|---|---|---|---|---|
| CS KWARTIER | 0 | 0 | 1235 | 90 | 0 | 90 |
| OUDE WESTEN | 210 | 0 | 133 | 170 | 1280 | 170 |
| LIJNBAANKWARTIER | 60 | 0 | 1050 | 830 | 540 | 830 |
| LAURENSKWARTIER | 1.110 | 10 | 1235 | 610 | 1410 | 610 |
| HOBOKEN | 600 | 0 | 172 | 130 | 30 | 130 |
| COOL | 50 | 0 | 60 | 290 | 90 | 290 |
| WATERSTAD | 110 | 120 | 1116 | 1280 | 110 | 1280 |
| NIEWE WERK | 500 | 0 | 490 | 290 | 60 | 290 |
| KOP VAN ZUID | 260 | 310 | 1697 | 0 | 0 | 0 |
| TOTAL | 2900 | 440 | 7300 | 3690 | 4560 | 540 |

TOTAL NEW HOUSEHOLDS **19.430**

compared to **20.250** in the original strategy

# 6.2_ Potential Added Values

In order to fully touch upon systemic approach to design additional opportunities need to be investigated in terms of resource scarcity and flows. One is considered of great importance for urban environments, and that is food provision. By using the transformation densification strategy, we can supply the entire inner city with several basic vegetable needs, all year round.

## Food

As mentioned before the built stock available for transformation is essentially comprised out of large buildings with huge roof space which is currently unused. This offers to opportunity for urban agriculture. With a proposed future population of 60.000 inhabitants (compared to today's 30.000) Rotterdam inner-city would need roughly about 11ha of hydroponic rooftop greenhouses in order to provide year-round tomatoes, lettuce and herbs for all inhabitants (Bright Farms, Sunset Park greenhouse, 2012). The data is taken form already implemented hydroponic farms worldwide, and is based on their technical output.

potential for food production

The total roof space of existing available transformation strategy construction is 75.300m2 (Municipality of Rotterdam, 2012). This means that if all this space would be translated into hydroponic greenhouses they would provide tomatoes, lettuce and basic greens for roughly 35.000 inhabitants (Bright Farms, Sunset Park greenhouse, 2012), and additionally would take up 49 million liters of storm water, lowering the pressure on the sewage systems (Bright Farms, Sunset Park greenhouse, 2012).

1ha of greenhouse
5000 inhabitants (tomatoes, lettuce and greens)
500 tons of produce
7 million liters of storm water
(Bright Farms, SunsetPark greenhouse, 2012)

## Water

In what water in concerned, two major tasks are facing cities today. One is as mentioned in discussing climate scenarios, storage for shortage and peak rainfall (KNMI, 2006), and the other would be potentially providing self-purification systems for greywater and rainwater harvesting. In this sense the proposed strategies for green space in Rotterdam are explored to see whether a systemic approach can generate solutions which not only green up Rotterdam but also store and manage water, and purify greywater for use in households.

water storage

When it comes to water storage and peak rainfall management, some common landscape architecture techniques are: water plazas, swales, storage in gardens or roofs (van Dijk & Veul, 2010). These will all be considered in the following paragraphs when trying to work out the potential for realizing storage and filtration in Rotterdam.

First the water assignment of the inner-city should be worked out. This refers to exact space needs for storing water in drought seasons and for safely managing peak rainfall.

**For this some basic data is needed:**

Total surface of the inner-city – 330ha
Draining paved surface – 207,35ha
Paved – 63%
Storage capacity (mm) – 9
Storage capacity (m3) – 18.539
Pumping capacity (m3/h) – 1.197
Overflow drainage capacity m3/h – 3.334

(data from Municipality of Rotterdam, 2012)

shortage storage

Using scenario projections by KNMI , and comparing the extreme scenarios (wettest in the winter and driest in the summer) it to the current situation we can observe the highest difference in rainfall as being in May.
Overall shortage in the summer time in the current situation is 15+31+29+23+5 = 93mm. In the W scenario the shortage projected is 16+34+31.5+26+6.5=114.
The maximum water shortage will occur in May and it will be on average 34mm.
The 34mm difference over an area of 330ha (surface of the center) translate into a space need of roughly 22ha

S(storage) = 34mm X 3.300.000m2 = 112.200m3
Supposing an average fluctuation level of 0,5m (Qian, 2011), this results in a surface need of
112.200m3/0.5m = 224.400m2 = 22ha (fig 6.3.2)
(storage need for shortage periods)

**fig. 6.3.1**
rainfall in shortage season scenario W and current situation
based on: Qian, 2011

| Current situation | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug |
|---|---|---|---|---|---|---|---|---|
| Average precipitation | 70 | 58 | 70 | 48 | 58 | 68 | 78 | 80 |
| Average evaporation | 9 | 16 | 35 | 63 | 89 | 97 | 101 | 85 |
| Precipitation surplus | 61 | 42 | 35 | -15 | -31 | -29 | -23 | -5 |

| KNMI Scenario W | Apr | May | Jun |
|---|---|---|---|
| Average precipitation | 51 | 61 | 72 |
| Average evaporation | 67 | 95 | 103.5 |
| Precipitation surplus | -16 | -34 | -31.5 |

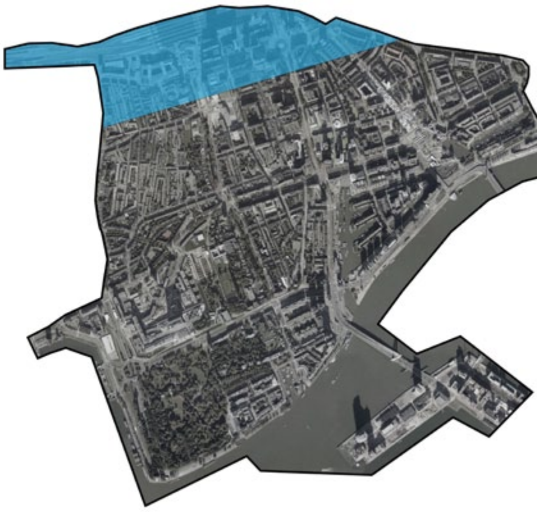
**fig. 6.3.2**
shortage storage assignment mapped (22ha)

In order to calculate the space needed for peak rainfall storage, the rational method described by Davis and McCuen is used, along with worked out examples of Qian (Qian, 2011).
The rational method:
qp=CiA
“relates the peak discharge (qp, ft 3/sec) to the drainage area (A, acres), the rainfall intensity (I, inches/h), and the runoff coefficient (C). The following formula in words was used to calculate the storage assignment and is based on this rational formula: Storage assignment = Runoff (Precipitation – Infiltration) – Storage within the drainage system – Discharge” (Qian, 2011, p. 74)

peak storage

After imputing the data from the municipality with regards ot pumping capacity, storage capability and so forth we can determine the space need for peak storage.
In the highest precipitation days the inner city will approximately incur about 323.400 m3 of rainfall/day (KNMI, 2006).

**fig. 6.4**
peak storage assignment mapped (39ha)



The storage surface storage is translated into 30.000m3 and the pumping capacity into 80.000m3 while additional storage provides 18.539m3 (storage in the system). This means that from the 323.400m3 falling on the inner city 30.000m3+80.000m3+18.539m3=128.539m3 can be managed. This leaves aprox. 195.000m3 worth of water to be stored and managed.

This water translates into 39ha of space (fig. 6.4) according to the previously applied method. (assuming a 0,5m fluctuation)

## Filtration

Also, if taking into account overage water use per inhabitant in the Netherlands which is 129l/day (CBS Statistics Netherlands) and as mentioned sticking to the goal of filtering and recycling greywater, this would require a certain amount of wetlands, distributed and interlinked within the urban fabric. According to data from several examples of constructed wetlands around the globe, compiled by Vymazal in the paper "Constructed Wetlands: a review" (Vymazal, 2008), a wetlands system of approx. 10ha (with a depth of 40-50cm) can purify up to about 8000m3 daily (Vymazal, 2008). For Rotterdam, if we aim to filter enough greywater for the projected population after densification takes place we would require greywater for 60.000 inhabitants daily. This is translated into

60.000 X 120l = 7200.000 l = 7200m3 (which we could overestimate to 8000m3 to compensate for uncertainty in consumption)

filtration in wetlands

Therefore, if taking date from previously implemented wetlands we would require roughly 10ha of wetlands to purify water for 60.000 inhabitants without any problems, and not damage the water harvesting system (Vymazal, 2008).
These 10ha of wetlands would be integrated within the storage and harvesting system of Rotterdam and therefore we would only require the maximum space needed which is 39ha.(assuming areas used for peak storage can also be used for shortage storage and that the wetlands are implemented in a way that does not damage the system). For this we could look at the greenification strategy for Rotterdam presented in the making Rotterdam study and adapt these areas where potentials arise, in order to see weather storage and filtration is possible. Similar to the densification strategy the research defines 7 greenification strategies. In order to store and filter water, certain percentages out of the space dedicated for these strategies will be used for water storage(fig 6.6).

adjusted green strategy to filter greywater

**Boulevards**
The green defined here refers mainly to line planting and spall green patches acros long boulevards.
From a water storage perspective these areas should function as gullys (van Dijk & Veul, 2010), harvesting runoff water and distributing it to major storage areas, therefore becoming the primary harvesting infrastructure.
**Squares**
The spaces defined as squares refers to public spaces of representative nature for the city, capable of welcoming large numbers of users (Municpality of Rotterdam, TNO, & DSA, 2012). These form a total of 23-24ha for the inner city (Municpality of Rotterdam, TNO, & DSA, 2012).

**fig. 6.5**
water filtration system integrate in urban water ways
source: ManMade Land, 2011

Assuming that space can be used in a creative manner, by implementing floating squares and water plazas (van Dijk & Veul, 2010), we can assume that some squares can function as water harvesting areas without losing its ability to welcome people. Therefore it should be safe to assume a 30% usage for storage, which would mean and overall 7ha for the inner city. (storage in squares)

**Quays**

The quays are defined as green spaces along canals and water bodies in the inner-city, and including the adjacent water (Municpality of Rotterdam, TNO, & DSA, 2012). A total surface of 25ha of quays is developed around the city (Municpality of Rotterdam, TNO, & DSA, 2012). These spaces can be used in very creative ways, not just to store water, but to filter it as well, making use of a section of the canals of water bodies. Similar examples have been researched, such as Flussbad Berlin, winner of Holcim gold prize in 2011(fig 6.5) . If we make use in a similar way of just 10% of the canal for filtering we gain a total of 2.5 ha for filtering in quays.

**Parks**

Park surface added to the existent one is totaling 7 ha, and if this would be used for water filtration and storage in a dynamic way, so that it can also accommodate human usage we would get to a total of 7 ha of filtration capacity.

The results of these potential calculations ca be viewed in figure 6.6 mapped and quantified.

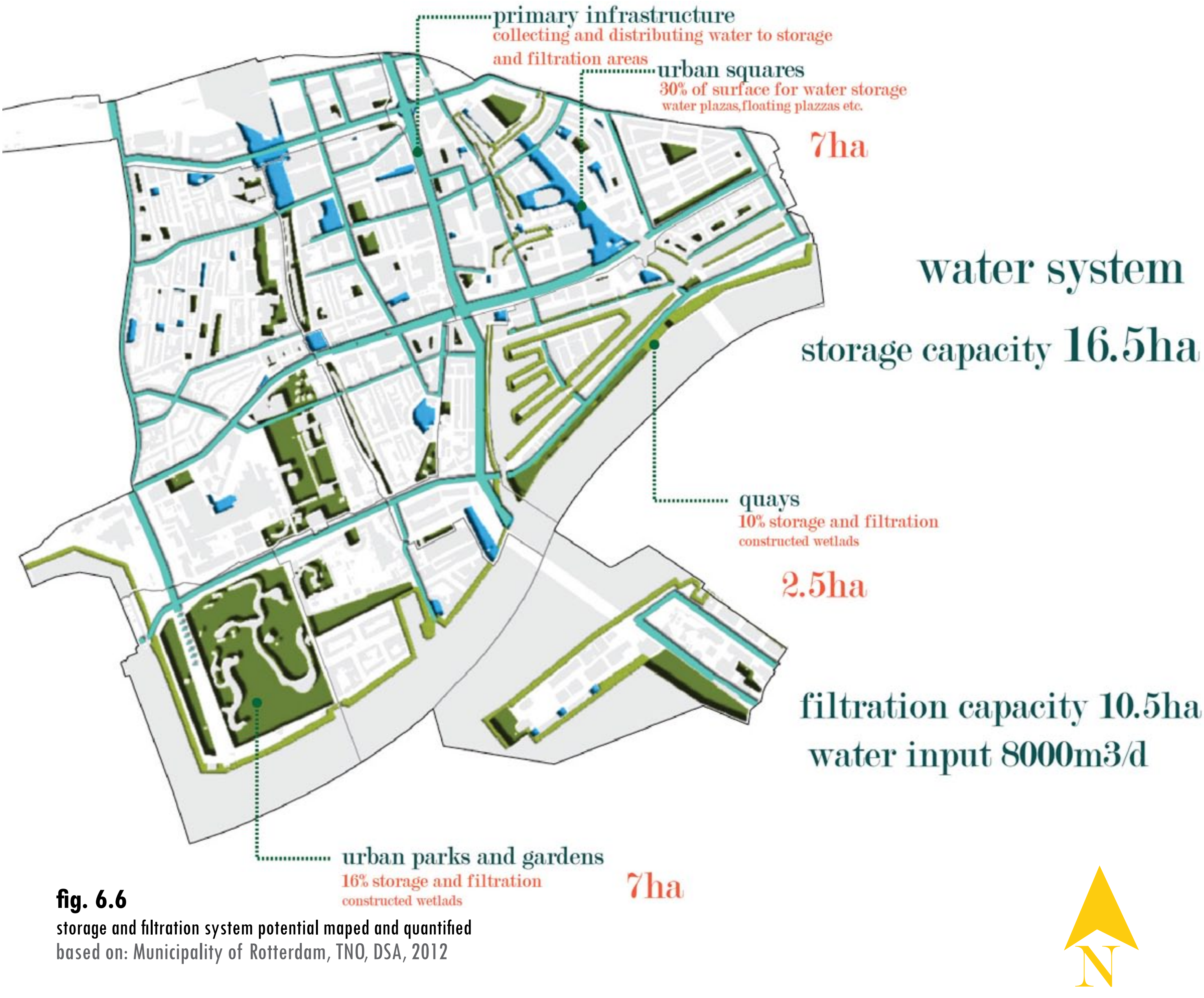



**fig. 6.6**
storage and filtration system potential maped and quantified
based on: Municipality of Rotterdam, TNO, DSA, 2012

# 6.3_ Conclusion

In total the roughly estimated capacity for filtration can reach 10.5ha (needed 10ha estimate) and water storage capacity of roughly 16.5ha.
This number is only covering less than 50% out of the needed 39 ha for peak storage, and therefore, the conclusion would be that further storage systems should be implemented o block level in order to release some of the pressure from public spaces.

systemic approach

Nevertheless this shows that quickly a systemic approach can bring added value to current initiative, and although it need further research and further space( in the case of water storage) it can produce considerably more valuable and sustainable solution for the city solutions

To sum up, from an initial strategy focused on increasing density and green space, the results of the systemic approach made it possible to reach similar numbers of densification and at the same time reduce the energy consumption of future households considerably. Also food was integrated and more than 50% of the proposed inhabitants (all of the current ones) can benefit from locally grown produce. At the same time. The green strategy was adjusted to act as water storage platform and filter greywater for the entire projected population of 60.000.

All these theoretical results of the investigation demand a more in depth research and design making use of the same approach, which will be the focus of coming chapters.

# 07 SYSTEMIC DESIGN RE-SHAPING THE URBAN FABRIC

Following the testing of the potential of systemic design on existing strategies for Rotterdam, the natural conclusion would be that, a process which is incorporating this particular approach in a fundamental way, would yield much more complex solutions. Therefore, the systemic approach is applied on a specific location in the inner-city of Rotterdam.

approach guidelines

The approach will follow the guidelines presented with regards to importance and focus of design:

1. The most important goal is energy efficiency as understood by SLT (second law thinking).
2. The solution revealed by a thermodynamic approach is molded in order to improve microclimate and address the goals of climate proofing
3. Potentials for added value are explored: renewable energy supply or even energy self-sufficiency; potentials for food provision or even food self-sufficiency.

Therefore, the starting point will be adopting a conceptual approach in which thermodynamically suitable solutions are applied in a systemic way, design being the guiding factor for research, paying special attention to the evolution of urban form and rethinking it, all this in a holistic way, while embedding a special care for resource scarcity (Read, 1993).

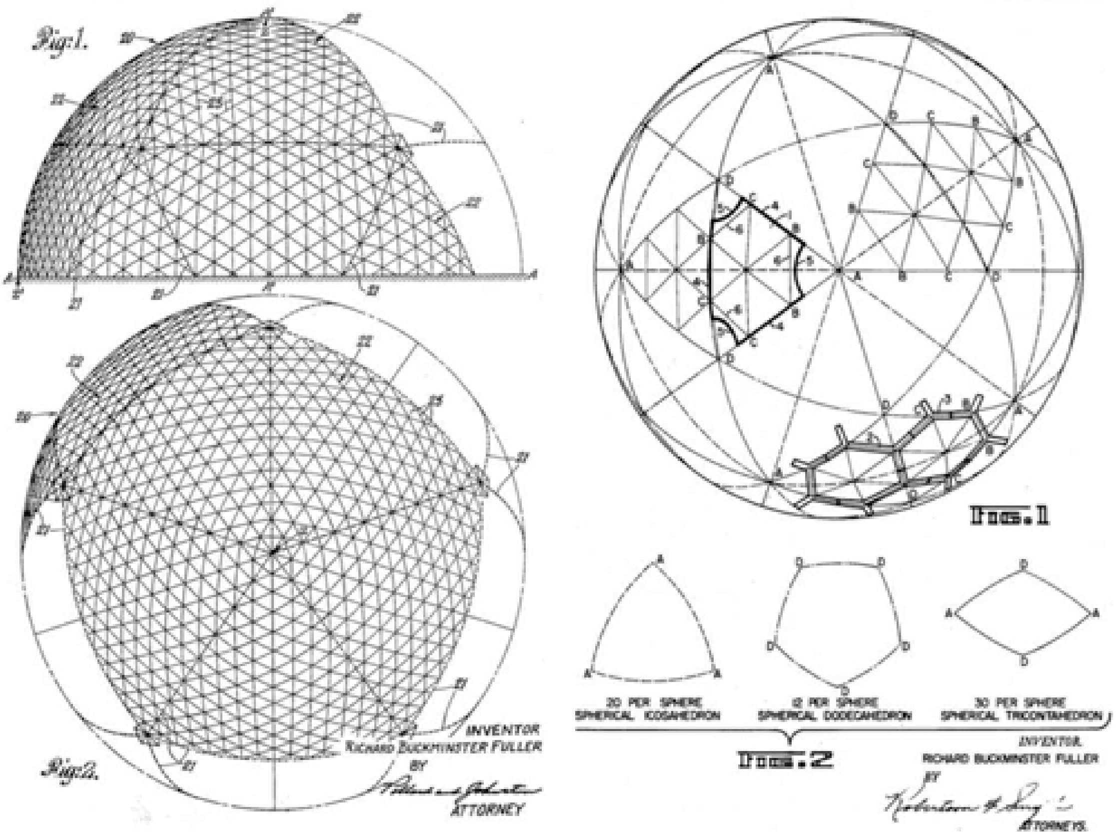



**fig. 7.1**
drawings of the geodesic dome by Buckminster Fuller

# 7.1_ Thermodynamic Framing

The thermodynamic guideline's in terms of second law thinking, as defined by Stremke, Dobbelsteen, & Koh, 2011 are:
1. Increase exergy efficiency (heat recovery systems)
2. Decrease exergy demand (building orientation, passive housing)
3. Increase the use of residual exergy (residual heat for room heating)
4. Match quality levels of supply and demand (cascade)
5. Increase assimilation of renewable energy (geothermal)

trias -energetica

dissipative structures

The focus of this research, as specified previously, are along the lines of trias-energetica, and mainly begin with energy "saving" , or decrease exergy demand , and increasing of exergy efficiency (Stremke, Dobblesteen, & Koh, 2011). According to Pulselli, the concept of dissipative structures, should be able to validly function for cities as well, and if guided correctly we could end up with cities maintaining constant entropy levels, close to 0 (Pulselli & Tiezzi, 2009).

The main condition behind this is the city (which is a static, entropy increasing system), find ways in which to "communicate" (in a thermodynamic way) with its environment . The interaction between these two environments should function in very different ways than it does today. The urban environment is increasing entropy at a much to greater speed for its environment to balance it out.

The idea is to provide new ways in which to slow down the increasing of entropy in urban settings. For this a focus area (in terms of typology) needs to be chosen.

The densification strategy of Rotterdam means of increasing housing facilities within the inner-city by a factor of 2 (Municipality of Rotterdam, 2012). This is a great opportunity for the city, while undergoing a fundamental change, to address its interaction with the site in a way that it becomes more balanced.

housing

Housing in Rotterdam, consumes currently roughly around 9-10% out of the total energy consumption, and future projection put the sector at a share of approximately 15% (Municipality of Rotterdam, 2012). If taking into account the great densification proposed. Out of this energy roughly about 75% is used just for the heating inhabited environment (Energy Efficiency Indicators in Europe, 2012). This area is therefore offering enormous potential for reducing exergy demand(fig 7.2).

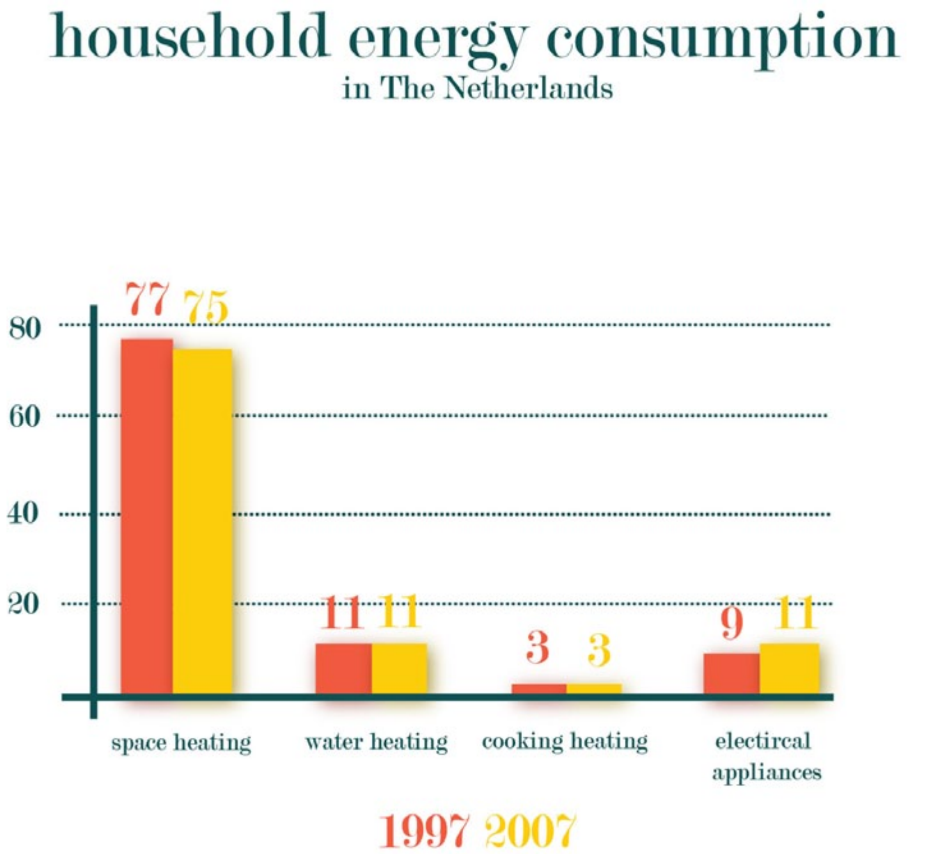



**fig. 7.2**
household energy use
based on: Energy Efficiency Indicators in Europe, 2012

## Heat loss described

heat loss

In order to evaluate the exact potential of "saving" both in exergy terms as well as monetary representation, the process of heat loss and heating up needs exploring and quantification. The power used to heat a building is given by multiplying together three quantities:

**power used=(average temperature difference × leakiness of building) /efficiency of heating system**

(McKay, 2008, p. 93)

"The average temperature difference between the inside and outside of the house depends on the setting of the thermostat and on the weather. The leakiness of the building describes how quickly heat gets out through walls, windows, and cracks, in response to a temperature difference. The leakiness is sometimes called the heat-loss coefficient of the building. It is measured in kWh per day per degree of temperature difference.
The product:

**average temperature difference × leakiness of building**

is the rate at which heat flows out of the house by conduction and ventilation." (McKay, 2008, p. 140)

Energy loss
=
leakiness *(ΔT* durration)

$\Delta T = T_{inside} - T_{outside}$

From this formula we can describe the heating process as consuming energy in order to compensate for the difference in temperature between the inside(desired temperature) and the outside temperature(figure 7.3).

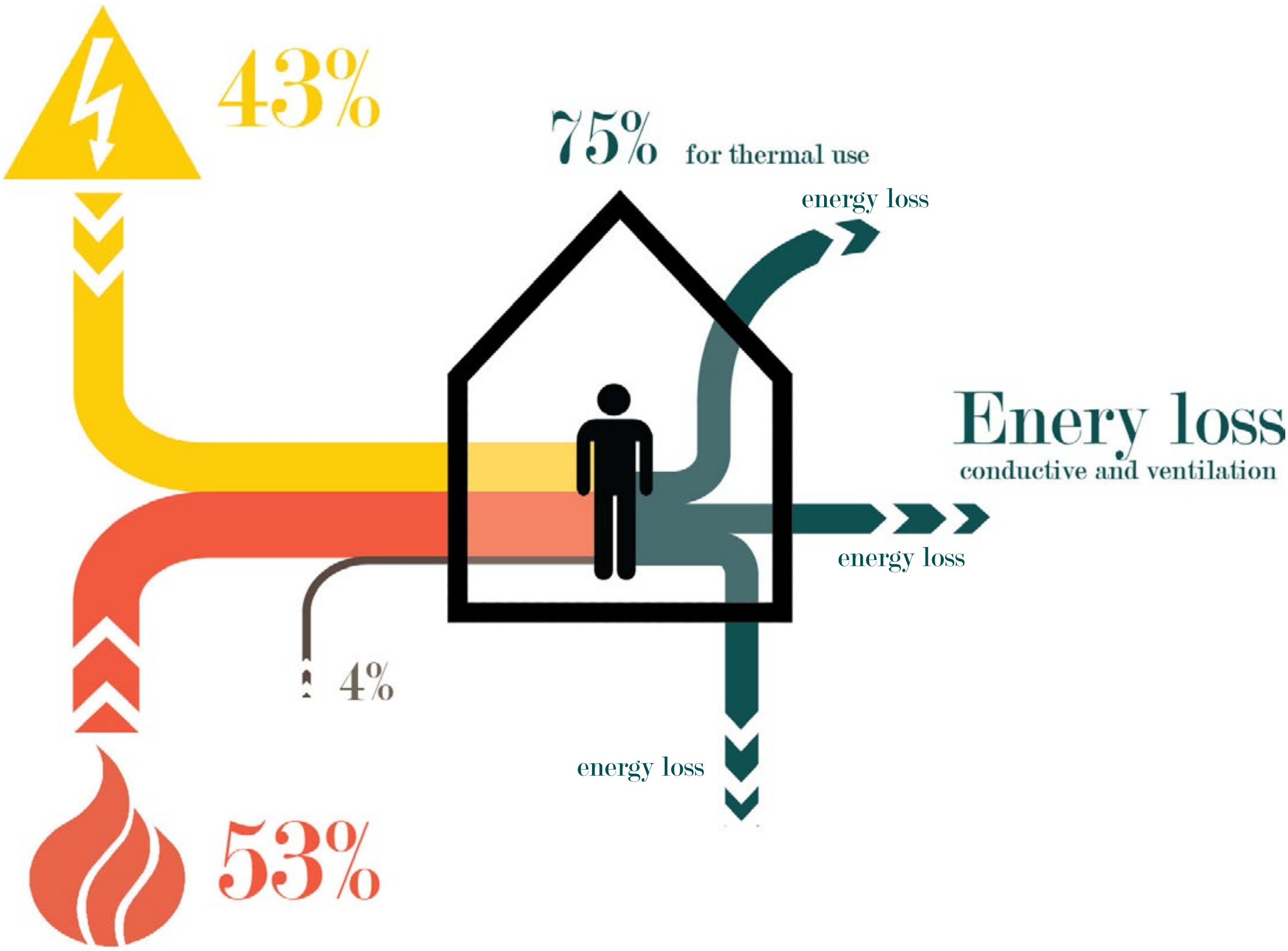



**fig. 7.3**
thermal energy loss
energy supply (mainly electric and gas) lost trough walls/roof/windows and for ventilation

The leakiness of the building is also very important as it regulates the speed at which heat is lost. "A perfectly sealed and insulated building would hold heat for ever and thus would need no heating. The two dominant reasons why buildings lose heat are:
1. Conduction – heat flowing directly through walls, windows and doors;
2. Ventilation – hot air trickling out through cracks, gaps, or deliberate ventilation ducts."
(McKay, 2008 p. 93)

# Heat loss in Rotterdam Quantified

Rotterdam has a total of roughly 300.000 households, out of which some 90% can be considered as collective housing areas (Municipality of Rotterdam, 2012). This includes row housing, townhouses, low rise, mid-rise and high rise alike, all with the exception of detached individual housing areas (Rotterdam Woont, 2012). Many of the construction in the city have been built in the post-war reconstruction phase which makes for relatively similar insulation, construction materials and so forth.

average leakiness

From this we can estimate the overall leakiness of households in Rotterdam. On average standard apartment constructed prior to 2000 has an overall leakiness of 250 W/C (Poel, Cruchten, & Balaras, 2007), with about 30% of this accounted for by ventilation leakiness and 70% by conductive leakiness (McKay, 2008). Detached individual houses can have a lot higher leakiness values, averaging at 350 W/C, and depending on year and condition (McKay, 2008), and hew housing areas can have much lower values depending on the same criteria. Rotterdam generally has a very low percentage of new households.

For an area in Rotterdam comprised of about 76.000 households:

250W/C

44.273 are dated prior to 1980
(leakiness more than 250 W/C)
27.574 between 1980 and 2000
(leakiness between 150 and 250 W/C)
4400 after 2000 (low leakiness)

It is therefore sensible to approximate Rotterdam's average leakiness at around 250 W/C for simplification purposes.
At the same time meteorological data form KNMI shows that Rotterdam has had in the past decades on average 25 days with temperature under -2.5 degrees and 15 days with temperatures of 30.6 degrees (KNMI).

**In the summer energy lost (15 hottest days) to keep inside temp at 22C is:**

15 days of +30.6 outside and 22 inside;
meaning average temperature difference = 8.6

250W/C x durration= 250W/C x (8.6 x 24h)=
250W/C x 206.4 degree hours = 51.600Wh = 51,6 kWh
for 300.000 households this is
300.000 x 51,6 kWh = 15.480.000 kWh = 55,72 TJ (in one day)
for the entire 15 days it is 55,72 TJ x 15 = 835,8 TJ

**In the winter coldest days (25) energy lost to keep inside temp at 21C is:**

25 days of -2.5C outside and 21C inside;
meaning average temperature difference = 23,5C
250W/C x durration= 250W/C x (23.5 x 24h)=
250W/C x 564 degree hours = 141 kWh =
152,28 TJ (for 300.000 households/day) =3.807

loss

If within those days the desired temperatures inside are around 21-22 degrees inside, we can calculate how much energy is used to heat up and cool down the entire 300.000 households in Rotterdam. This number is roughly around 835TJ in the summer for cooling and 3800TJ in the winter for heating.

# Biological and engineering inspiration

conventional measures

In the case of heat loss of buildings, the speed in which energy is lost is defined by leakiness (McKay, 2008). Common measures of decreasing this value are insulation, retrofying of buildings, replacing windows and doors, roof works etc. (Poel, Cruchten, & Balaras, 2007). In the context of climate change and challenges facing future urban environments, more integrative solution should be developed. Solutions that bring forth new ways of problem solving, and which address not just one issue. Landscape architecture as a discipline, becomes more and more involved with the management of urban microclimate and with energy efficiency as well. Planting is used to provide shade in the summer, or protection in the winter, to regulate humidity and so forth (Moffat & Schiler, 1981).

limitations

This approach is becoming more and more necessary for urban environments but at the same time it has several limitation and critiques.
1. Urban areas do not always provide enough space to place vegetation according to microclimatic needs
2. Although theoretically valid, a clear cut link between planting and energy efficiency is hard to prove and quantify, mostly because of the individual nature of household consumption and large number of variables influencing urban energy consumption.

the need for new methods

This raises the need for a new type of approach, one which can be quantified and which can be implemented in area where planting or vegetation are unable to provide the required results. In second law of thermodynamics this is exergy loss and increasing of entropy. When a system is driven away from thermodynamic equilibrium, by outside factors, and the system begins to exchange entropy with the exterior, then the irreversible processes begin to operate, and entropy is being exchanged due to exchange of heat and matter. (Stremke, Dobblesteen, & Koh, 2011).

biological inspiration

At the same time Dincer and Cengel stated that the entropy flowing out of a system is always larger than the entropy flowing into the system (Dincer & Cengel, 2001). This might be true for most systems but, Pulselli believes it is not the case for biological organisms and Prigogine defined the dissipative structures as such systems (Pulselli & Tiezzi, 2009). From a purely thermodynamic standpoint the maintaining of constant entropy levels might be somewhat very ambitious, but at the very least the speed in which the exchanges occur can be influenced. If this is achieved, theoretically it should yield more robust, energy efficient systems.
When faced with very cold environments, the animal body, lowers its surface temperature to slow down the rate at which heat is lost (Moffat & Schiler, 1981) , essentially creating a entropy regulating barrier. If it would do the same, our built environment would be closer to biological structures therefore approaching Prigogine's dissipative structures.

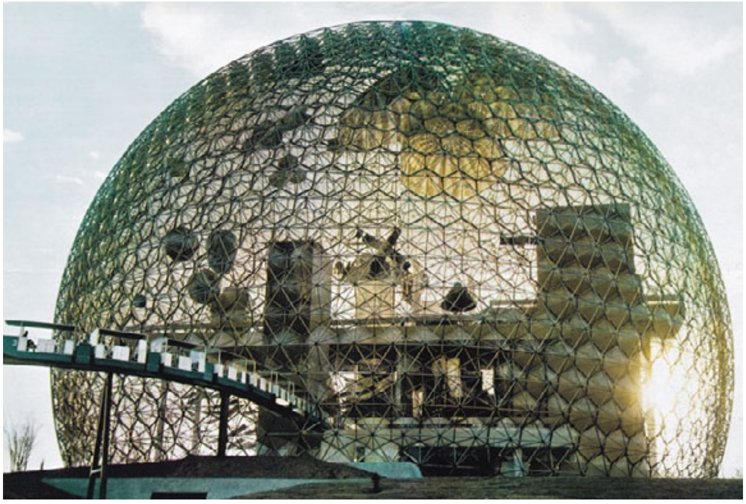


**fig. 7.4**
US pavilion in Montreal, by Buckminster Fuller
source: The Buckminster Fuller Institute
http://bfi.org/

Fuller

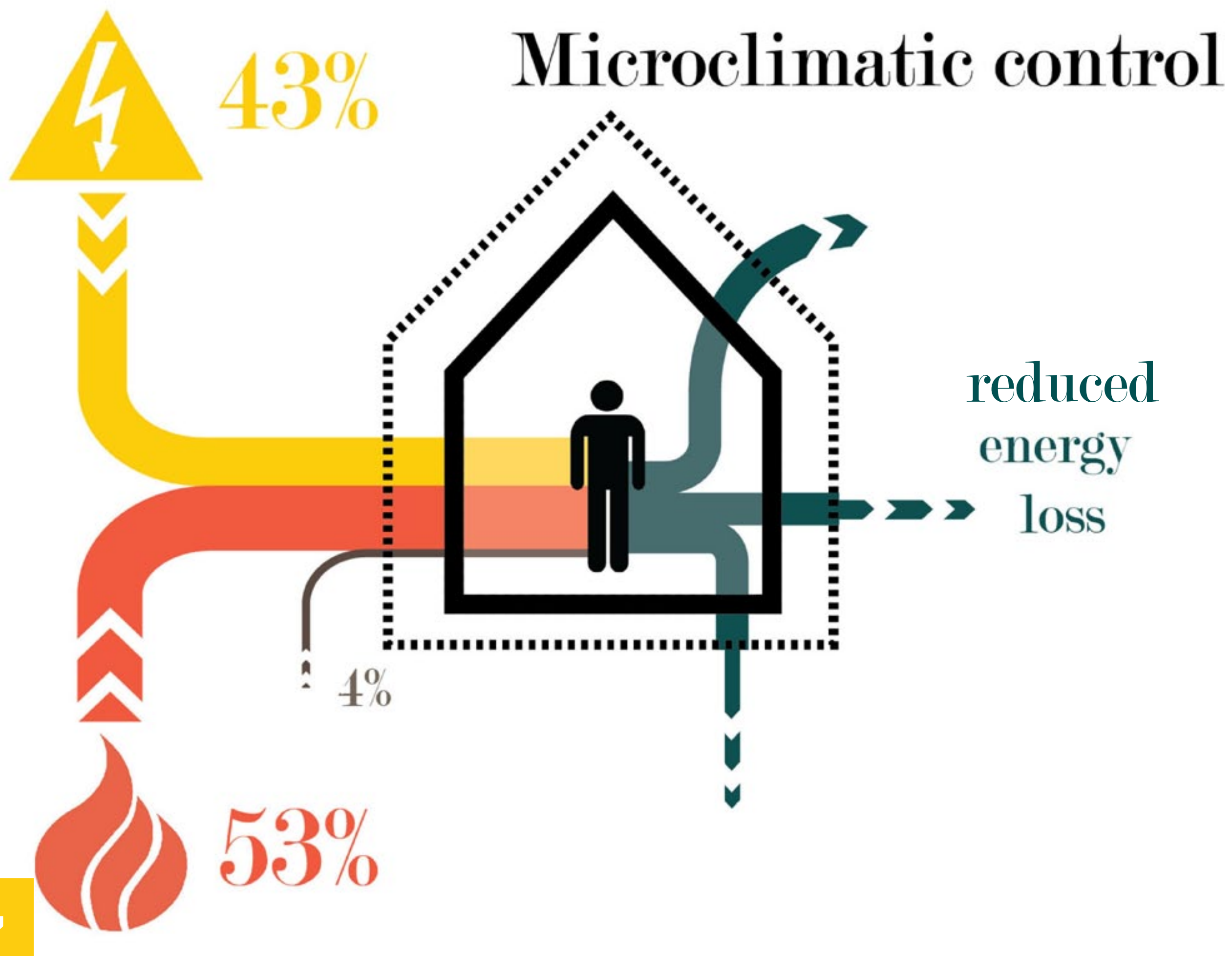
Buckminster Fuller, proposed a radical engineering solution, based on microclimatic engineering(fig 7.4) . In his US Pavilion for the 1967 Architectural Expo in Montreal, he applied his geodesic dome structure upon a built structure, generating a controlled microclimate which would regulate air quality, remove pollutants and offer protection. This proposal represents the inspiration for the thermodynamic solution. It is essentially providing the approach which would mimic the behavior of the mammal body in the case of buildings. By applying this design approach to the built environment in Rotterdam, essentially we would be generating a new microclimatic layer (fig 7.5), which would act as a thermal regulator, regulating the speed by which heat is lost or gained.

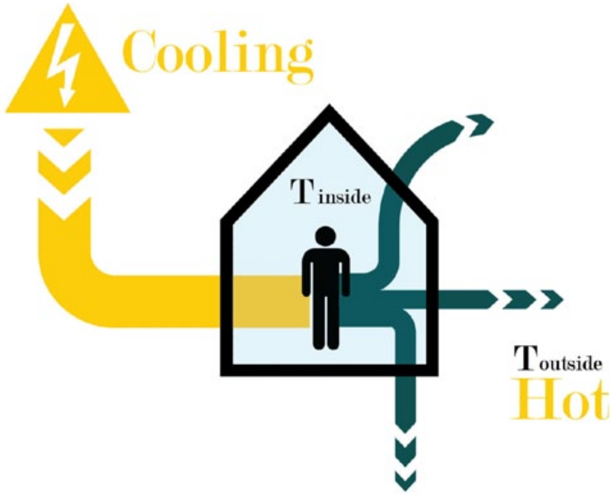
## Saving potential

If during these extreme temperature days, landscape architecture cold improve microclimate in the city, and influence the outer temperature with 3 degrees, (higher in the winter and lower in the summer) we get a potential saving of about 900 TJ (0,9 PJ) which is about 5% of the total yearly use for heating in households. If we translate this saving of 300 TJ in the summer and 600 in the winter (fig 7.6) into gas and electricity prices for the different seasons:
0,05 eur/kwh gas in winter
0,26 eur/kwh electricity in summer data from cbs.nl

this means potential saving of
21.6 mil euros in the summer
8.4 million in the winter
Total 30 million euros potential saving (100 euros/households)

**fig. 7.5**
exergetic optimization concept visualized

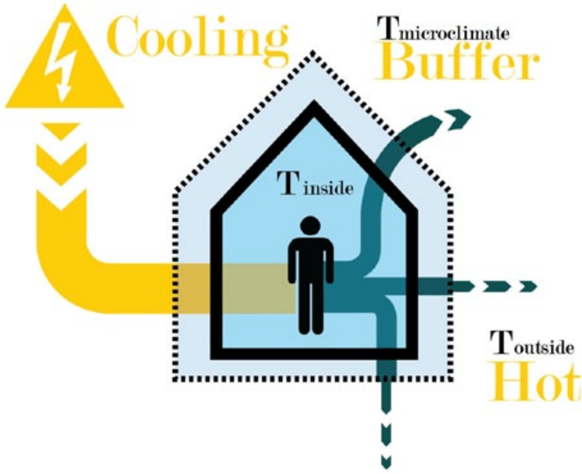





## Summer

15days with 30,6 °C
T inside = 22°C
av. leakiness 250 W/°C
300.000 homes

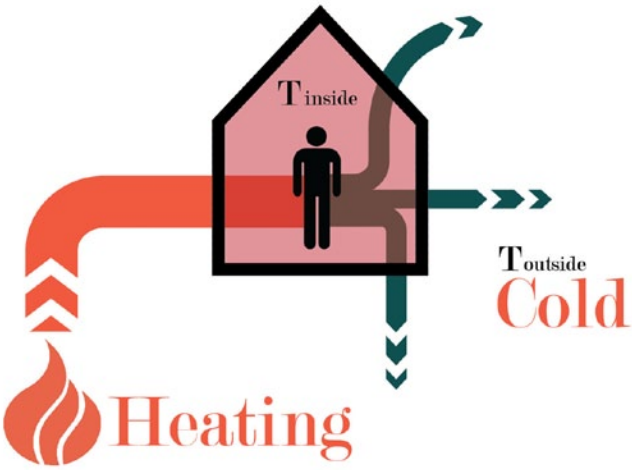
energy lost = **835TJ**




## Summer

15days with 27,6°C
T inside = 22°C
av. leakiness 250 W/°C
300.000 homes

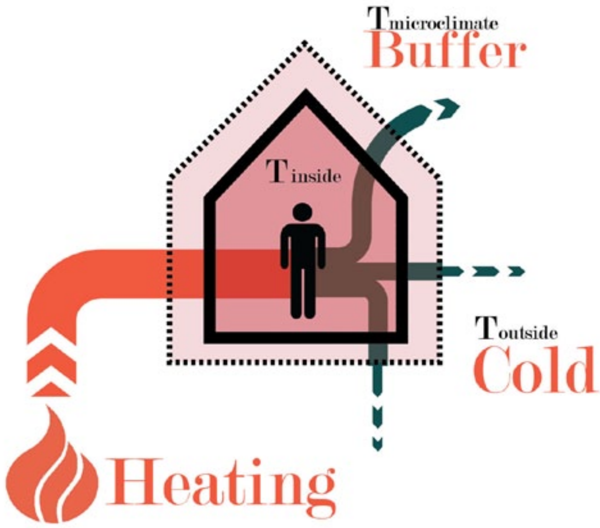
energy lost = **544TJ**




## Winter

20days with -2,5 °C
T inside = 21 °C
av. leakiness 250 W/°C
300.000 homes

energy lost = **3806TJ**




## Winter

20days with +1,5°C
T inside = 21 °C
av. leakiness 250 W/°C
300.000 homes

energy lost = **3200TJ**

**fig. 7.6**
optimization potential quantified in summer and winter hottest and coldest days

# 7.2_ Microclimatic Adjustment

**fig. 7.7**
water erosion process and meandering river patterns
source: http://edu.glogster.com

## Water

In line with the systemic guidelines formulated, once thermodynamic goals are achieved, the concept should be adapted towards improving microclimate. In the case of an intervention like the one described above, its impact on urban microclimate can be dramatic, and this impact can be steered towards beneficial results of it can yield very negative effects.

Previously the water storage assignment for Rotterdam center was calculated. Roughly 22.5ha of water storage space is needed to be taken up by small bloc size interventions. Therefore the generated morphology should be responsive to this challenge. The goals it for every area to be able to take up its share of water storage assignment in a way that will not hinder its functioning.

## Wind

One of the major ways in which the concept will influence the urban fabric is in terms of morphology and urban geometry. This can have great impact on air flow dynamics in the city (Bottema, 1993). It can generate turbulence and yielding very uncomfortable urban spaces, or it can prevent ventilation of streets and yield in pockets which gather pollutants (Bottema, 1993). In order for this not to occur, and potentially correct and adjust some of the existing negative conditions in terms of wind dynamics, care should be given to molding of the new urban geometry.

Within the theoretical framework chapter the link between constructal theory and microclimate was explored, referring to wind patterns and shape generation. This is taken as a starting point and form then, by means of testing and adjusting, the final design is shaped. The main starting point in terms of approach is the concept of erosion, as described at the beginning, in which organisms are "eroded" by forces conditioning their capacity to evolve. It is in a sense a organismic phylogenetic consideration of the evolution of buildings.

## Testing

The starting point in terms of wind dynamics is tested in terms of characteristics and influence of different shapes. Therefore basic forms are taken into account and their properties simulated and compared.

A sphere, and cube, of similar size are evaluated in a wind simulation software. The general conditions simulated are winter specific. A wind speed of 5m/s is taken into account and an environmental temperature of -2 degrees. The goal is to see how these shapes influence wind patterns, speeds, and temperatures at the surfaces of the objects, and therefore be able to make a scientifically valid choice for general characteristics of the urban geometry proposed (fig 7.7).

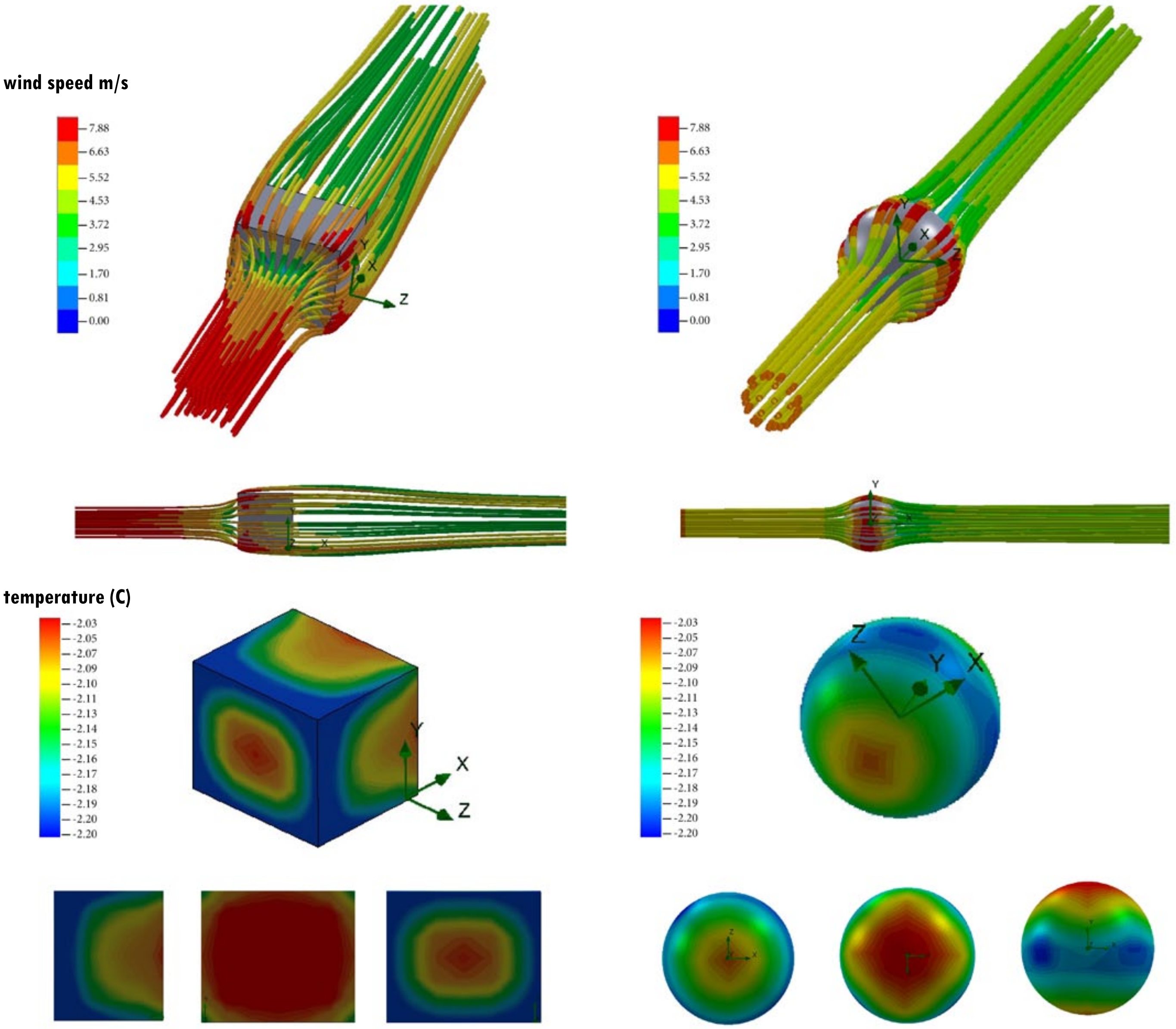
best shape

The general conclusion following the study is that rectangular shapes tent to have more varied wind dynamics, generating lots of turbulence areas, and corner streams  (Bottema, 1993). At the same time, spherical shapes have a more arranged air flow with less overall area of increase wind speeds. Overall the spherical shape yields somewhat smaller wind speeds and smaller areas of accelerated wind flow.

In terms of surface temperature, rectangular shapes, due to the corner streams generated, are cooling down the surface of the object in much larger areas then the spherical shapes.

Therefore, in line with guidelines specified by Bottema, spherical, round geometry is preferred to rectangular geometry. While this is talking about single objects, special attention must be given to the geometry entire cities, and a general starting point must be taken in that sense. The test performed combined with constructal theory, reveals, a process of erosion which shapes must undergo in order to adapt their form to environmental conditions. Inspiration for larger more complex "erosions" is taken from natural processes of water erosion. Meandering river patterns and water erosion of rocks are also described by constructal theory as being efficient complex flow forms.

**fig. 7.7**
wind flow dynamics simulation and surface temperature changes (for rectangular and spherical architectural shapes)
by the author using solid works CFD flow simulation software)



# 7.3_ Potential Added Values

After solving the heat loss issue by means of envelope, wind dynamics by means of morphology and water storage, according to research guidelines, added value potentials must be explored.

## Energy added value

PV panels and heat collectors

In terms of energy, the potentials for energy generation explored for Rotterdam revealed it to be suitable for solar PV implementation, geothermal heat storage and residual heat cascading. The last one being elaborated in detail within the REAP methodology (van den Dobelsteen & Tillie, 2009) the focus will be more on the other two potentials. The approach has a huge potential for heat capture and storage systems, making use of the aquifers running underneath Rotterdam. In this process, heat will be collected, stored in underground aquifers and used in the winter to heat up the microclimate of the envelope, essentially yielding artificial microclimates. The potential for PV cell implementation should also be explored, keeping in mind the importance of proper lighting and ventilation within the apartments.

## Food added value

roof gardens

The potentials for decentralized food production should also be explored. Apart from individual apartment intervention which are somewhat out of the range of influence of landscape architecture, other potentials are explored. Urban agriculture is a function which is difficult to make competitive with large scale agriculture and therefore additional connections should be made (Bright Farms). The microclimate created for heating purposes, also yields conditions closer to the controlled greenhouse environment, and therefore becomes interesting in terms of plant growing.

In this sense the potential for implementing rooftop allotment gardens should be taken into account, as a means of connection sentimental attachment toward the garden with the environmental opportunity for growing decentralized small scale produce.

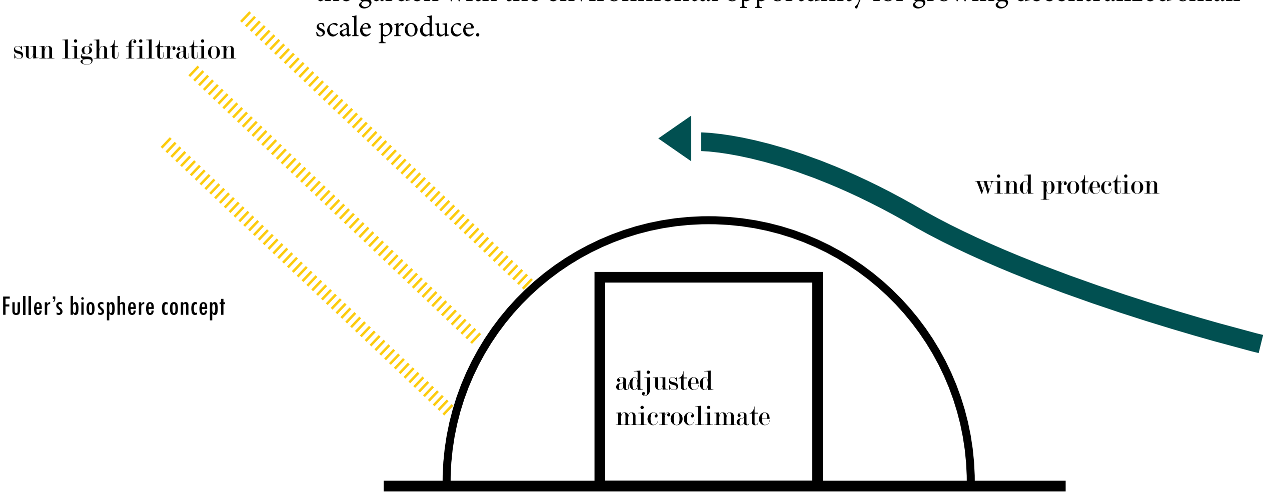



**fig. 7.8**
Buckminster Fuller's biosphere concept

# 7.4_ Concept

concept

The end result of mixing all the structured guidelines and goals is much different from Buckminster's original dome (fig 7.8), which is essentially focused on air filtration and temperature adjustment with the aid of a blinds system, without being actively engaged in exploring more added value potentials . In a sense the new approach is framed by systemic design and aided by technological advance ( at the time of Buckminster's proposal heat collection and storage technology was not available).

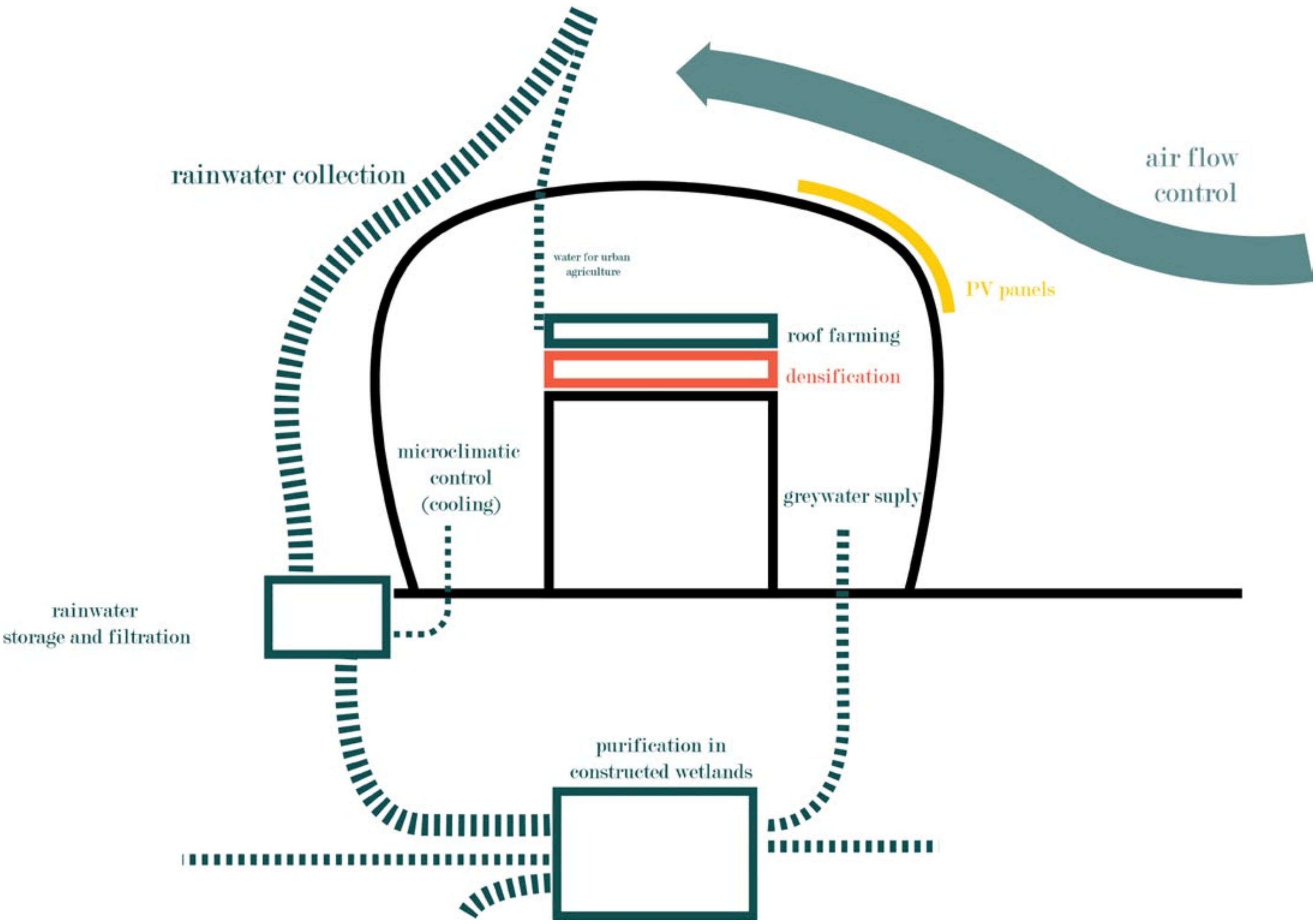
**Thermodynamics**
Envelope providing artificial microclimate for buildings.

**Microclimate**
Water storage within the housing courtyards
Wind as morphology, shaping the envelope.

**Added value**
Heat collection and storage implemented
PV cells implemented according to space and light needs
Allotment roof gardens

(fig 7.9)

**fig. 7.9**
Systemically adjusted dome concept



# 08 PROPOSITIONAL DESIGN FOR ROTTERDAM INNER-CITY

The guidelines presented previously are implemented in a chosen area of Rotterdam inner-city. The process of generating design is gradual and begins with an initial somewhat intuitive design. Although grounded on previous research, there is a great degree of uncertainty, especially when it comes to shape generation. Therefore the initial approach is modeled and tested, with constant adjustment and adaptation.

**fig. 8.1**
Satellite image of Rotterdam Inner-city
source: google earth

# 8.2_ Site Introduction and Analysis

## Introduction

site

The site chosen for design is a residential quarter of Rotterdam Inner-city, specifically part of the Laurenskwartier (fig 8.1). The area is generally dominated by residential apartment blocks, mostly portiek flats, with some having ground floor commercial areas facing street profiles.

Characteristic for the area is a generally low percentage of built space, compared to other cities of Rotterdam's importance and size. Major boulevards, surrounding the block have a very large section. The Burgermeester van Walsumweg axis has a section of approximately 70m. This 70m space between street fronts in huge, even when compared to some of the largest monumental boulevards.

comparison

Champs Elysees in Paris, one of the world's most famous large boulevard has a width of approximately 60 m, comprised of about 10 traffic lanes (if factoring in parking and public transport refuge) and large pedestrian promenade supported by heavy commercial activity. Burgermeester van Walsumweg in Rotterdam has nowhere near that type of commercial, touristic and activity support, and it is 10 meters wider. La Defense boulevard has a width of roughly 50m, and without the type of historical and spatial character of Champs Elysees is considered a design failure.

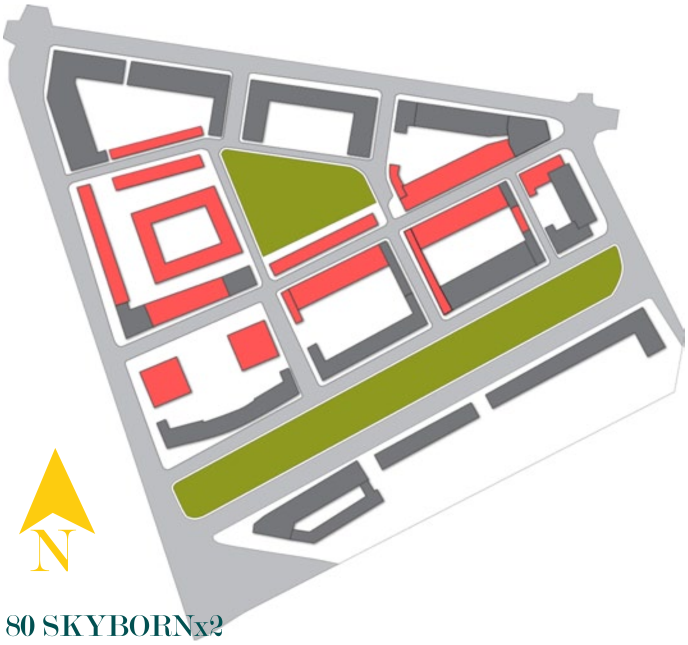
The area is also relatively heavily paved and the existent green space is not properly designed and managed, being closer to green fields than public access platforms for supporting urban life and activity.

800 CURRENT SITUATION

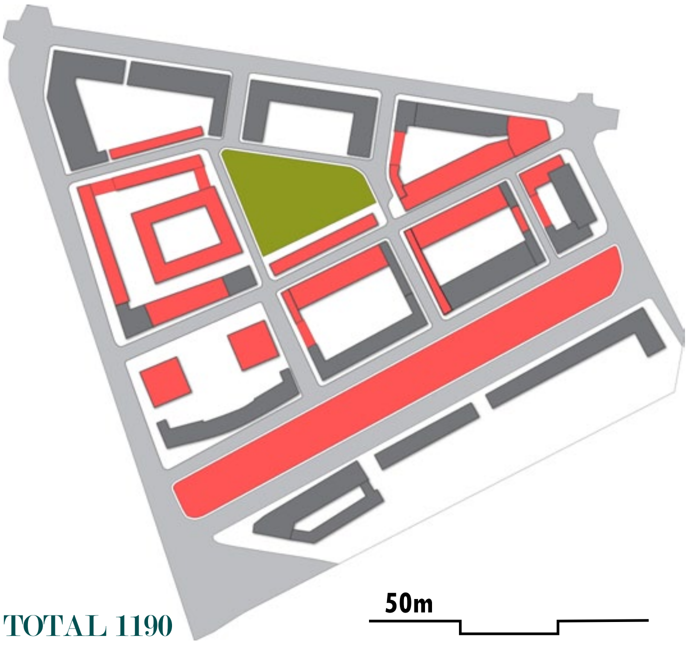
150 GROUNBASED INSERTION

80 TRANSFORMATIVE

INFILL




80 SKYBORNx2




TOTAL 1190

# Projected Changes

densification

The area is very interesting in terms of potential changes that might occur in the coming decades. The densification strategy proposed by the Municipality of Rotterdam together with TNO and Doepel Strijkers architects, places a high density of change in the site. It is one of the few areas in Rotterdam were 4 out of the 7 types of densification are found (Municpality of Rotterdam,TNO, & DSA 2012). This means that the area will be subject to great change in the future, and that this will alter its geometry fundamentally (fig 8.2).

**fig. 8.2**
Potential changes in the area based on densification strategies planed
based on Municipality of Rotterdam, TNO, DSA,2012

Currently the block is comprise of roughly 800 households. The evaluated potential puts the projected households at around 1110 households by implementing groundbased, skyborn, transformative and infill strategies (Municpality of Rotterdam, TNO, & DSA, 2012). Previously the original strategy was altered according to systemic design, considering energy and climate, and yielded a similar end result. The altering of the strategy makes for a new potential of 1200 households for the area.

**Existent households – 800**

| STRATEGIES | ORIGINAL | ADJUSTMENTS |
|---|---|---|
| Groundbased | 150 | 150 |
| Skyborn | 80 | 160 |
| Transformative | 80 | 80 |
| Total insertion | 310 | 390 |
| TOTAL HOUSEHOLDS | 1110 | 1190 |

These changes become a great opportunity for guiding the process in a systemic way and generating a new type of urban fabric, with energy and microclimate considerations embedded in its morphology.

**fig 8.3.1**
characteristic images of the site:paved/residential/modernisitc

# Microclimate Analysis

From a microclimatic stand point two aspects defined previously are of focus(water and wind).

water storage

For water, the filtration goal is achievable in centralized spaces around the inner-city, but there is still a heavy need for storage space. Roughly about 22ha of storage space is missing if we only take into account storage public spaces, within the system and pumping capacity.

In total Rotterdam inner-city has about 330ha, out of which roughly 150ha account for public spaces such as streets, boulevards, parks, squares and playgrounds (Municpality of Rotterdam, TNO, & DSA, 2012). These 150ha are taking up some 17ha worth of storage and filtration space according to the adjusted strategy.
The rest of 22ha will have to be shared by the remaining 180ha.

water assignment for the site

This means roughly 1ha of storage for every 8ha of other functions, which for a contemporary metropolis aiming at increasing its inner-city density is somewhat impossible, if we only look for surface storage. In this case underground storage needs to be considered (Haitsma, 2011). Coincidentally the area chosen for design is also roughly around 8ha in area, which gives it a share of water storage of 1ha (at surface level or underground).

Apart from the water storage assignment for the area, wind dynamics are also considered important. It is important to mention that wind problem in the specific area are not such that they generate extreme microclimatic conditions. With the exception of a few places, the area is somewhat a typical urban microclimatic setting in terms of wind dynamics. However this does not mean it is by any chance an ideal, or necessarily desirable situation.

winter wind dynamics

Strong winds still penetrate the area in wintertime specifically south-westerly winds, and even if they do not generate heavy turbulence around much of the area, it does however chill the buildings, making for a more difficult and energy consuming heating process (fig 8.3).

To this, the envelope solution comes as a response, sheltering the buildings from strong winds. This however is also a opportunity of addressing wind issues on street level, and protecting the buildings by using the most efficient approach.
Looking at wind dynamics in the winter, only a few of the areas are under immediate threat of wind exposure. The most prominent issue is at the intersection of Mariniersweg with Burgermeester van Walsumweg, where due to the gaps created by the Cube houses, and overall exposure to the south west, the buildings are faced with increased wind speeds (even more so than usual). The gaps in urban geometry caused by the cube houses, generate the Venturi Effect, in which air flow gets pressured into the gap and wind speeds increase. Due to principles of continuity in flow dynamics, a flow speed must increase when traveling through narrow spaces(building gaps) (Bottema, 1993).

The speed does afterword's return to normal, but not immediately after the gap. South westerly winds hit the street front of Mariniersweg causing turbulence at corners of taller buildings, and this is especially valid in the case of proposed heightening of the geometry by roof densification. At the same time, some other areas can be exposed to strong winds, and generate tough conditions (especially areas north of the central square), but none are so pressing as the above mentioned.

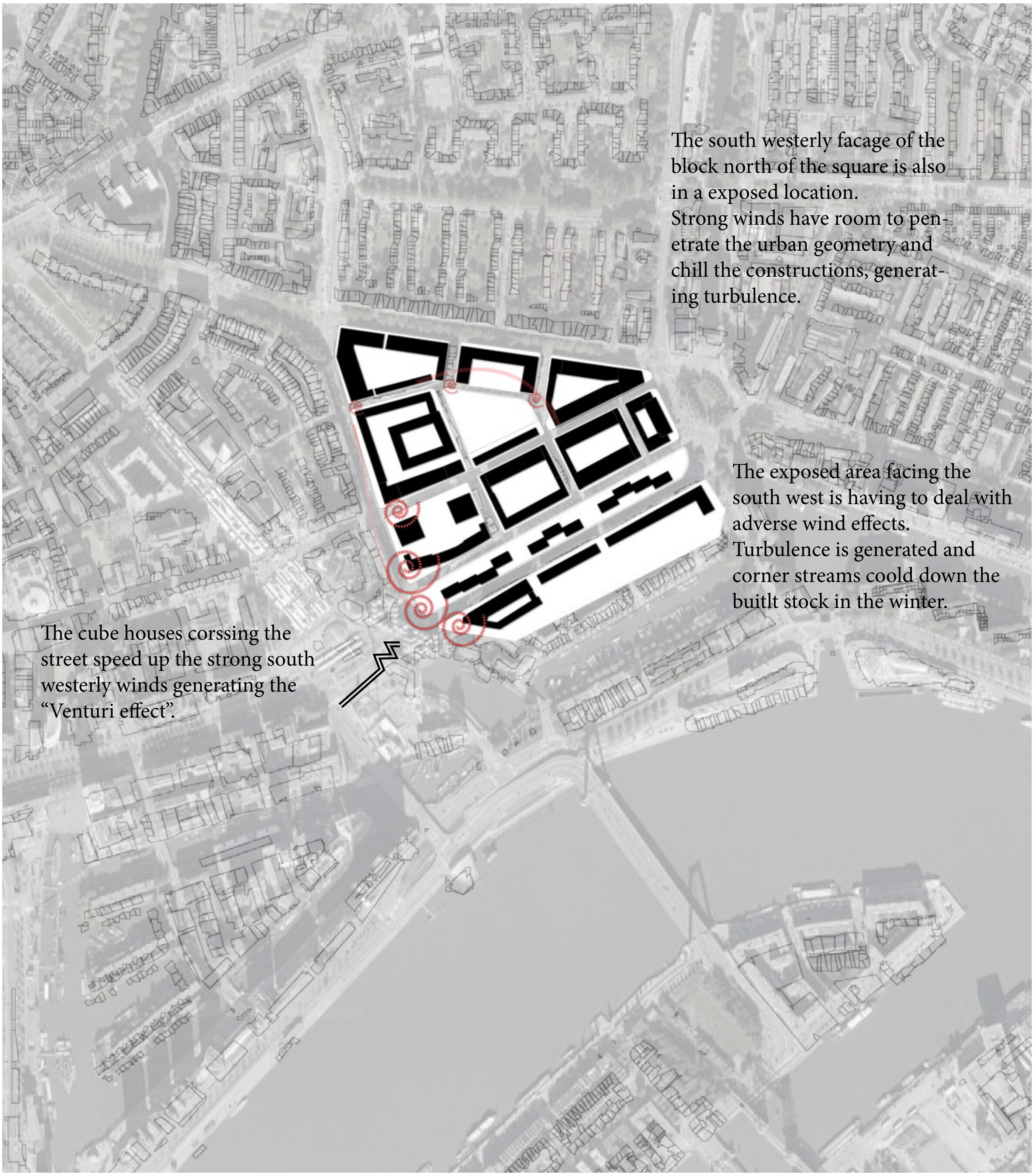



**fig. 8.3**
Potential wind dynamics problems of the site

summer wind dynamics

During summer time there are no major wind dynamics issue caused by urban geometry, with the exception of potential ventilation issues, which are relatively common to urban streets (Bottema, 1993).

convective breeze

Essential to summertime cooling is the convective breeze process. The cooling process described in fig.13 works during hot summer nights, when heat accumulated by buildings is raising, pulling in its place the cool air coming from the green patches by means of convection(fig. 8.4). Green patches should be distributed evenly around the area.

In order for this to function the air must circulate freely due to its thick nature, meaning no low vegetation, no fences or other types of possible obstacles (Bedem Wurtemberg, 1977). This however leave the green areas somewhat exposed to winter winds, and in a urban setting that needs to be resolved. The importance of good air flow management becomes obvious.

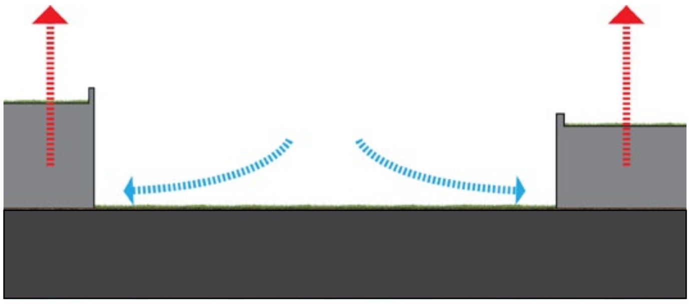


**fig. 8.4**
Convective cooling process in hot summer nights

design principles for climate

After reviewing the major points of interest from landscape, energy and climate perspectives, a synthesis of the conclusions can yield a set of design principles for the specific site. This is in direct line with the guidelines mentioned at the end of chapter 5 ("The need for a systemic approach")

1. Densification will be accompanied by enveloping of the housing block

2. The shape of the envelope should yield better wind microclimate (wind erosion concept)

3. Patches for water storage and cooling should be implemented

# 8.2_ Systemic Approach to a City Block - "urban erosion"

## Design Guidelines

The concept is further translated into specific shapes. The process translates guidelines formulated with theoretical foundation, in an intuitive way. The results are detailed and testing, and adjusting takes place, describing a research by design process (fig.8.5).

SLT thermodynamics

1.Densification will be accompanied by enveloping of the housing block.
The initial approach here, is similar to what is described in the REAP as climate facade (Dobelsteen & Tillie, 2009). The climate façade concept refers to doubling the façade of buildings with a second envelope (typically glass), in order to provide sheltered spaces and extra insulation (Dobelsteen & Tillie, 2009). In phase 1 this covers the entire block, with no regard to any phenomena other than sheltering the existing built stock in a conventional way.

microclimate

2. The shape of the envelope should yield better wind microclimate (wind erosion concept)
Following phase 1 the actual "erosion" process needs to be described. This process I thought out following specific guidelines, extracted from literature and previous experiments, with regards to form generation.

turbulence

a. Areas with turbulence problems are rounded off starting with the most problematic (Bottema, 1993; and wind flow experiment)

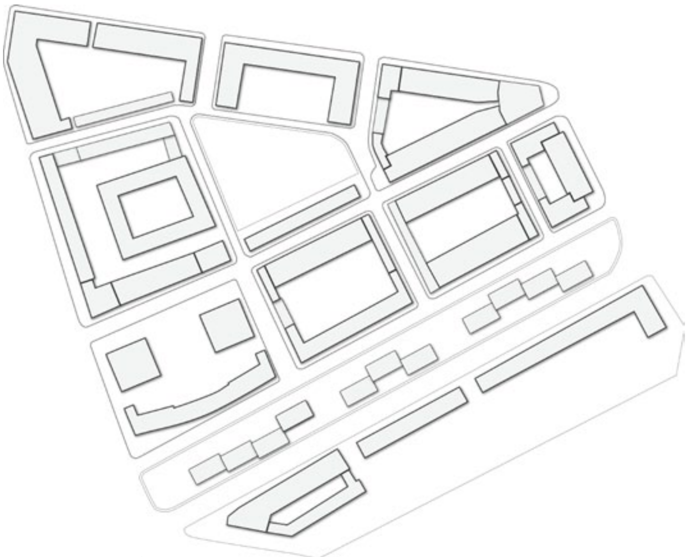
b. Even areas that are not currently experiencing wind problems should be rounded off, although not as strong as more problematic ones. The reason for this is twofold. First, wind dynamics are highly unpredictable; even if a general tendency is established, wind patterns in streets and cities are depending on much more than general tendencies. A place which is sheltered in one moment can become exposed when wind direction is changing, a process which happens much too often (Bottema, 1993). Secondly, rounded, "eroded" forms are proven time and time again to be more suitable when dealing with wind dynamics, and therefore there should be no reason to not take this action; especially when basic geometry of the actual building that it is covering are not changed.

ventilation

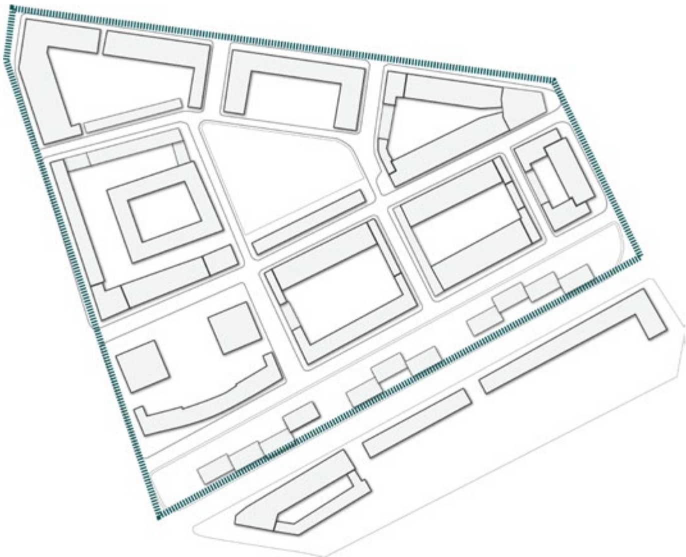
c. "Narrow streets with perpendicular buildings or irregular building faces yield much wind reduction and are generally acceptable from a wind comfort viewpoint" (Bottema, 1993, p. 193); therefore irregularity is preferred in terms of street morphology, in order to prevent street canyon speeding up of wind flows.

water storage

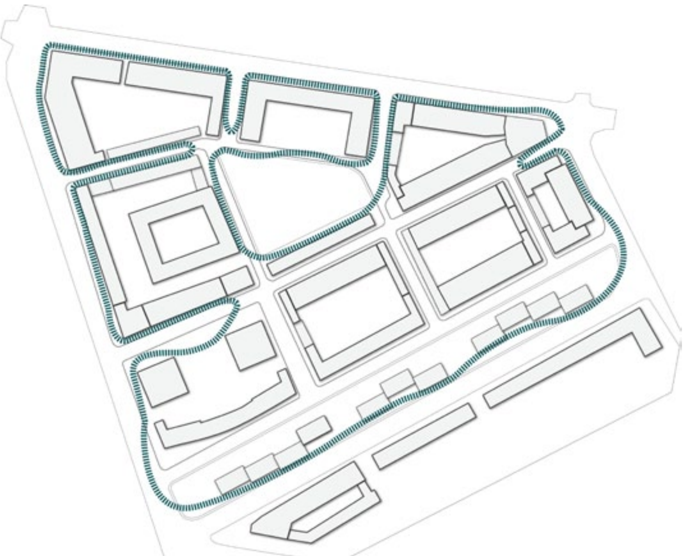
3. Patches for water storage and cooling should be implemented
In this sense courtyards become infiltration and storage areas for water and should be greened in order to aid convective cooling.



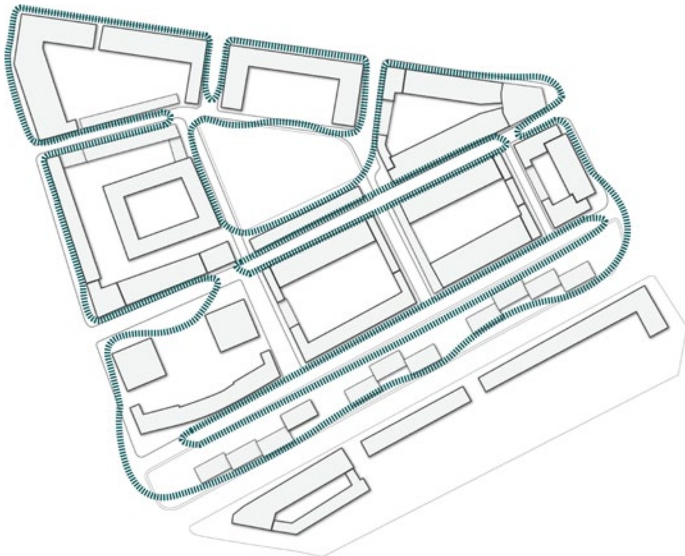
Phase 0 - existent situation



Phase 1 – cover the urban block with the envelope



Phase 4 – Outer edges and gaps get eroded. Following the irregularity principle at point c.



Phase 5 – Main street axis get eroded

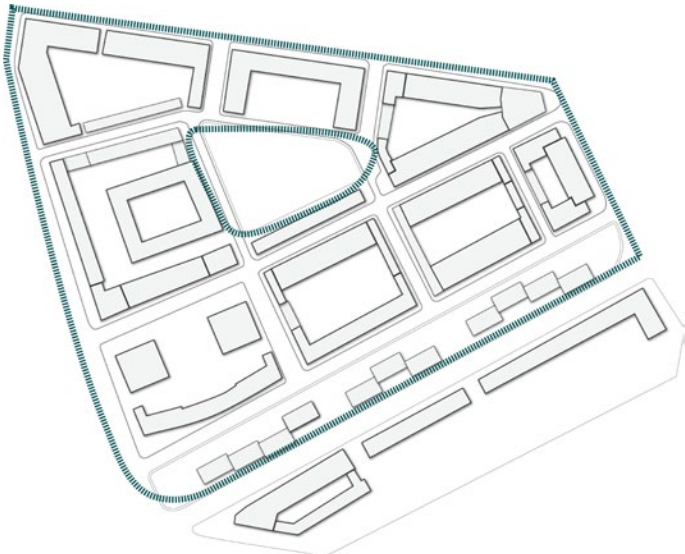
**fig. 8.5**
Stages of the "erosion" process

## Erosion process

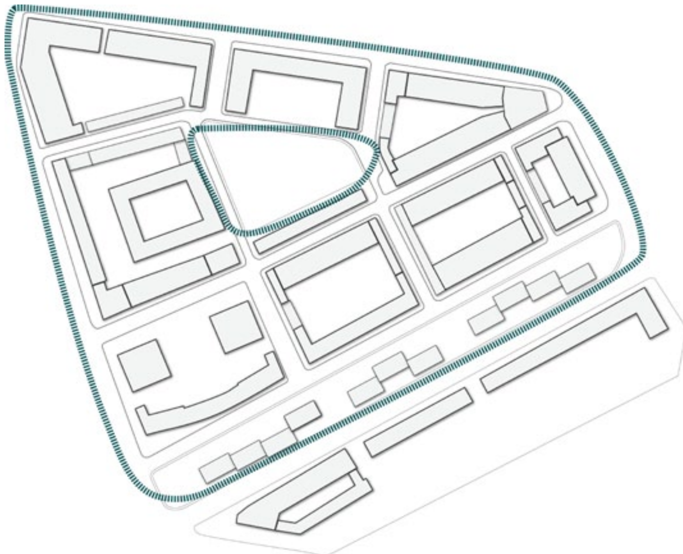
A general process of "erosion" describes the generation of the new urban shape. It is structured according to formulated guidelines and aims at generating more natural urban fabric. This initial erosion in 7 phases can be considered the first stage of the erosion total erosion process (fig 8.5).

Phase 1 – cover the urban block with the envelope
Phase 2 – main wind problem areas get rounded off
Phase 3 – secondary, border corners (at the outer edge of the geometry) get rounded off (less prominent)
Phase 4 – Outer edges and gaps get eroded. Following the irregularity principle at point c.
Phase 5 – Main street axis get eroded
Phase 6 – Street axis get shaped according to irregularity principle
Phase 7 – Green/water storage patches are eroded

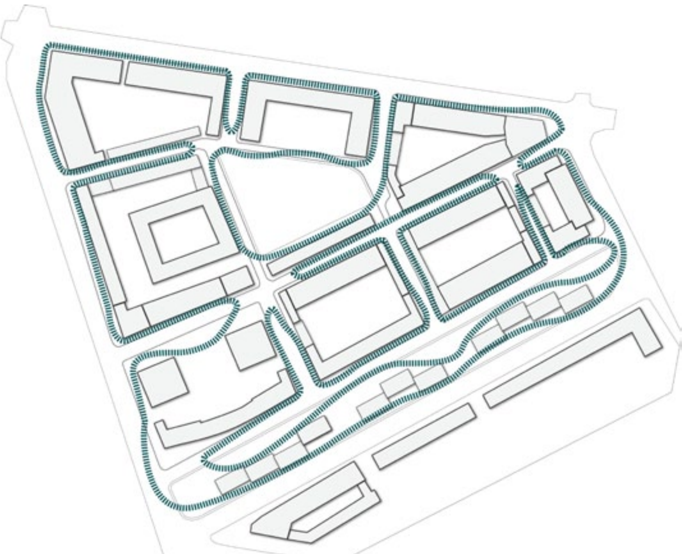
N



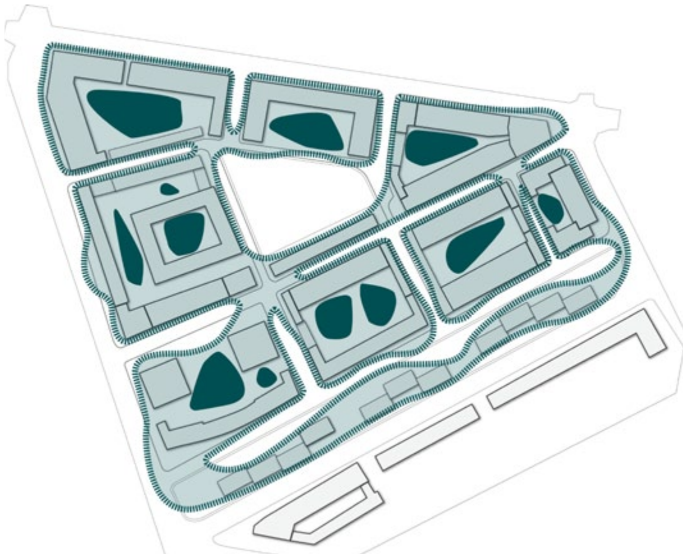
Phase 2 – main wind problem areas get rounded off



Phase 3 – secondary, border corners (at the outer edge of the geometry) get rounded off (less prominent)



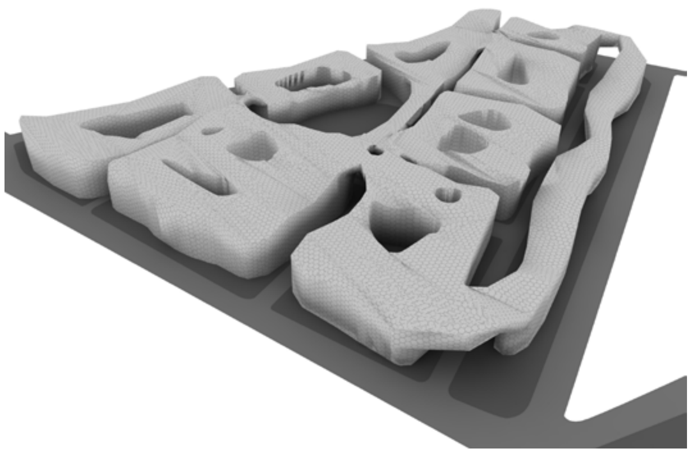
Phase 6 – Street axis get shaped according to irregularity principle



Phase 7 – Green/water storage patches are eroded

50m

**fig. 8.6**
3d model of the membrane after the first stage of erosion



# Technical specifications

After the first approach on the form has been generated, an important step is determining materials and structural approach. This, although not directly under the influence of landscape architecture, is important if we are to determine light penetration within as well as leakiness of the new structure and energy potentials.

The inspiration of Buckminster Fuller's geodesic dome, is applied in the structural approach as well, similar to the case of the Eden project (Knebel, Sanchez, & Zimmerman, 2005). Following exact geodesic specification will be, however impossible as it would require a complete remodeling of the urban geometry, not just a enveloping of the existent structures. For this, like in the case of the Eden project, and even moreso, structural adjustment will be needed.

The overall hexagonal tile approach, specific to geodesic structures, will be kept as it "allows more sun light to enter" (Knebel, Sanchez, & Zimmerman, 2005, p. 3). While the exact structure remains to be adjusted, the material enclosing the "gaps" is more important at this point. Glass is a heavy and expensive material and would be heavily inefficient. Therefore, EFTE is a more suitable choice. `The very low weight of this material in contrast to glass allows a further reduction of the necessary steel weight. This foil material allows much more U.V. light to pass into the Domes and also provides good heat insulation` (Knebel, Sanchez, & Zimmerman, 2005, p. 5).

EFTE ( Ethylene tetrafluoroethylene) is a polymer which can, theoretically be produced infinitely without impacting natural resources, other than the energy it takes to produce. It weighs 1% of glass, transmits much more light and costs up to 70% less to produce (Todoarquitectura Magazine, 2012). The average radiation permeability of glass is around 70% to 80% while EFTE can reach up to 90% (Todoarquitectura Magazine, 2012). This is especially interesting when quantifying thermal storage potentials and when discussing light permeability for inner households.

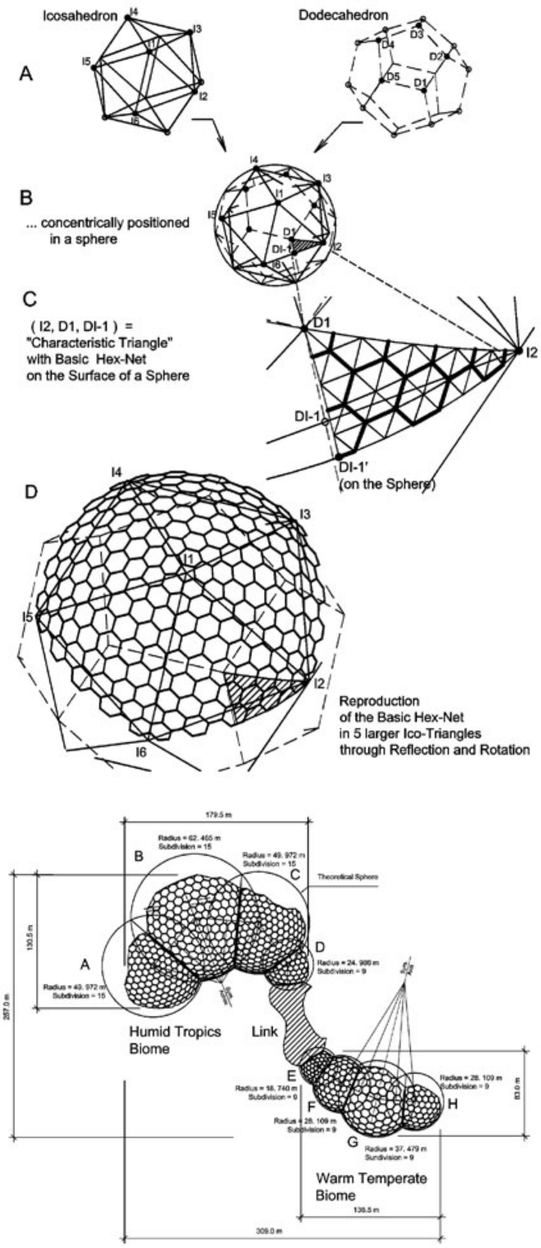



**fig. 8.7.1**
structural sketches of the geodesic dome structure for the Eden project
source: Knebel, Sanches, & Zimmerman, 2005

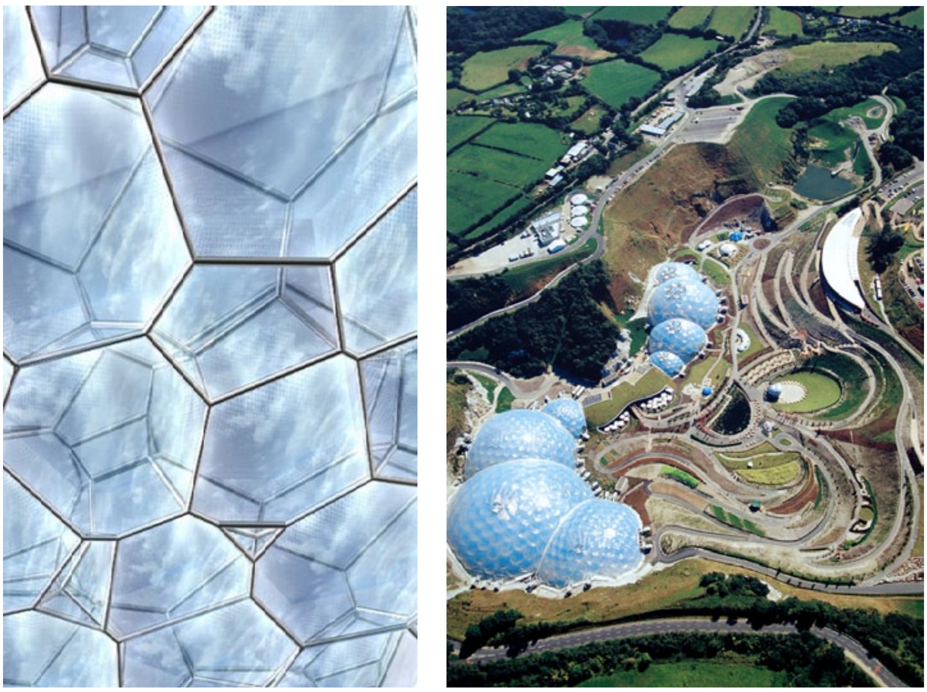


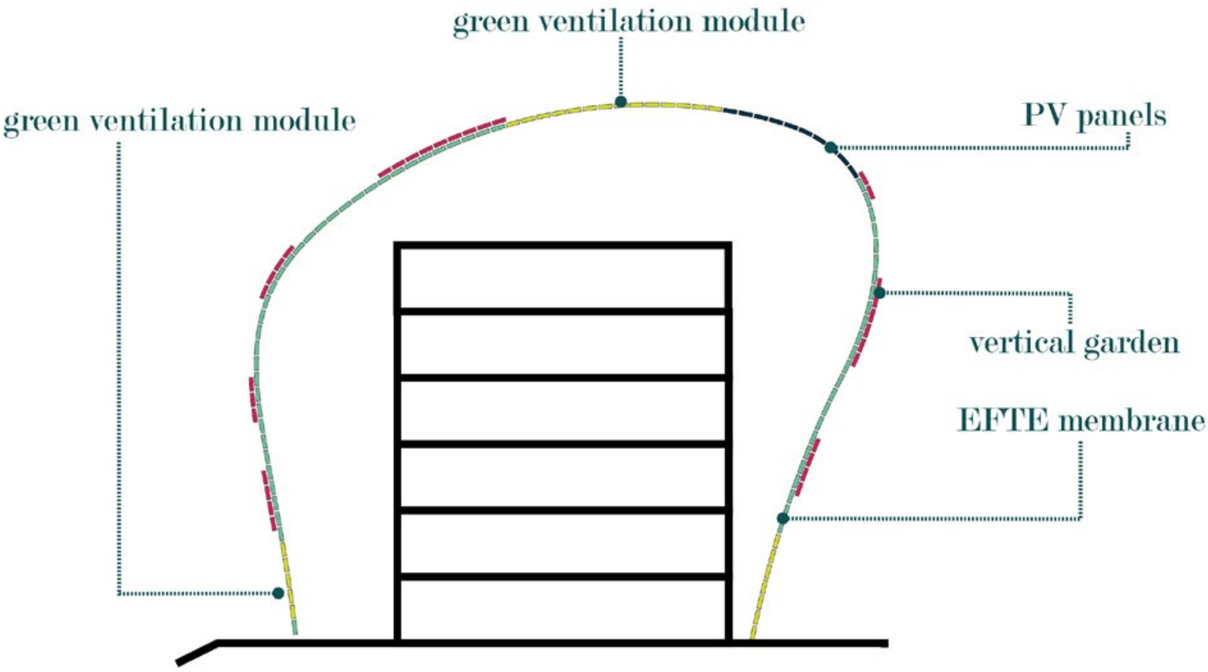
**fig. 8.7.2**
EFTE membrane for the water cube in Beijing and Eden project
source: Knebel, Sanches, & Zimmerman, 2005

# Membrane components

The resulted design is similar to what is referred to in the REAP methodology as climate facade, the only difference being its morphological approach is allot more guided and conditioned by a landscape architecture approach. The initial goal was that the approach would benefit both the inner microlcimate as well as the (outer) city microclimate, acting with alternative approaches where conventional landscape architecture measures are insufficient. Therefore the potentials for inserting green, as a new approach on green facades is explored. The described concept is

In a conceptual section the membrane is viewed as having several components and integrating green patches with "vertical gardens", for microclimate improvement, as well as PV planes for energy conversion and of course the EFTE membranes for insulation (fig. 8.8).

**fig. 8.8**
initial approach on the membrane functions and components




A ventilation system is thought out based on encouraging natural air flow dynamics. The system described in figure (insert figure) is based on mobile ventilation modules, which when temperatures are to high open in order to ventilate the space. They are placed in the lower parts of the membrane, in order to draw in cool air, and in the upper section so that as air heats up and rises it is evacuated (fig. 8.9).

**fig. 8.9**
natural convection and air circulation due to the spherical form and cooling vents

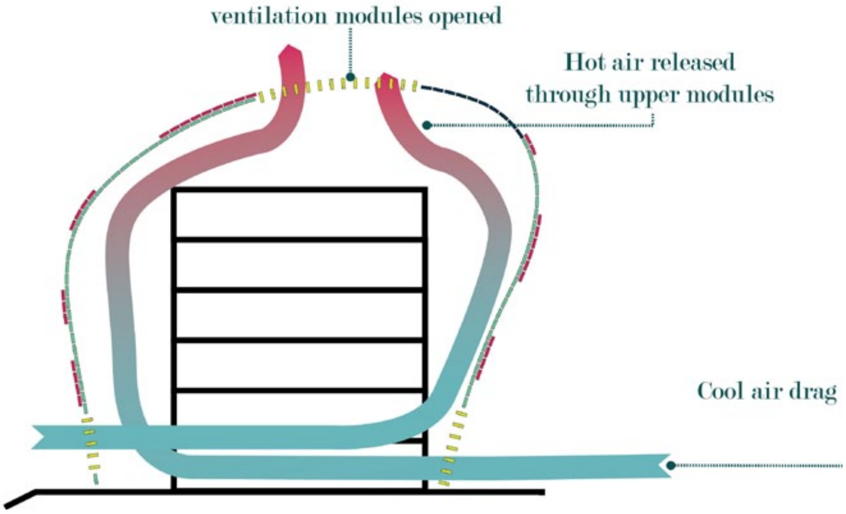
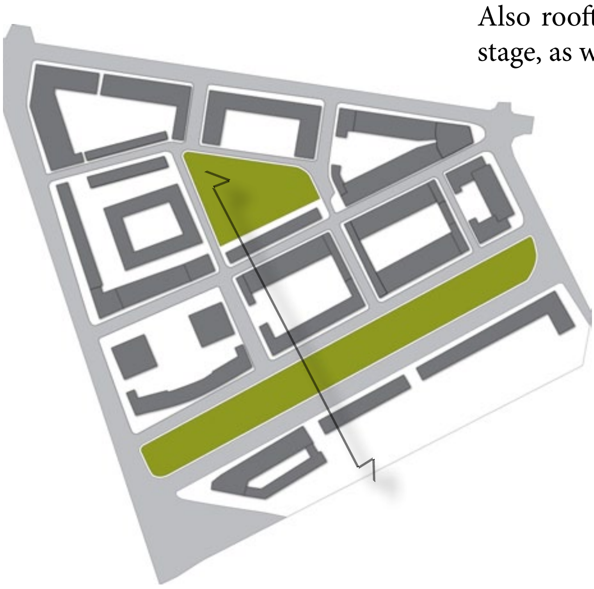


**fig. 8.10**
plan of the intervention site showing the section line and direction



The process can be observed in a step by step section "story" (fig 8.11). The existent situation with the high degree of empty unused space to which the densification strategies come as modifiers and afterwords the membranes are attached.

The image at this stage of the erosion process (fig 8.12 and 8.13) reveals the impact of the interventions with the membranes extending over the built stock and inner courtyards as well as water storage and infiltration devices, and underground storage basins
Also rooftop allotment gardens and green balconies are implemented at this stage, as well as outer vertical green and flower gardens.

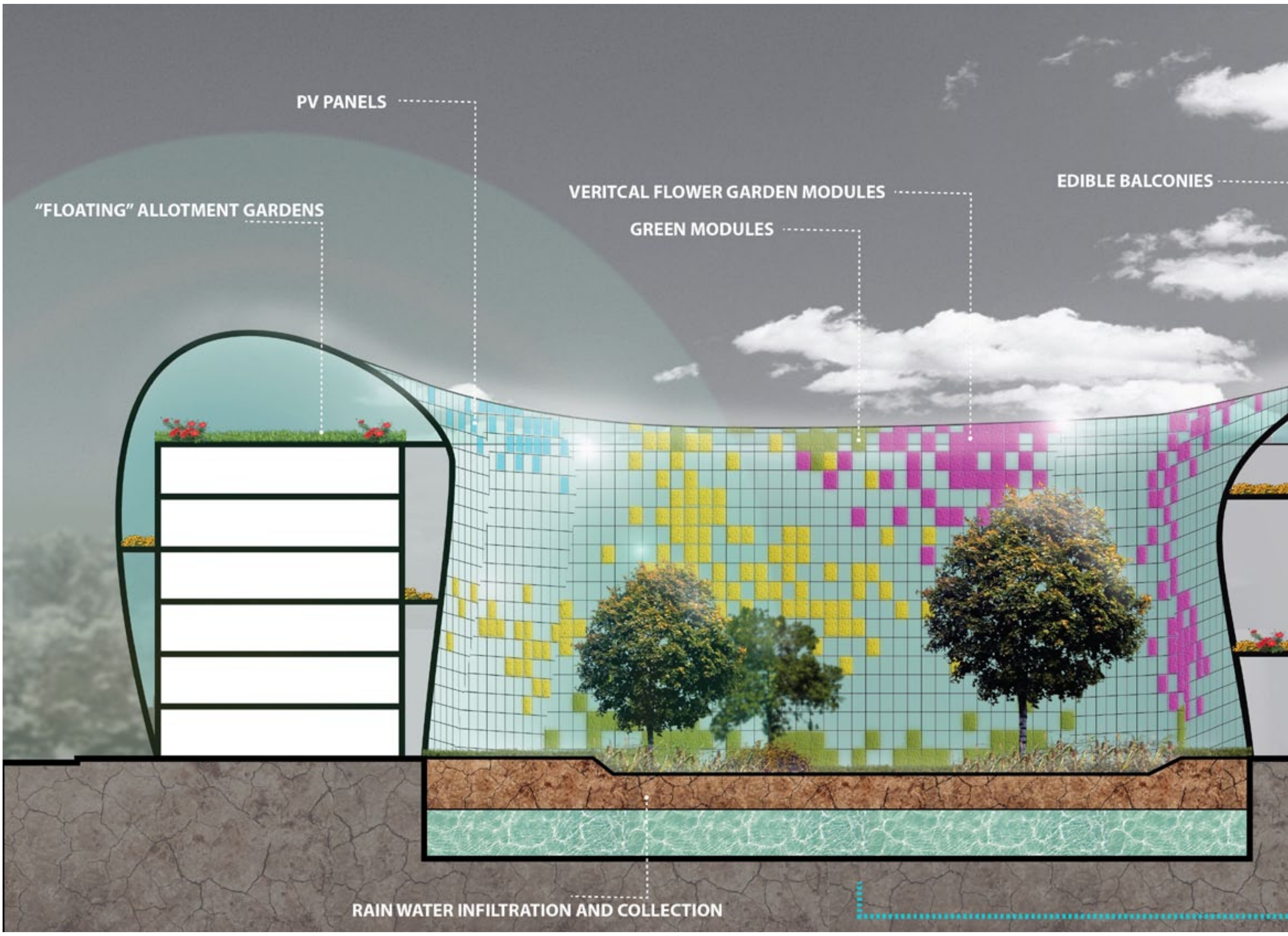


**fig. 8.11**
section phasing of the change process including densification intervention and membrane insertion

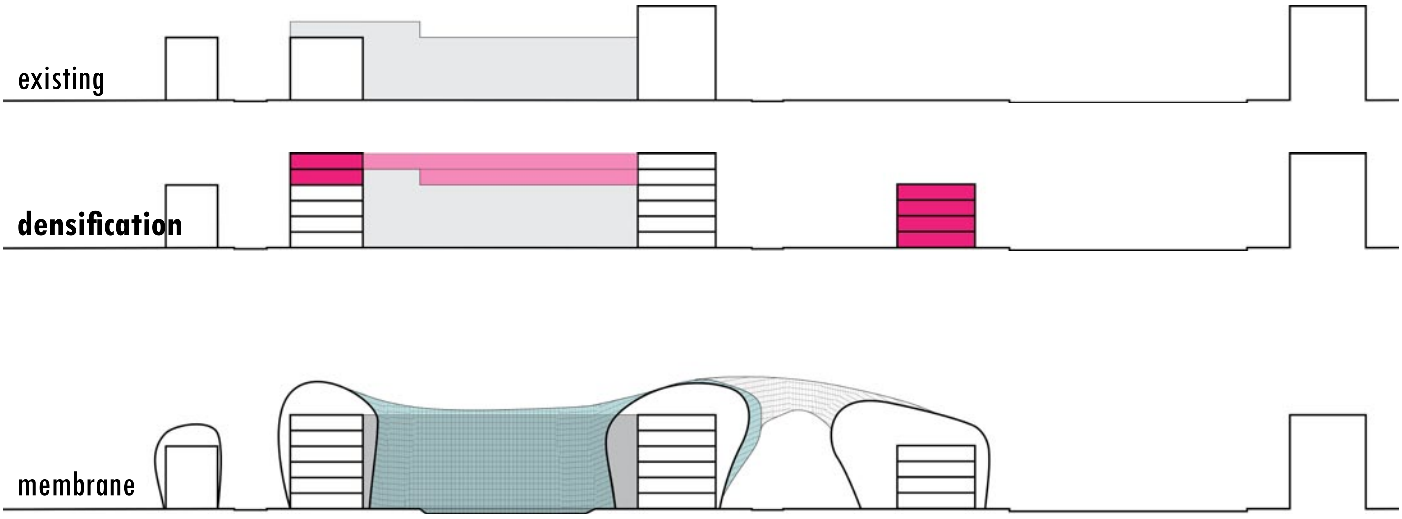
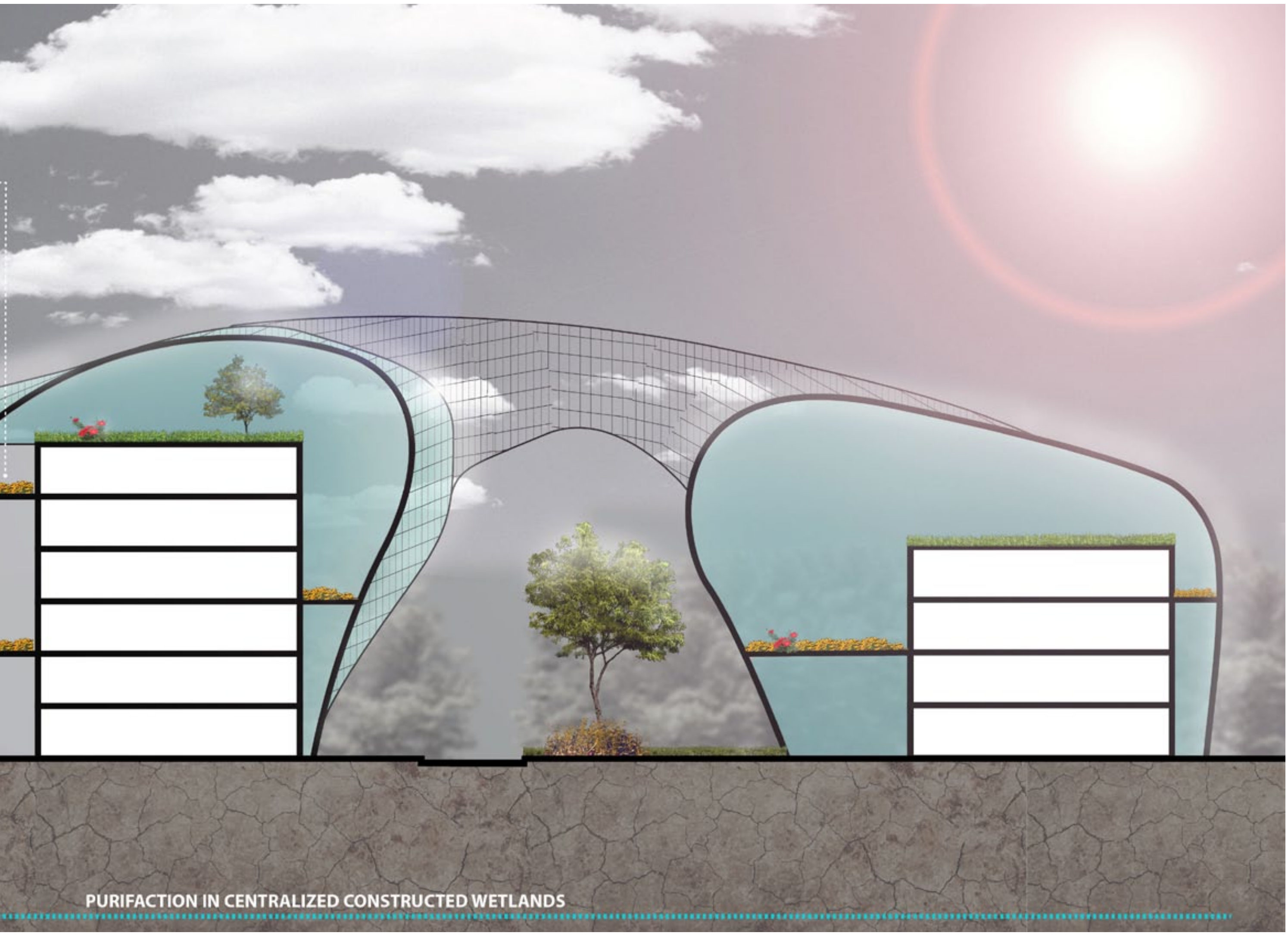
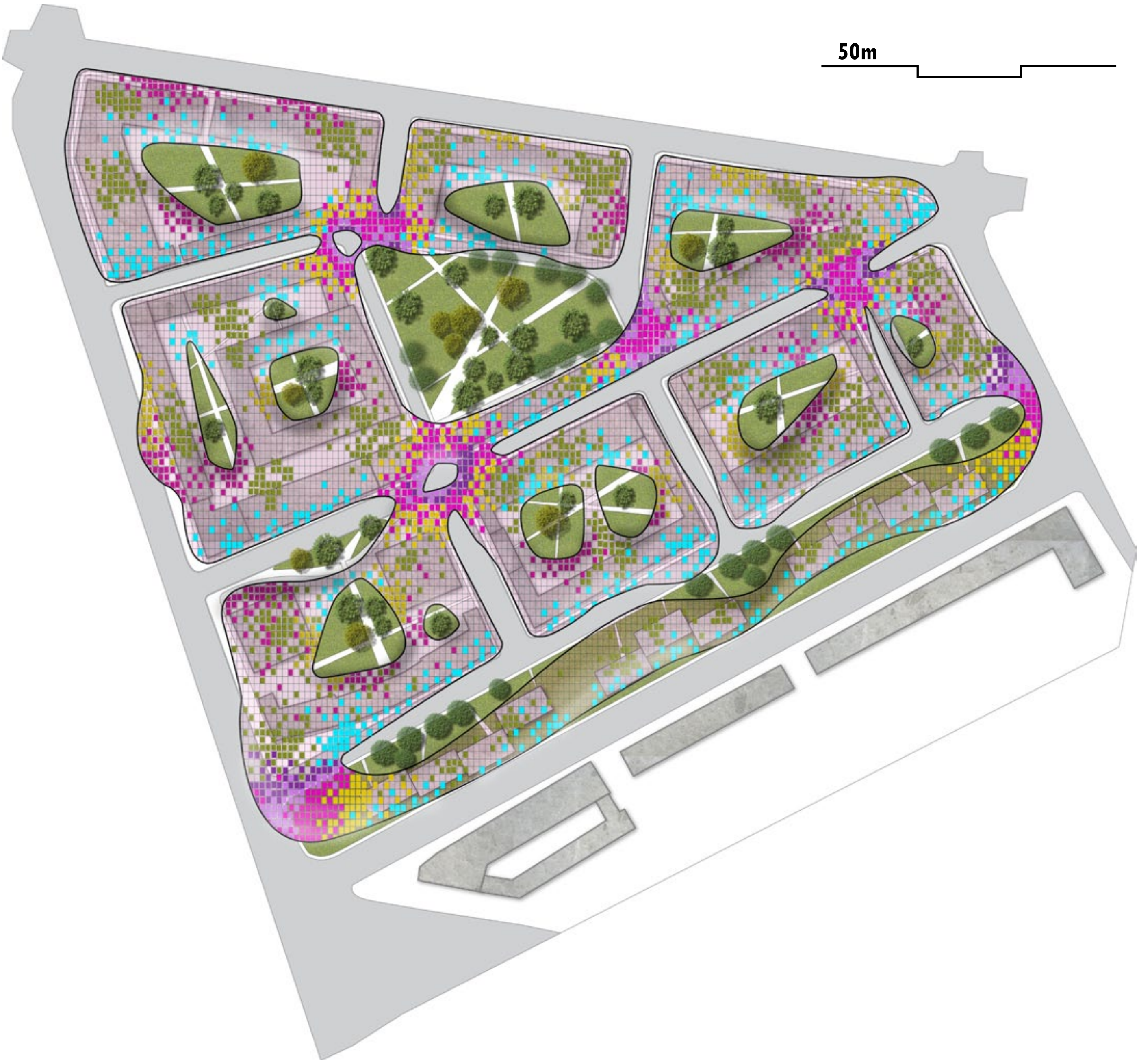


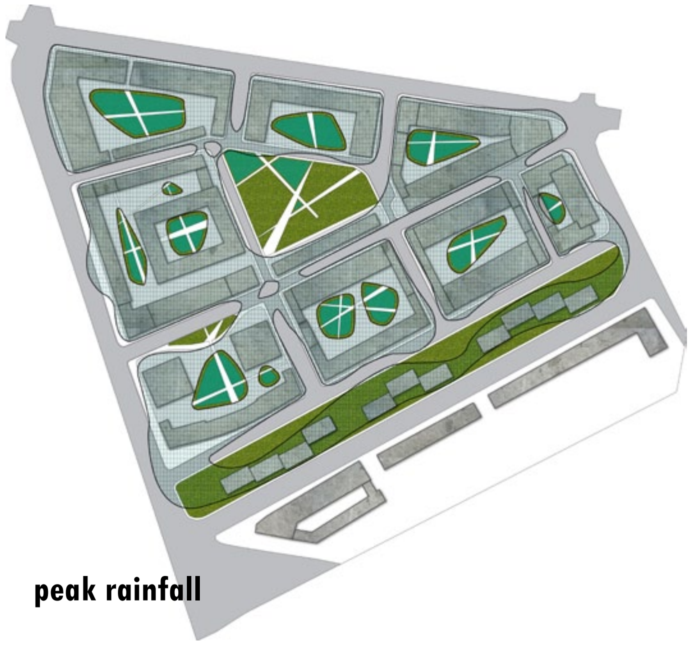

**fig. 8.12**
section of the initial stage with important design features







normal dynamics



peak rainfall

**fig. 8.13**
plan of the initial design

**fig. 8.14**
exemplification of the water storage and infiltration feature

# 8.3_ Testing and Adjusting

## Wind simulation

After a clear enough picture of the design is obtained, testing can begin. A major point of interest is wind dynamics, and ensuring that the resulted shapes, mitigate the adverse effects of wind dynamics and do not yield a even more unpleasant situation.

simulation

Wind simulations are run with the aid of flow simulation software and problem major areas are revealed (fig 8.15 and 8.16). After these are analyzed some main conclusions can be drawn. Which can form the basis of adjustment guidelines.

turbulence

Areas which have been modeled in a way which yields abrupt major changes in the overall dynamics of the form can yield wind issues.

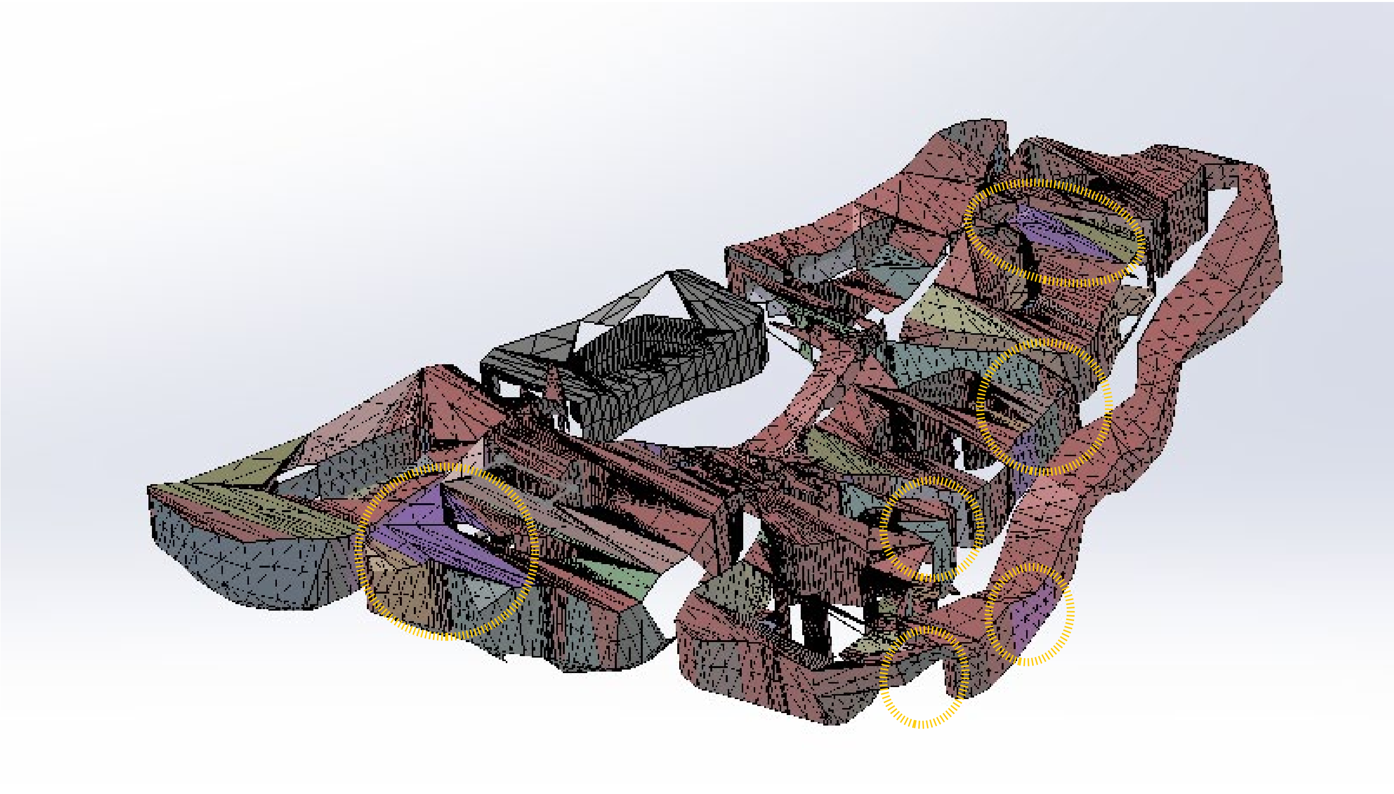
venturi effect

The "leftover" connections between individual blocks can yield the Venturi effect, speeding up winds and generating unconformable situations

Most of the wind issues are not situated at ground level and therefore are not necessarily important.

Following these conclusions areas in immediate need of adjustment are identified and, the shape is further eroded, entering a new stage of erosion. This process is therefore meant to generate a end design which is more suitable and describe a general process of research by design.

**fig. 8.15**
wind simulation results and potential problem areas revealed in different colors
PURPLE /GREEN (all shades) irregular wind patterns or abrupt speed change (turbulence)
by the author using CFD flow simulation software, Solidworks flow simulation



# Shadow and sunlight simulations

3d modeling shadows

The membrane is also tested with shadow simulations as well as comparing with theoretical guidelines, and, right form the beginning one of the main problems evidenced by tests is the decreasing of light permeability (fig 8.17).

light issues

The existent housing blocks have a somewhat minimum required light permeability and if all the elements describe above are to be implemented the result will be drasticly influencing the amount of light penetrating the apartments. This essentially decreases the passive volume of apartments as described by Sallat (Sallat,2011), and therefore can yield more electricity consumption ,even if heat requirements are decreased.

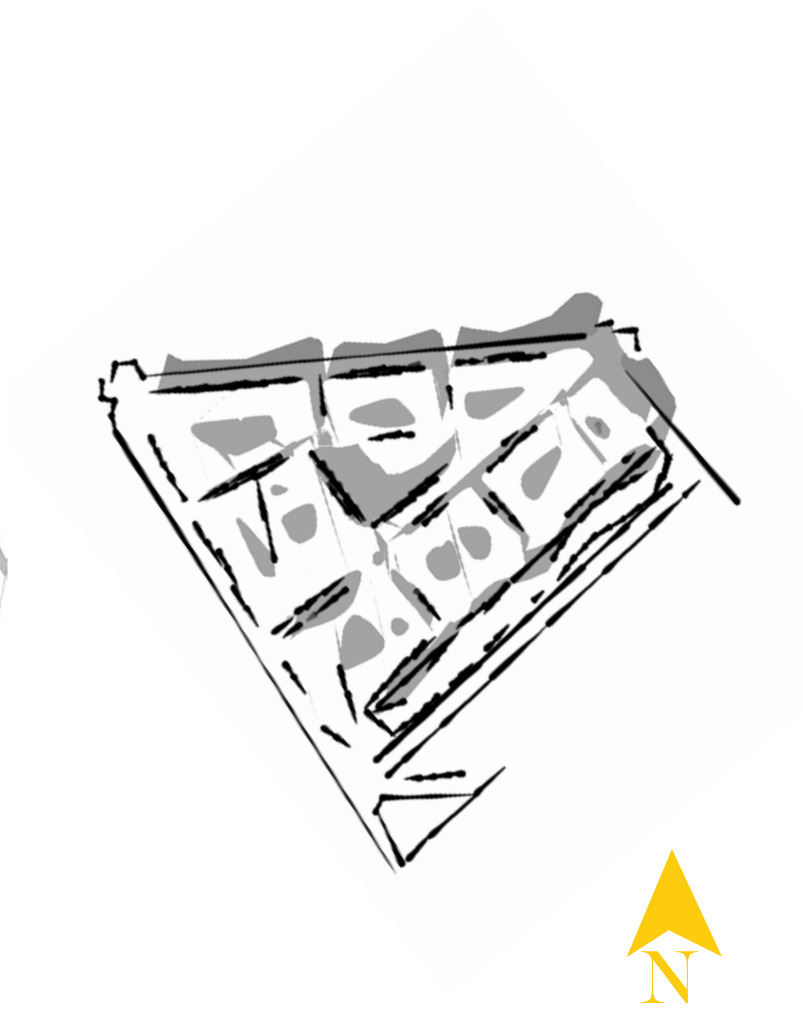
extra energy consumption

Moreover due to extra shade in the winter it can yield lower temperatures than normal instead of higher. Although protecting form the winds, the structure casts shadows due to the presence of a high percentage of green, and the added structural load they generate. These prevent warm sun rays to penetrate and generate a chilling effect.

**fig. 8.16**
potential form problems are identified for adjustment

chosen for adjustment are problems which have big impact or affect pedestrian traffic (not rooftop wind dynamics)

**fig. 8.17**
sketch of shadow simulation



# Conclusions and Adjustment Guidelines on the Membrane

initial approach

The initial approach on the membrane is not yet functioning as proposed at this stage. Some adjustments are needed in terms of shape modeling in order to remove wind problems. At the same time, more dramatic changes need to occur in terms of membrane components and sun penetration.

simulation

After the testing phase some clear guidelines and re-framed approaches can be formulated. One thing that becomes clear is the interconectednees of the problems. A intervention which is suitable for outer climate might have dramatic adverse impacts on inner climate. Before moving further in the design process more comprehensive design guidelines need to be put in place.

These have to take into account the conclusions of the simulations as well as future overall goal of the research.

# Reframed guidelines for membrane adjustment

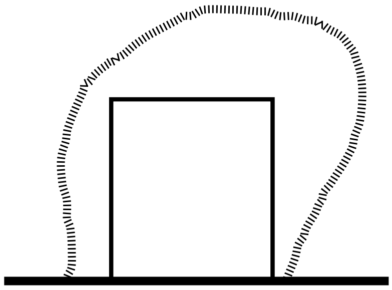
**Energy (Adjust form for better sun exposure)**

1. South facing and inclination need to provide best conditions for heat collection as well as P.V. panel implementation.
2. Provide suitable light and sun exposure conditions to avoid drastic fluctuations in electricity use
3. Maintain the closed, artificial microclimate environment for better thermal performance

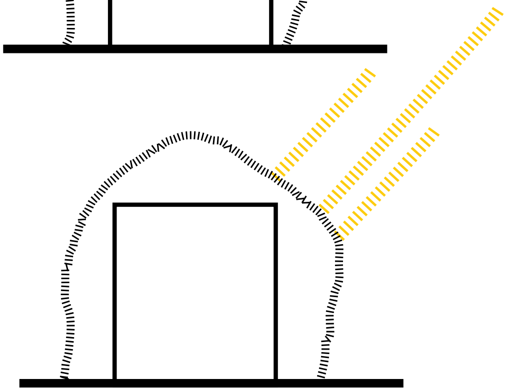
**Microclimate**

1. Mitigate the adverse effects of wind flow dynamics (even if they are only mild)
2. Stimulate ventilation and natural air circulation on the streets as well as newly defined outer courtyards.
3. Stimulate natural air circulation within the artificial microclimate
4. Address water storage assignment for the site

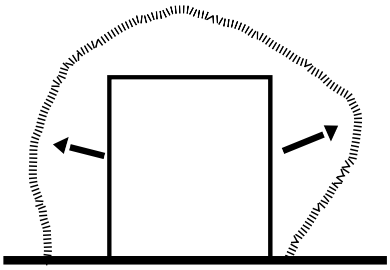
**fig. 8.18**
form adjustments following the testing phase



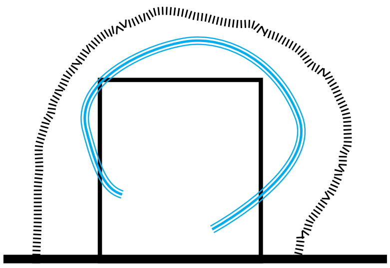
**erosion phase 1**
resulted shape of the membrane



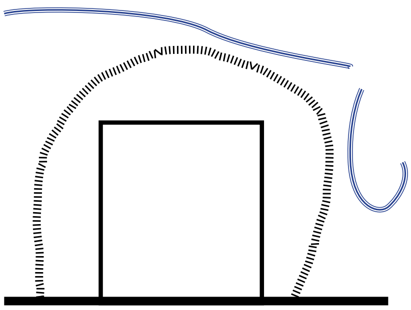
**erosion phase 2**
adjusting according to guidelines
proper solar inclination



**erosion phase 2**
adjusting according to guidelines
increasing inside volume for air quality

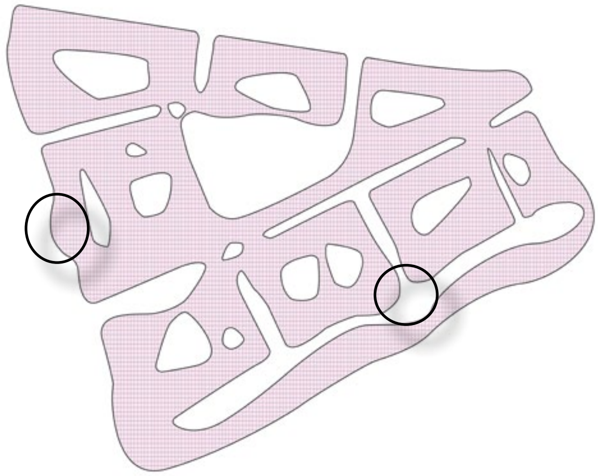


**erosion phase 2**
adjusting according to guidelines
shaping the membrane for natural air circulation



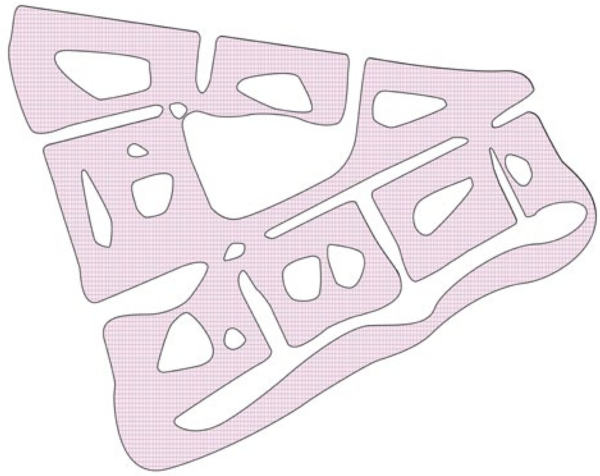
**erosion phase 3**
adjusting according to guidelines
eroding exterior volume step by step to decrease turbulence

**erosion phase 1**



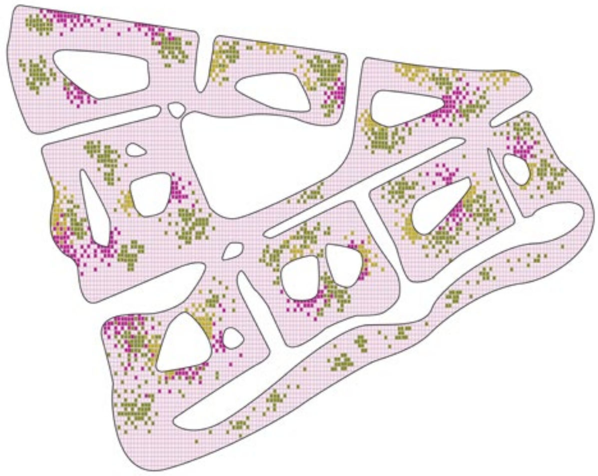
form problems (turbulence)

**erosion phase 2**



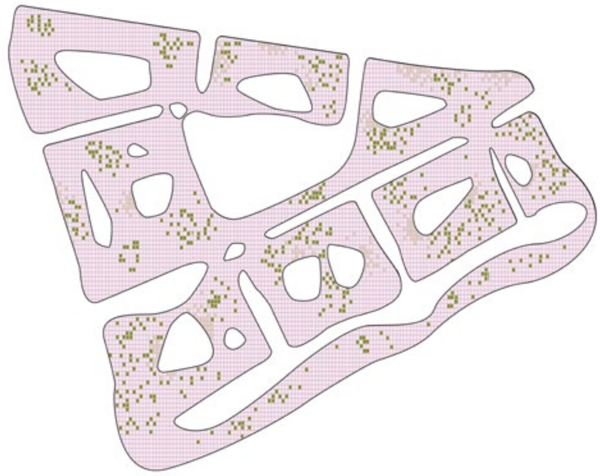
adjusted (eroded)

**erosion phase 1**



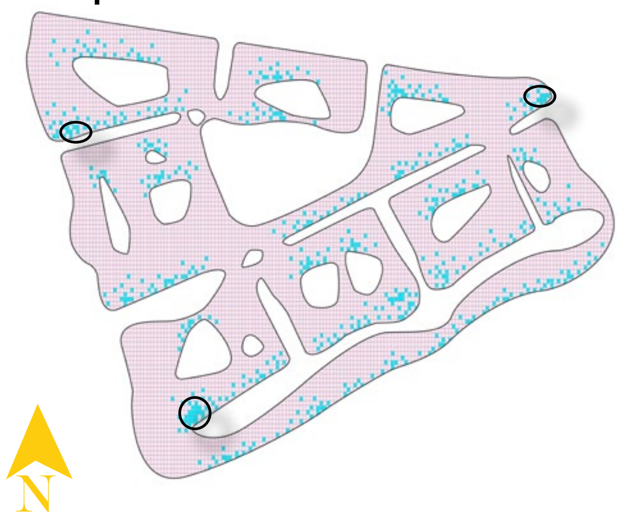
shade issues (to much cover)

**erosion phase 2**



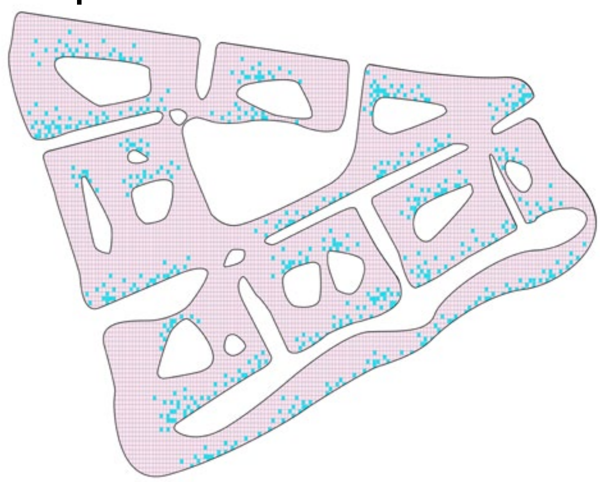
adjusted (optimized cover)

**erosion phase 1**




shading issues (areas with to many solar panels)

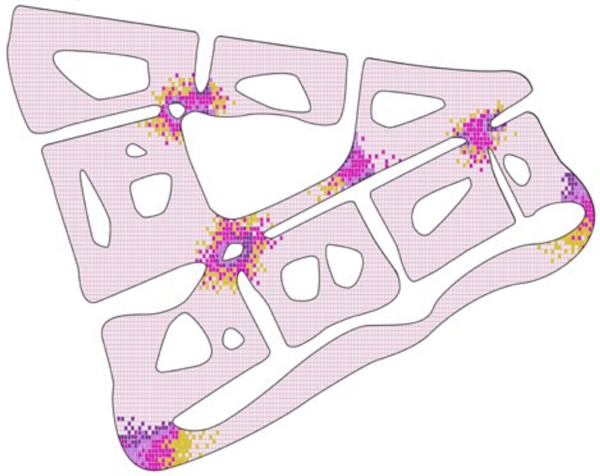
**erosion phase 2**



adjusted (optimized cover)

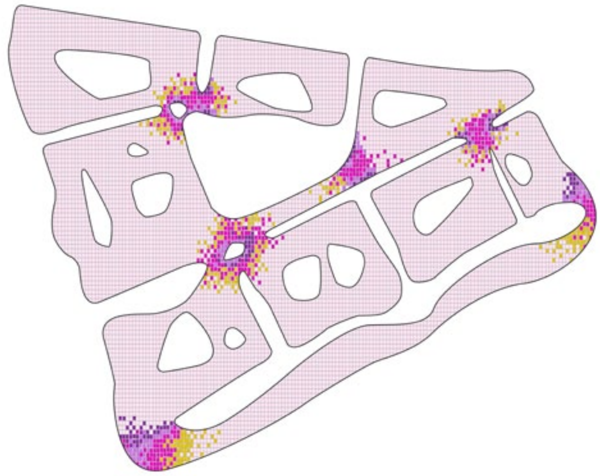
50m

**erosion phase 1**



gaps problem win winter (Venturi effect)

**erosion phase 2**



adjusted ( mobile modules -brisole; closed in the summer opened in the winter)

**fig. 8.18.1**
form and feature adjustments following the testing phase

# 8.4_ Design Proposal

## Adjustments (erosion phase 2)

Areas that are revealed as most problematic in the wind flow simulation are adjusted or "eroded". This does not meant they are removed completely but rather that the form is gradually sculpted until suitable results are obtained. This process can be repeated as many times as necessary (fig. 8.18 and fig 8.18.1).

A second set of measures following the simulations, and perhaps more important measures, are those related to sun shine penetration. The simulations revealed very shaded spaces, due to the presence of a large number of green "patches" in the membrane and due to the large number of balcony extensions. In this adjustment stage they are drastically reduced. The actual reduction in vegetation covered surface is roughly around 70% for the individual blocks. Additionally some of the PV covered areas are reduced in fragments which can potentially generate adverse effects.

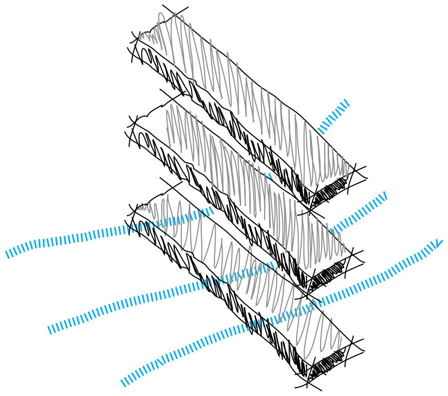
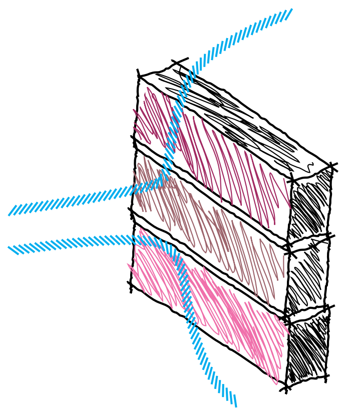


**fig. 8.18.2**
brisole concept

opened in the winter allowing wind to pass
closed in the summer directing wind in the gaps



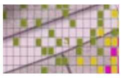
The areas which maintain their vegetation covered surface are the over-street connections or leftovers from the "erosion" process. These area are maintained in order to make use of a fluid physics phenomena identified previously as the Venturi Effect (Bottema, 1993). In the summer time wind speeds are considerably lower. Combining this with the phenomena described by Bottema as mutual sheltering (referring to urban geometry providing wind shelter to one another) (Bottema, 1993), this can yield situation in which streets are not properly ventilated in summer time, and pollutant removal does not occur at a rate which maintains air quality at good levels. Normal approaches in cases like this make use of changing proportions of street sections, of changing street orientation or building from arrangement in order to balance wind shelter with pollutant removal and ventilation (Bottema, 1993). However this works best in initial stages of design, and not when designing over an already set geometry. The changes we can provide in terms of street orientation or street front arrangement are, however dramatic, still minimal.
The over street links are used here as a mobile ventilation system. Composed out of "brisole" modules which open in the winter allowing strong winds to pass through and not opposing resistance and close in the summer to generate gaps which encourage the generation of the Venturi effect (fig 8.18.2).


**fig. 8.19**
adjusted design (second phase of erosion)

**fig. 8.19.1**
initial proposal (below)

## legend


membrane cover


top green ventilation modules
natural air circulation


brisole system
venturi effect in the summer


PV panels


central square
public use and water storage/infiltration


interior courtyards
semi-public use and water infiltration

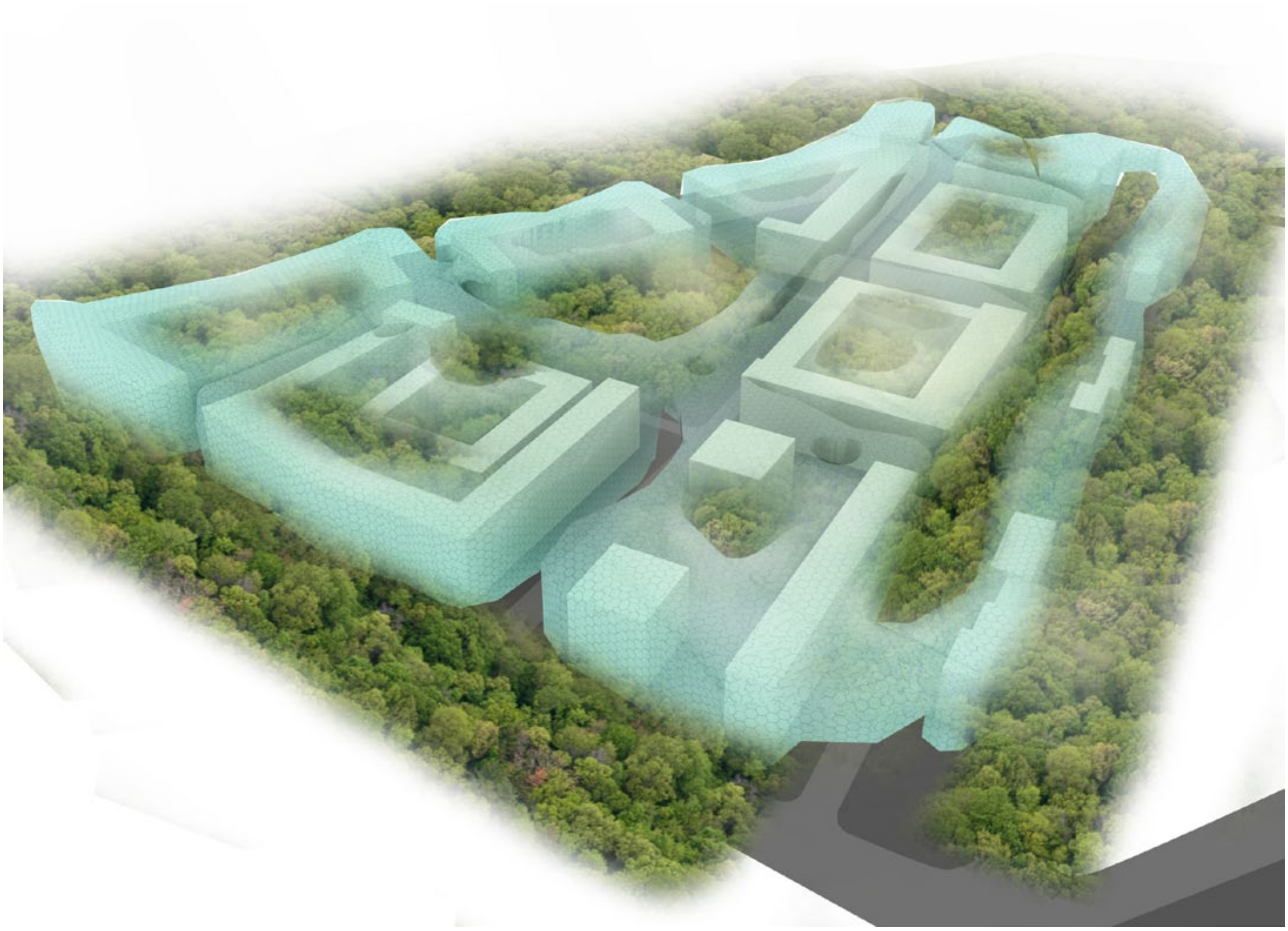


**fig. 8.20**
aerial view of the membrane

This will of course not ventilate the entire street, as the phenomena does not extend far from the gap itself, but it will generate area of cool breezes and shade around the block which can provide relief in warm days.

The resulted design after this second phase of "erosion" described by adjustments following the simulations is presented an elaborated in more detail. Although not considered the perfect solutions (especially in terms of wind dynamics and actual shading) it is considered to be a close to optimal result, which is following the right principles (fig 8.19).

# 8.5_ Carrying Capacity; Design in Numbers

## Thermal potential

The introduction of the envelope, makes, heat collecting a feasible strategy for the area. The process benefits from the artificial microclimatic conditions, which allow for control of air flow, to capture solar thermal energy, and store it in underground aquifers. Essentially this, is, along the lines of controlling entropy levels, a good step towards achieving the goals of lowering entropy considerably.

In order to quantify its theoretical potential, the shape, material and surface area of the envelope established in the technical specifications chapter become very important. The percentage of solar radiation that penetrates the envelope is what will ultimately form the basis for harvesting heat, and therefore should be as high as possible. Compared to conventional glass EFTE has a LZT (light permeability factor) of 90% (Todoarquitectura Magazine, 2012).
Furthermore what is important is the actual surface that is inclined at a proper angle in order to receive radiation form the sun. The surface facing the sun is the one which determines how much radiation is absorbed and not the area of the site (McKay, 2008). Therefore this surface should be as extensive as possible.

solar collectors

The overall process of harvesting thermal energy and storing in in aquifers can be described in 7 steps (fig 8.21).

1. The raw power of the sun for Rotterdam is 1000 W/m2 out of which approximately 2/3 is harvestable thermal energy (McKay, 2008). Therefore the potential raw power outside the structure will be 666.6 W/m2. The square meter potential refers to, as mentioned surface facing the sun not overall surface.

2. The permeability of EFTE is 90% (compared to 70-80% glass) and therefore out of the 666.6 W/m2 only about 600 make it inside the area.

3. This radiation "hits" the ground and then part of it raises to the top of the structure, some 25% is lost through the membrane back into the atmosphere (Otte, 2009), and only about 50% out of the radiation remaining inside can be harvested vie heat collectors (Otte, 2009). This means that out of initially entered power of 600W/m2, some 225 W/m2 can be collected.

4. From this point the collected energy needs to be stored underground for usage in the winter. Out of the total energy harvested, only 60% actually makes it in the aquifer, the rest being attributed to transport loses (Otte, 2009). Therefore from the 225W/m2 captured, 135 W/m2 is stored in aquifers.

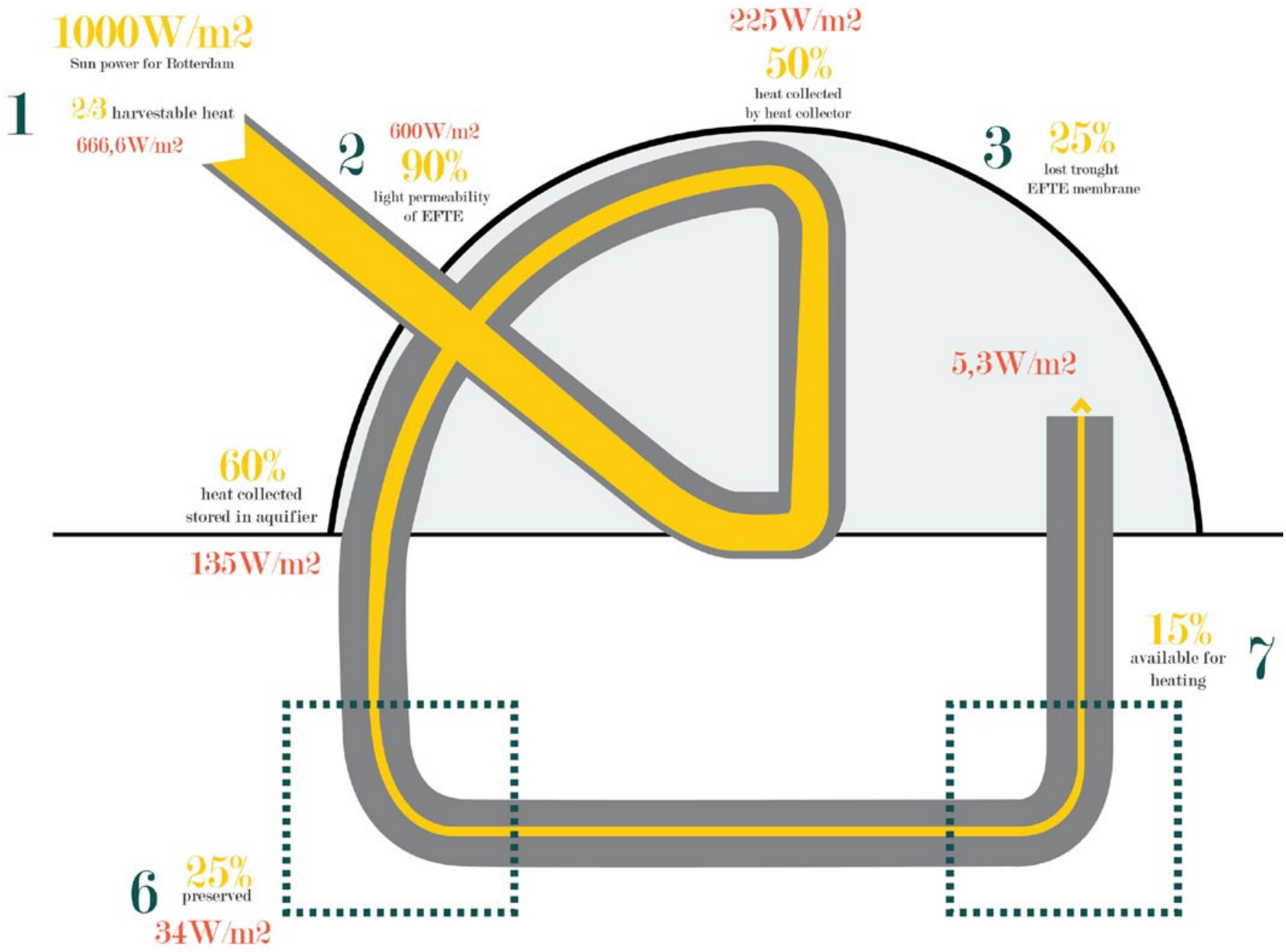



**fig. 8.21**
solar thermal energy collecting and storing process and potentials

5. Further loses can occur when storing heat in aquifers, and on average, only about 25% out of the heat initially stored is actually preserved, taking the power from 135W/m2 to 34W/m2.

6. From the remaining heat 15% can be counted as actual power heating up the environment, taking the final potential number to 5.3 W/m2 (of surface facing the sun).
If we know the surface of the membrane and the percentage facing the sun, as well as light permeability factors we can calculate how much energy can actually be collected and stored, and to what extent can this influence the winter climate inside the space.

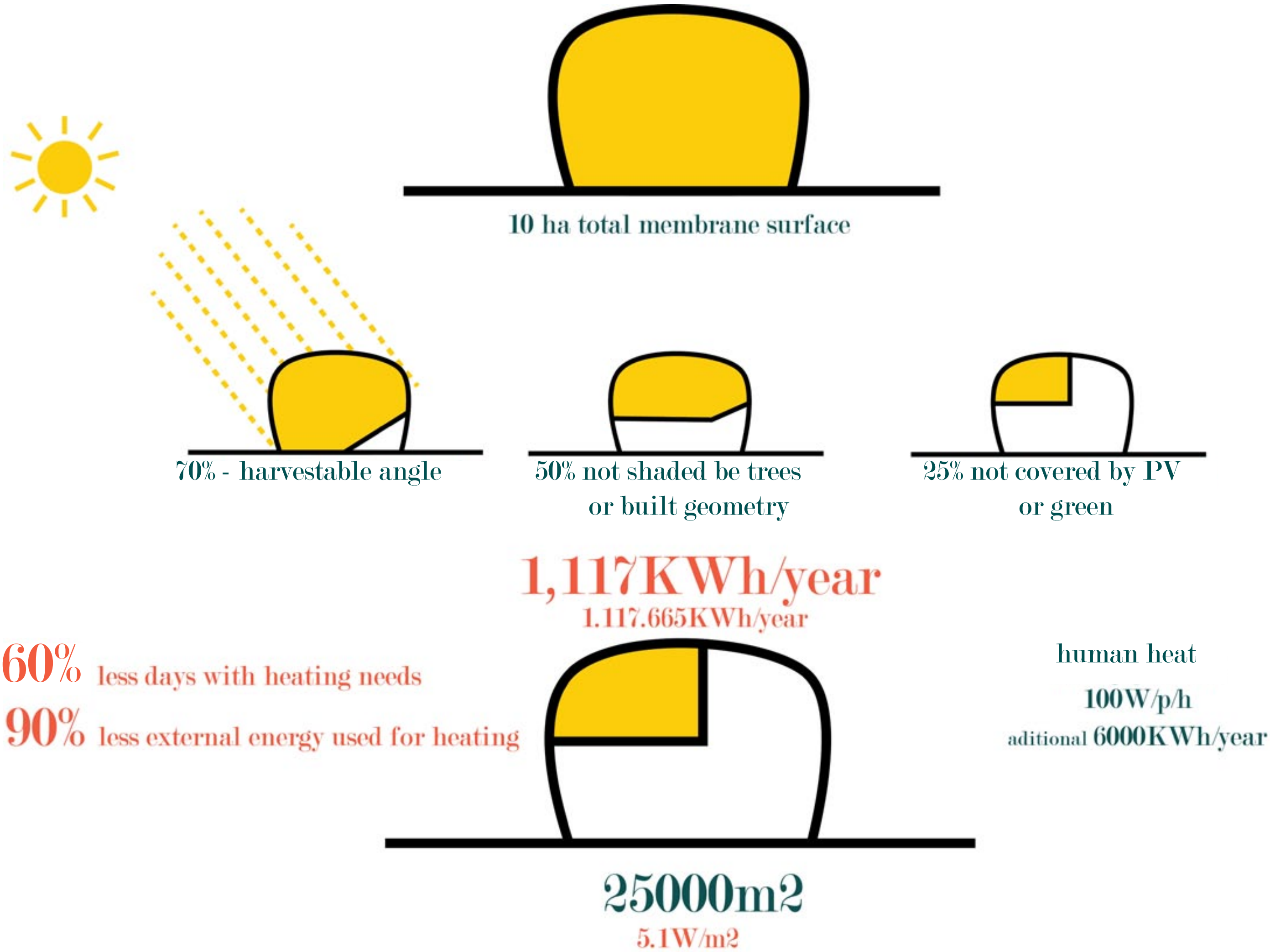



**fig. 8.22**
surface suitable for solar thermal energy harvesting (good solar inclination)

suitable harvesting surface

The structure as it is now has an overall area of approximately 10ha. Out of this surface, only about 60% can be counted as potentially facing the sun. Furthermore we must subtract areas which are shaded, either by other buildings or vegetation. These could further decrease the potential surface by another 20% of the remaining.
Out of the remaining surface some, will be covered by solar panels, some lost due to the presence of the structure supporting the membrane, and therefore another 50% can be subtracted. This leave the remaining surface at 2.5ha (fig 8.22).

2.5ha=25.000m2
25.000m2 X 5.3W/m2 = 132.500 W
Over the year this means
132.500 W/m2 X 24 X 365,25 = 1,117 GWh/year

To this we can add the heat generated by human bodies 100W/p/h.

human body heat

After taking the human generated heat through the steps of collecting and storing, out of the initial 100W/m2 only about 1W/m2 makes it back as usable power. Rotterdam has an average of 2 persons/household (Municipality of Rotterdam, 2012), and within this structure we can about 1600 people.

Therefore, the end potential of human body generated heat is:

1W/m2 X 1600 = 1600W

Yearly this amounts to 1600W X 24 X 365,25 = 14025600 W = 0,014 Gwh

This is a very low number compared to other potentials, even if every person would spend every hour of every day inside the structure (which is not the case). Therefore this potential is not factored in for this particular research.

To this there are also potential sources such as heat generated by electrical/household appliances and so forth. These are however difficult to estimate exactly, and for this paper they are regarded as a potential bonus, rather than having the feasibility of the system rely upon them.

We are left with 1,117 GWh/year of thermal energy.

*heating use*

In Rotterdam, one household uses about 0,011 GWh/year, out of which 75% for heating purposes (Energy Efficiency Indicators in Europe). This means that per household 0,008 GWh/year are used for heating and therefore the 1,117 GWh harvested have the potential to heat up roughly around 150 households (1,117/0,008 = 151 ), at the rate consumption is currently.

This is just 20% out of the total number of households inside. The adding of the membrane as a climate façade can contribute to decreasing energy needs by as much as 25-30% (REAP – Ikazia cluster case), therefore the new number of heading need would be 0,0056 GWh/year/household.

*heating potential of individual homes*

This would make the stored 1.117GWh sufficient for 200 households out of 800, raising the percentage of coverage from 20% to 25%. If we only rely on harvested heat and not district heating from the city or collected heat from asphalt collectors or residual heat from other nearby function this is not nearly enough. Therefore a new approach is sought.

*heating the membrane*

On average, a day in which heating is needed is considered a day in which temperatures outside are lower than 18 degrees Celsius (McKay, 2008). In Rotterdam there are roughly around 200 days/year with temperatures under 18 degrees Celsius (KNMI) ,and the average temperature for those days is 11C.

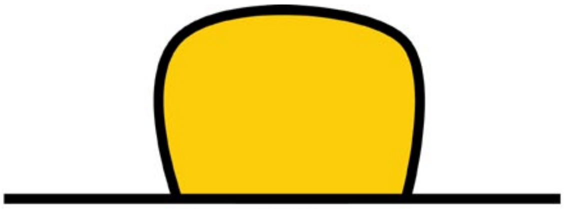
The power usage of a given space is :

Power usage = (average temperature difference X leakiness)/efficiency of energy system

Leakiness = ventilation loss X conduction loss

For triple glazed windows U value is 0,7 (McKay, 2008)
EFTE membrane can be some 50% more efficient, taking U values to 0,35 for the structure

**fig. 8.23**
heating potential of the stored heat




power used = (ΔT x leakiness)/efficency of heating system

ΔT = 7°C
heating needed when T<18°C
200 days/year with T<18°C
average for those days T-11°C

leakiness of incubator 1,5 W/°C/m2
1330KWh/d/C

90%
efficency of heating system

1,117GWh/year = 5 °C heating capacity

60% less days with heating needs

For a normal household an average heat loss parameter is around 3 W/degree Celsius/m2. This is for individual households (detached) with poor insulation. For EFTE we could estimate a reduction of 50% similar to insulating a household. Balancing a far better insulation with somewhat more ventilation loss, the structure should still have a better thermal performance.

estimating leakiness

"Combining these two actions – the physical modifications and the turning-down of the thermostat – this model predicts that heat loss should be reduced by nearly 50%. Since some heat is generated in a house by sunshine, gadgets, and humans, the reduction in gas consumption should be more than 50%" (McKay, 2008, p. 296).

Therefore we can have a power heat demand of
1.5W/degree Celsius/m2

For about 30.000 m2 this means
30.000m2 x 1,5W/Degrees Celsius/m2 = 45000 W/degrees Celsius

average temperature difference of 7C for 200 days

This means:

0,000045 GW/degree Celsius

With a 7C difference in temperature for 200 days this equals

0.000045 X 24 X 200 X 8 GWh = 1,728 GWh/year

This is the heating need for the entire covered membrane if we are to maintain the temperature at 18C in the days when the outside temperature would be below.

Essentially the 1.117 GWh stored has the capacity of influencing the temperature in the structure with 5C in the 200 days.

heating potential for the membrane

This is only enough for 60% of the 200 days, but the remaining 40% of the days also benefit from a 5C increase in temperature, making the need for heating much lower, even if the 18C threshold is not reached.

Essentially with little input from other sources, the system can be self-sufficient in terms of heating.

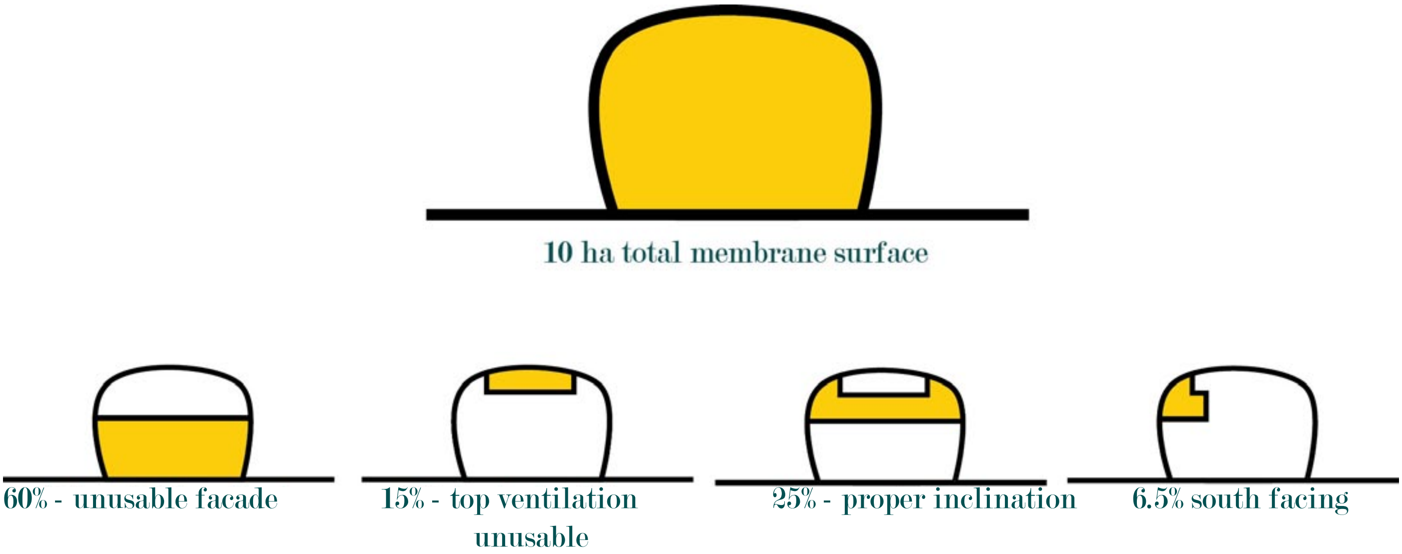



**fig. 8.24**
suitable surface for PV cell implementation

# Electricity potential

Extra consumption
While the application of the climate façade, is of great benefit for thermal saving, it does however raise the electrical power usage per household. Within the REAP case study of climate façade for the Ikazia hospital cluster an increase of electrical power consumption of 15% is estimated (Dobelsteen & Tillie, 2009). This share will be incorporated in the current model as well.

15% extra electricity consumption

Household energy of 0,011 GWh/year with electrical usage holding 0,0012 GWh/year. Therefore in the studied cluster of 800 households an overall electrical need of 0,95GWh/year.

With an increase of 15% due to the membrane this would amount to 1.1 GWh/year/800households

Generating
Within this context it is important then to think of potentials in terms of electric power conversion. From the potential study, PV was revealed as suitable.

I is important to keep in mind that any extra PV coverage will increase the need for electricity, due to decreasing of daylight within. Therefore a good balance has to be obtained.

An overall coverage of coverage of 4% with PV was taken into account when estimating thermal potentials for storage. The same will be elaborated in terms of potentials and added consumption. In the overall increase of electricity an extra 5% is added due to the coverage with PV making the consumption per household increase by 20% instead of 15% and taking the overall electricity consumption to 1.15GWh.

After factoring in the increase in consumption due to extra coverage, the potential for generating electricity is assessed. A 4% coverage with PV is translated into 4000m2 of PV surface (fig 8.24). For Rotterdam the potential for solar power conversion is situated at 200 kWh/m2/year, at an average of 1700 sunshine hours (KNMI), and more efficient panels it means that the overall yearly solar potential per unit is:

1000kWh/m2x4000m2=0,8GWh/year

powering 600 households

At an electrical consumption of 1.15 GWh yearly for the 800 households, the potential is enough to power about 600 of them. Currently there are 400 households so therefore this would be enough to power all of them and feed electricity to the grid

As an end conclusion of this section, in terms of energy, the most important design guideline would be to have as much as possible from the membrane facing the sun.

# 8.6_ Discussion and Design Heuristics

Heuristics are in short, rules of thumb developed through trial and error, and heuristic evaluation as method of evaluation and design become spread in the late 90s (Afacan & Erbug, 2009). If this process, incorporates research and scientific, critical assessment at every step of trial, then it essentially describes a process of research by design.

a systemic approach

Within a systemic approach, there are always numerous considerations to the design (Berger, 2009), which makes it difficult and resource consuming, to repeat this process until perfect results are obtained. Therefore a set of challenges can be revealed concerning this approach, with regards to taking the deisgn to its ideal final state.

constant testing and adjusting

1. The amount of factors which contribute and guide the design process is complex, and therefore, numerous trials and adjustments need to take place, before it can reach a final state. It is furthermore requiring further development and research in terms of structural and architectural approach. This would entitle architectural and engineering plans and the tests that go along with them, in order to verify and further adjust the design. In a sense this design would require a strong interdisciplinary approach in order to guarantee its feasibility.

high degree of uncertainty

2. The process of constant adjustment, means that the final image is hard to speculate even for a small residential block. Speculations on the final landscape image for an entire city, are even more harder to produce due to the amount of additional variables that enter the equation.

different morphologies

The main design challenge which this approach is facing is related to urban morphology. Mainly the morphological approach on the design is fundamentally different from major driving forces behind current urban morphology. This current approach is trying to dramatically alter the urban morphology, while at the same time acting as a protective layer for the existing built stock. This approach is suitable for small scale sites, but challenging to implement on a city level, without being intrusive and somewhat colonial even.

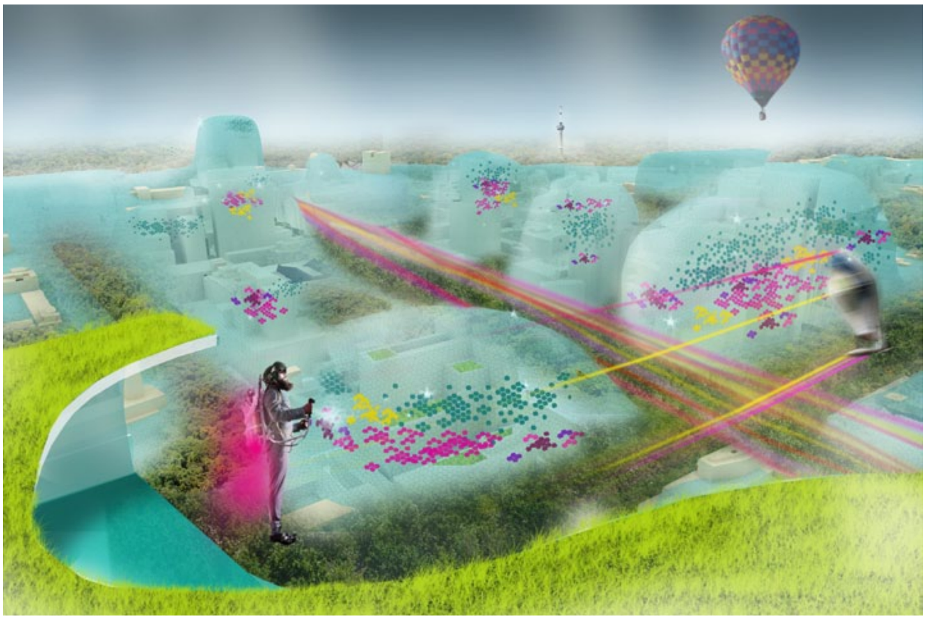


**fig. 8.25**
highly uncertain future/dream image of Rotterdam in 2050?

With regards to design goals, guidelines and principles the main concluding points when discussing this intervention would be:

thermal

Exergetic optimization of households can be achieved with regards to thermal energy up to a factor of 90% by implementing microclimating control.

water storage

The remaining water storage assignment for the inner-city of 22ha can be achieved in decentralized infiltration and underground storage areas in the redesigned residential courtyards, and can be even used for microelectronic control (providing cooling in the summer)

wind

Wind dynamics do not represent a major problem for the site, but further testing is needed for optimization of the membrane shape, much of which would fall under detailed architectural implementation design.

electricity

Introducing the membrane is a opportunity to generate added value in terms of energy by supplying for 75% out of the projected demand (after densification) and for the entire current demand.

food

Food production in decentralized, rooftop farming systems can add additional value to the intervention as well as directly engage living with farming by moving the popular allotment gardens on the rooftops.

courtyards

The newly resulted artificial microclimate can be a opportunity to reengage people with the courtyard by offering relief in hard climatic situations.

reflecting on RQ

Going back to the research question: Can exergetic optimization of energy and matter cycles yield an attractive urban structure that provides ecosystem services and supports human life, activity and growth?

We can state that this approach is in fact exergetical optimization, and is grounded in ecosystem ecology in what concerns certain aspects (like greywater, electricity and heat provision) and does support human life. One essential thing it is lacking is the growth aspect. This approach is limiting in the sense that, as observed previously, is hard to apply to city scale dynamics, and therefore cannot be considered as a platform for supporting human population growth in urban areas.

# 09 PROPOSITIONAL DESIGN FOR ROTTERDAM PERNIS

## 9.1_ Site Introduction and Analysis

### Introduction

Pernis

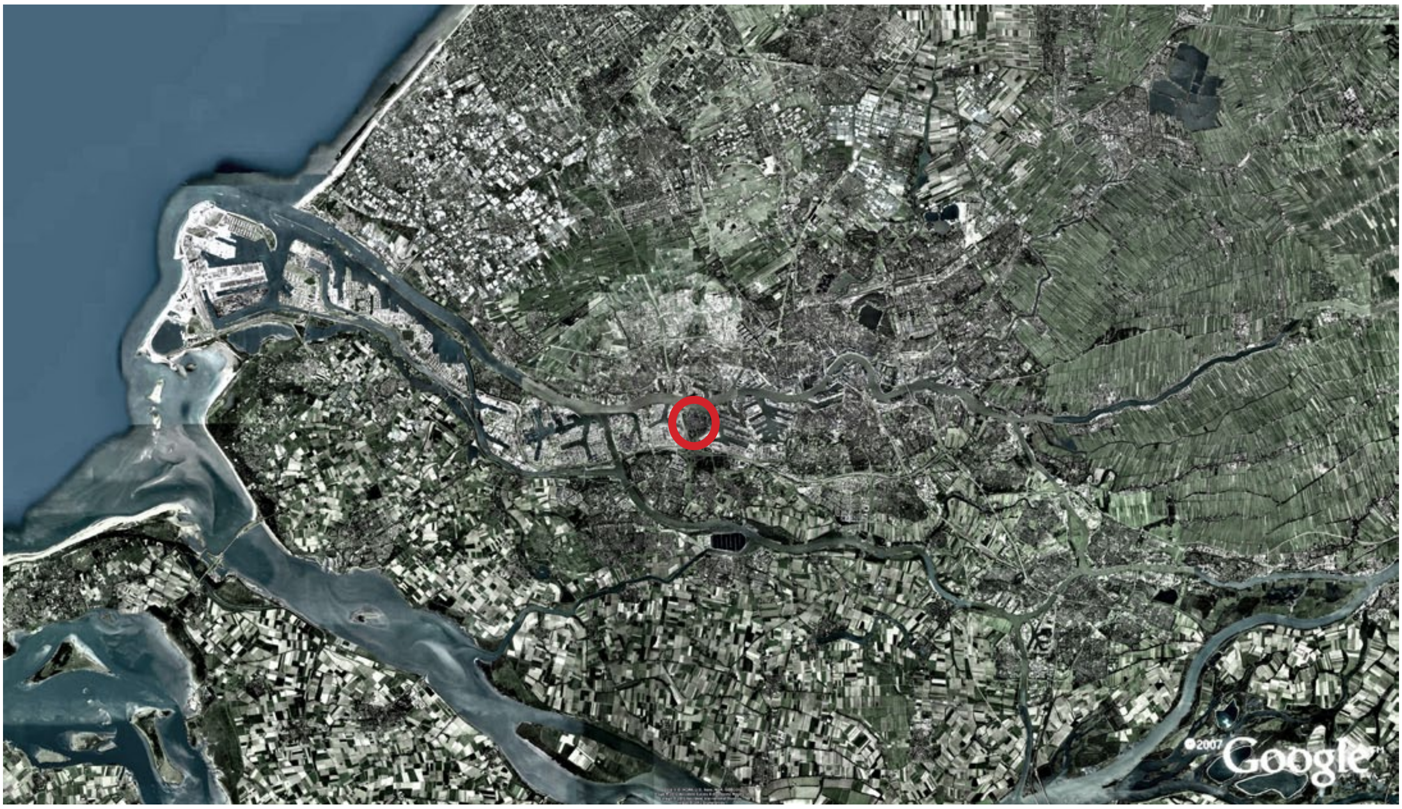
The site chosen for intervention is the district of Pernis. The area, located along the southern part of the port of Rotterdam, between the Shell refineries and the Stadhavens is an interesting case for this research (fig. 9.1). In terms of administrative history, the district always maintained a certain degree of independence from Rotterdam, which can be seen as an advantage when trying to implement a somewhat autarkic community approach. The district is composed of approximately 2500 households with roughly 5000 inhabitants.

With regards to location the district is adjacent to the A15, considered in the scenario as being very important for supporting future potential growth in traffic related to port industry. Pernis is isolated in the heart of the port and its industry. These particular observations make the district valuable and at the same time raise important issues with regard to its future.

heat island effect

When looking at the heat island effect issues in Rotterdam, immediately Pernis stands out between hot industrial, hard landscapes, as being a small relatively cool "retreat". This quality is greatly challenged and endangered by both harbor developments and need for additional industrial space as well as climate change and temperature raise (fig. 9.2).

**fig. 9.1**
satellite image of Rotterdam with Pernis identified
source: google earth



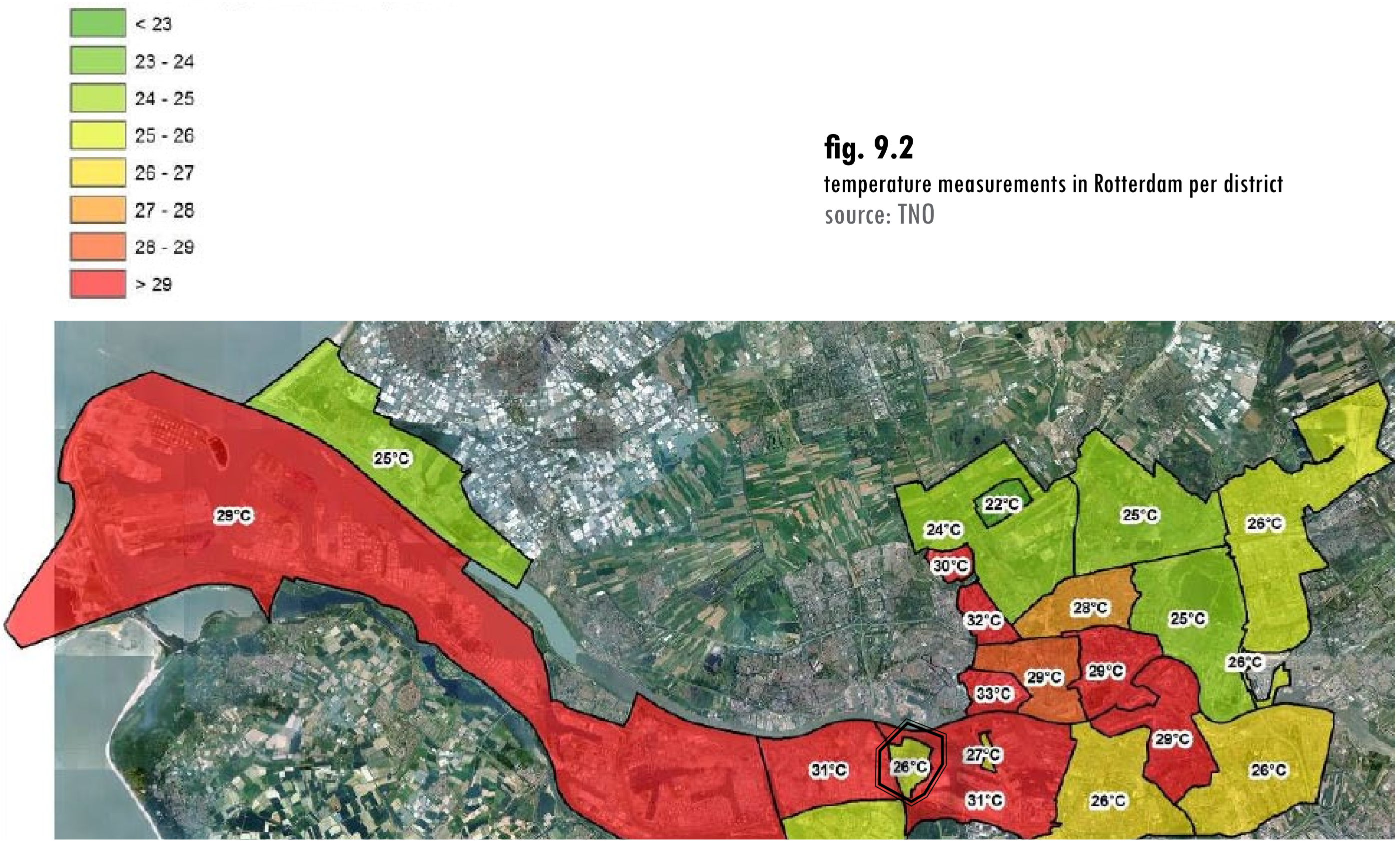




**fig. 9.2**
temperature measurements in Rotterdam per district
source: TNO

# Analysis

fig. 9.3.1
variety of architectural stiles/building periods

fig. 9.3.2
surrounded by industry

fig. 9.3.3
high percentage of green

## Spatial structure

The site is fundamentally different from its immediate surroundings. It is largely dominated by green and soft surfaces. Approximately 70% of the total surface of the study area can be considered either green or courtyards. Leaving only 30% of the space to account for actual hard paved surfaces, such as roads and built geometry. This general structure of the surfaces is one of the main reasons why the area manages to remain relatively cool during the summer instead of being overwhelmed by heat from industrial spaces.

The district has a low built density, much lower than the current density of the inner-city of Rotterdam. This is of importance due to the expected raise in population and specific interest for Rotterdam as housing area. In the context of economic prosperity for the area, and trends in population dynamics, areas near Rotterdam are expected to see pressures from the housing market for development to accommodate new professionals working in the city (Municipality of Rotterdam, 2012). When we count in new residential developments in the district (prior to the financial crisis) and the new metro connection with the city, the likelihood of these dynamics is even higher.

The general landscape green structure of the site, does not penetrate the inner district in a coherent way. The typical structure revolves around the district itself similar to a green belt, with tow weak penetrating green axis along main canals. To this we can add weak and improperly distributed clusters of vegetation (fig 9.6).

fig. 9.4
courtyard and inner green areas


**fig. 9.5**
hard surfaces (paved and built areas)


**fig. 9.6**
soft surfaces and networks (green and courtyards)


**fig. 9.7**
typologies

original structure/axis

historical/farmhouse ring

## District structure

**typologies**

When looking at housing typologies, character and inner structure of the district, some specific regions can be structured. These are structured in order to better understand both the historical genesis of the space as well as decrypt its functioning today (fig. 9.7).

**transit axis**

The main infrastructural line connecting the city with the road network of the region, becomes obvious as being part of the initial structure of the space. Older, low rise housing, dominates the axis, with small front gardens.

**farmhouse ring**

Along the outer ring of the district, a more varied architectural mix is observed. Here, older farmhouses are juxtaposed with commercial spaces linked to the industrial character of the nearby harbors. It becomes obvious that his area is continuously changing being adapted and extended according to economical dynamics.

**collective**

Within the quadrants described by the juxtaposition of the central axis with the outer ring , the major housing typology can be described as collective. It tis mostly composed of post war housing developments of low rise modernistic housing blocks. These quadrants are also accommodating clusters of row housing areas.

**commercial axis**

Perpendicular to the central axis ad second axis can be identified. Along this line, mostly commercial activities are found, represented by ground floor commerce, and an overall mix in typologies can be observed. This axis is important in the sense that it connects the metro station with the district.

**overall**

Overall, the area can be described as a low rise somewhat suburban district. The only height accents found are represented by the new housing developments in the north. At the same time, it consists of a mix of architectural typologies, generally in such a way that it can accommodate change and adaptation, either by way of retrofitting or extensions.

collective post war housing


commercial/mix

row housing

# 9.2_ Systemic Approach for Large Scale Sites; ”urban incubator”

## Domed Cities

geodesic dome

As for the previous design approach the main inspiration lies with one of Buckminster Fuller's provocative proposals. In this case he is taking full advantage of the geodesic dome's unique properties and proposing a enormous dome hovering over lower Manhattan (fig 9.8). He proposed this approach as a response to air quality problems facing major urban areas in the second half of the 20th century.

floating dome

Geodesic structures are somewhat counter intuitive in terms of physical properties. They are not faced with the same restrictions as conventional structures. A geodesic dome of more that 500m in diameter benefiting from a temperature difference of 2C between the inside and outside, is self supporting (being theoretically lighter than air). This property is already obvious in the case of the Eden project which had to be anchored down into the ground instead of having a normal structural foundation.

Therefore, geodesic domes are an interesting option when it comes to issues of site integration, as faced with the previous approach. They can theoretically “hover” over the area they are enclosing.

**fig. 9.8**
Manhatan dome proposal by Buckminster Fuller
source: The Buckinster Fuller Institute
http://bfi.org/

## The incubator concept

incubator concept

The incubator concept is associated with the dome approach as a underlining characteristic of the approach. It is simply put in order to frame the attitude towards design and implementation.

dissipative structures

The concept of dissipative structures keeps coming up in this research with regards to systems which interact with their environment In such a way that entropy levels are constant, and close to 0 (Pulselli & Tiezzi, 2009). The cities as we have been building them in the past century are fundamentally flowed. Sallat even goes so far as to say that the past century can almost been named as the century of death of the cites (Salat & Bourdic, 2011), elaborating in energetic terms what Jane Jacobs initiated in social terminology (Jacobs, 1961). The hypothesis marking this research is that, perhaps, we have gone too far in this particular direction, going beyond the tipping point in the point of no return.

"poldering" time for dissipative cities

This is to say that cities have gone so far in one direction that, considering the current energy and resource crisis we might not have enough resources left to power the transformation (into "dissipative cities"). Climate change and energy crises are viewed and hazards to the current urban structures, which need protection. The research is examining fundamental needs of our urban structures and generates possible measures for providing for those needs while offering room for the transition to happen. Therefore the incubator comes, not as a design in itself, but rather a risk management measure. In a sense it is similar to a much to familiar polder. It is an action of reclaiming "time" for our cities; time which we have been so careless with in past decades, and which now could be used to rethink the interior structures and connections of cities.

## Challenges

self-sufficiency

### Energy challenge

Such a dramatically grotesque intervention on the site has as paramount condition energy self-sufficiency and sustainability. The goal is to generate as comprehensive as possible self-sustaining energy system, grounded on the ecosystem services of the site. The intervention should not just provide thermal efficiency or insulation but address energy generation as well as intermitency issues, if the site is to be independent from regional or national networks.

proofing

### Climate Challenge

In terms of climate the challenge is, to address climate adaptation and mitigation in a fundamental way, and yield a 100% climate proof environment, which is adapted to dealing not just with current problems but can thrive far into the future.

adverse impact

### Social, Cultural and Ethical challenge

One of the most important issues that need addressing is the way in which the integration of such a dramatic design can occur when thinking about inhabitants and the impact it can have on them. More than anything the design needs to addressing the ethical issues and potential concern behind a enclosure of urban environments, and creatively propose solutions which not only mitigate the adverse effects of such an intervention but guided in such a way that it is culturally grounded as well.

# 9.3_ Testing and Adjusting

## Design guidelines

As framing the approach, a set of three principles framing the process were articulated.

framing principles

1. The most important goal is energy efficiency as understood by SLT (second law thinking).
2. The solution revealed by a thermodynamic approach is molded in order to improve microclimate and address the goals of climate proofing
3. Potentials for added value are explored: renewable energy supply or even energy self-sufficiency; potentials for food provision or even food self-sufficiency.

These of course were framing the initial approach on the center of Rotterdam, and after assessing the specific challenges of a dome insertion the principles require some adjustments. Exergetic optimization should remain the main focus as it is the driving force behind the research, and therefore should continue to frame the design. Furthermore the second the third point can also potentially address the same issue. The only consideration should be framing each principle according to direct impact on inhabitants. From cultural to social and ethical dynamics, as addressed previously, these considerations should re-frame the approach. Therefore, while maintaining the goals for SLT, microclimate and added value they should all be adjusted through the lens of their impact on inhabitants.

Such a strong intervention on the landscape has enormous implications both on the outer landscape as well as inner landscape it defined within. This requires a specific approach to landscape integration, one which will be re-framing the principle.

ethical guideline

Framing guideline:
Al principles are to be adjusted in order to mitigate their adverse effects on inhabitants and the landscape.

## Adjusting and testing for people

It has become clear that mitigating the impact on inhabitants should frame the approach. This requires consideration for both inner and outer landscapes and effects. Therefore the approach on the form will take into account specific goals for outer landscape and for the inner city landscape.

inner landscape

In terms of the inner landscape the main issue in terms of impact is dealing with adverse visual effects and barriers generated by the structure. Ideally the structure should blend into the skyline and be as little visible as possible from within. For this purpose, tests and 3d simulations are made in order to compare different shapes and their visual impact on the inner environment of the incubator. For the purposes of the test, two takes on the form are taken and compared.

On the one hand a geodesic dome structure as described above, benefiting from structural feasibility (fig. 9.8) and on the other hand a more modeled approach on the form which is irregular, and therefore integrated in the landscape and land use structures (fig. 9.9).

conclusion

From the test the main conclusion is that the more irregular the shape becomes the more it becomes visible on the skyline. At the same time irregularity will most definitely add to the structural needs of the dome making it even more visible. Therefore if blending in with the sky is important the incubator should remain as simple and regular as possible.

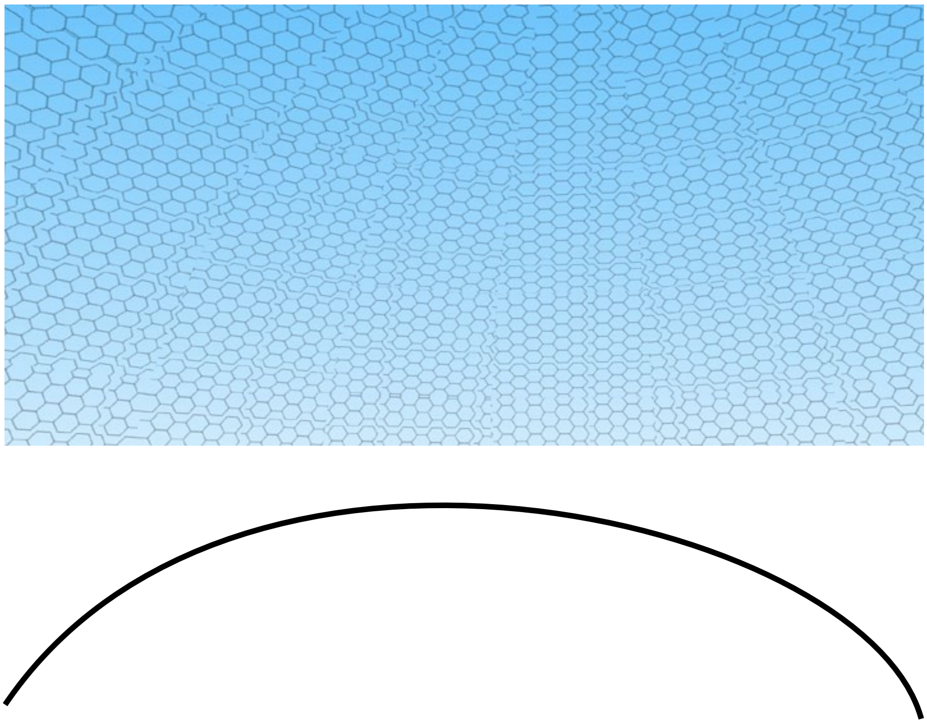


**fig. 9.8**
visual impact of regular dome shape
using 3d modeling simulations

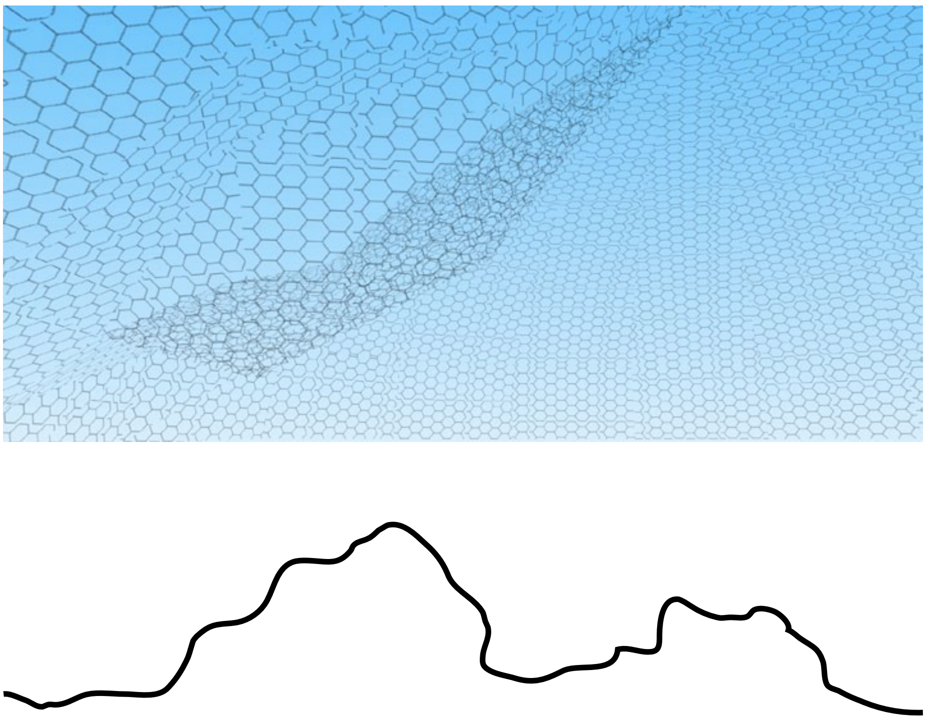


**fig. 9.9**
visual impact of irregular shape
using 3d modeling simulations

## Adjusted for the landscape

outer landscape

Integration and care for the outer landscape is also of great importance, following the guidelines. Its impact on the outer environment is impossible to downplay. The immense structure needed, will definitely impact the area in a dramatic way. In this sense the strategy chosen is trying to integrate the structure in the landscape as a statement of the intervention, rather than down-playing it. This means the impact is embraced and integrated according to landscape qualities found important for the area.

outer landscape

The immediate landscape is dominated by industrial structures, and, one of the most striking features is its industrial monumentality (fig. 9.10). With regular, simple, slick, self-standing constructions defining this "fossil landscape" of Rotterdam. In this context, qualities which should be strived for are simplicity, and regularity, which coincidentally are also driving the design towards the regular geodesic dome structure.

**fig. 9.10**
industrial "fossil"character
aerial images of the port revealing the industrial character of the urban landscape
source: PortofRotterdam.com

# Re-framed guidelines

After the tests and adjustments related to impact on people and landscape, the more specific guidelines need to be addressed and re-framed. As a prerequisite of the following guidelines the approach on the form of the incubator will be the geodesic, dome like structure.

**Energy (Adjust form for better sun exposure)**

optimized

1. South facing and inclination need to provide best conditions for heat collection as well as P.V. panel implementation (as long as the regular dome shape is not altered)
2. Provide suitable light conditions to avoid drastic fluctuations in electricity use
3. Maintain the closed, artificial microclimate environment in the winter and open the structure in the summer for better thermal performance

**Microclimate**

climate proofing and microclimate control

1. Stimulate natural air circulation within the artificial microclimate
2. Address water storage assignment for the site

**Added value**

self-sufficiency

1. Heat collectors to harvest and store thermal energy
2. PV panel coverage to provide electricity need
3. Solutions for intermitency
4. Encourage the integration of food production in all levels and scales.
5. Vegetation species chosen for air quality improvement
6. Filtration of greywater

# 9.4_ Design Proposal

## Energy

PV on the south side

The design principles regarding energy are translated into PV cell position within the structure of the dome, in such a way that and sun shine is not decreased drastically. In terms of impact on the landscape plan of the area these areas have no necessary direct impact. Other energy related principles are directly translated in the dome concept and thermal control it provides (fig. 9.11).

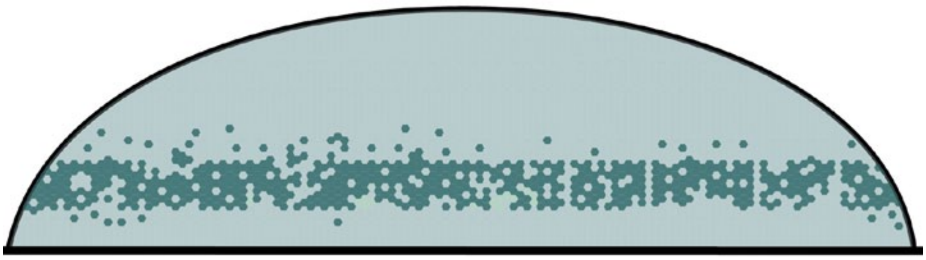


**fig. 9.11**
potential area for PV cells

## Water

traditional water management

Water management is very important in the case of this intervention. Traditional water management was based on technological hard measures. In line with the technocratic era, and human supremacy over nature philosophies, the post war systems for water management were all based on hard control of nature and heavily relying on pumping capacity for quick discharge of rainfall (Commissie waterbeheer 21e eeuw, 2000). The Netherlands have a long history of applying this approach, and probably one of the most reveling early failure of the system was the Queens Day Flood of the 15th century, when the policy of tightening the control of waters failed with deadly consequences.

contemporary water management

Therefore, the intervention needs to align itself to contemporary trends in water management, relying on a more flexible approach (Commissie waterbeheer 21e eeuw, 2000). In this sense it is not desired to take a position of tight, hard control over water. Therefore water shall be treated as an amenity and opportunity rather than en enemy. For this purpose both storage and filtration systems are put in place and linked with the city water network. A complete reframing of the approach on water management is proposed. The goals are to provide flexible water management, meaning storage capacity for predicted trends, but also to purify the required quantities of greywater for households.

filtration

For filtration, a system of outer wetlands is proposed, capable of filtering all the greywater needed by the inhabitants. This is combined with a storage system for peak rainfall storage. In order to reduce entropy, household greywater and rainwater are collected and purified in different systems (Berger, 2009).

storage

Another important feature is shortage storage, which is especially relevant when discussing food production. For these purposes water storage areas are proposed separately for the food production area. On a step by step basis the water cycle can be illustrated in two cycles which are interconnected. On the one hand we have the outer water system which is managing storing and filtering; and on the other hand the inside system which is provided ideal conditions.

**OUTER system (fig. 9.12 and 9.13)**

1. water gets temporarily stored on top of the dome – "floating lake"
Due to the unique properties of the dome with regards to its structure, it makes it possible to store water on top of it (temporarily). This step comes as an added bonus and revelatory feature. As the structure acts similar to a hot air balloon , it is conceivable, provided strong enough materials are found that up to 20 ton of water can be stored on top, reveling a "floating lake". The 20 tons represent the predicted peak rainfall over 1ha of land for one day (KNMI, 2006).

2. Making use of the controlled environment the dome is used to create ideal rainfall conditions inside which can be adjusted according to needs. If storage systems are also put in place for draught seasons, then ideal rainfall can be simulated year-round regardless of season of outer rainfall.

3. Excess water after proper levels are generated inside the dome is collected, and run through to the agricultural storage basins.

4 Excess water is then directed to the main storage area and filtration wetlands for storage and purification

5 In case of extreme scenarios where there is still excess water, the surplus can be pumped into to hydro-energy storage basin.

**INNER system (fig. 9.12 and 9.13)**

1. The "simulated" rainfall is slowly infiltrated in designated collection area (water plazas and garden in public spaces or street gully's)

2. For low rise housing areas small scale filtration reed beds can be implemented in order to recycle and filter some of the low contaminated water (fig 9.14).

3. Excess rainwater gets collected and taken through the outer water cycle

4. Excess greywater gets collected and guided to the filtration areas separately.

In this way a flexible yet controlled water system is described, which not only deals with shortage and surplus but filters greywater and can be adjusted according to wishes for the dome environment.

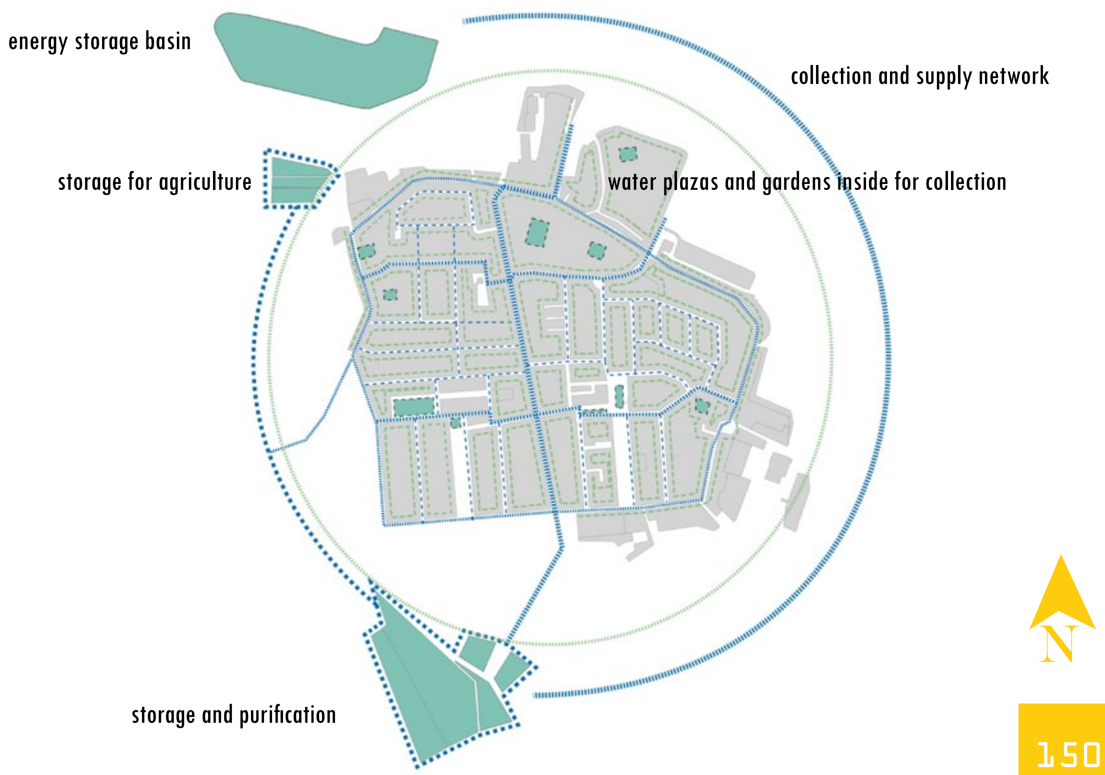
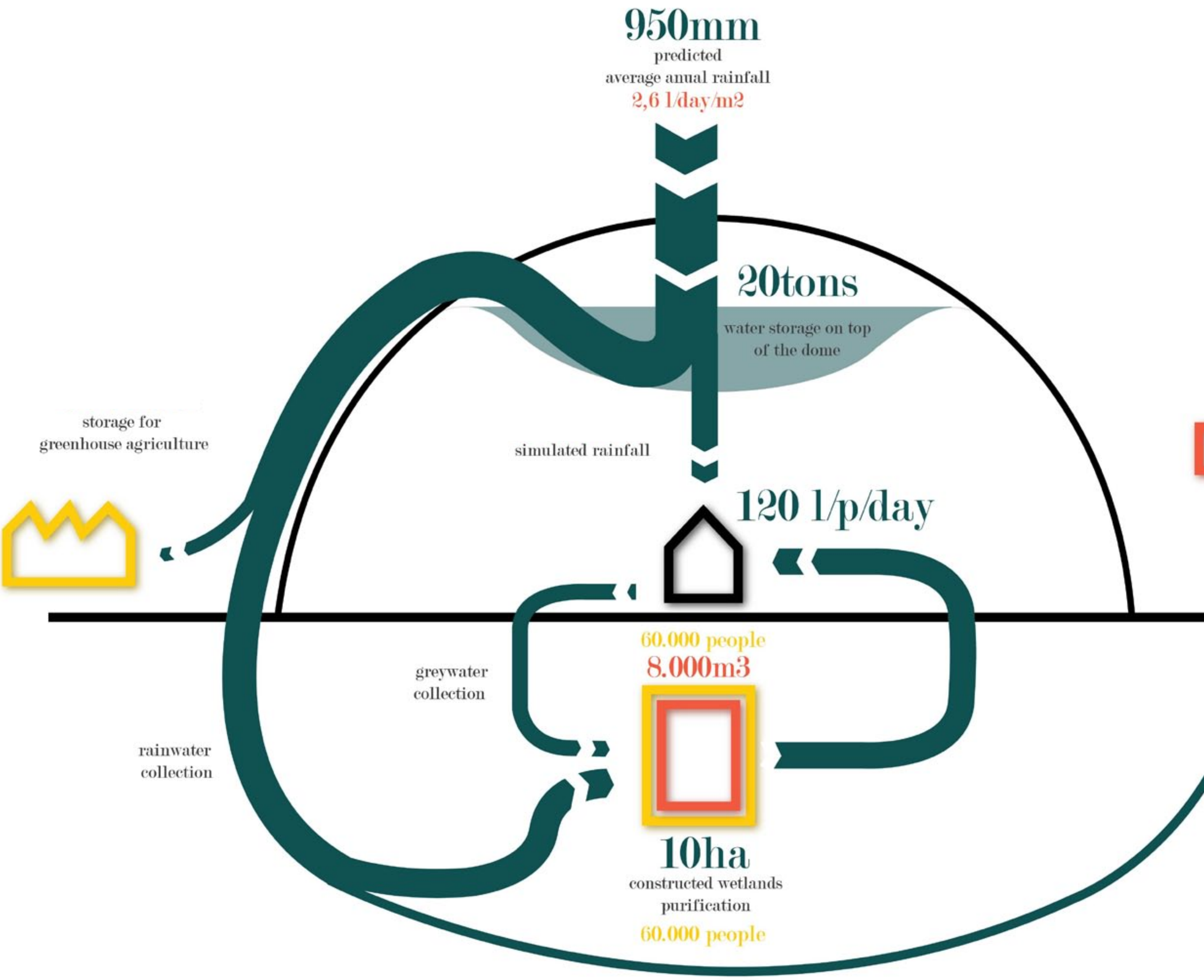
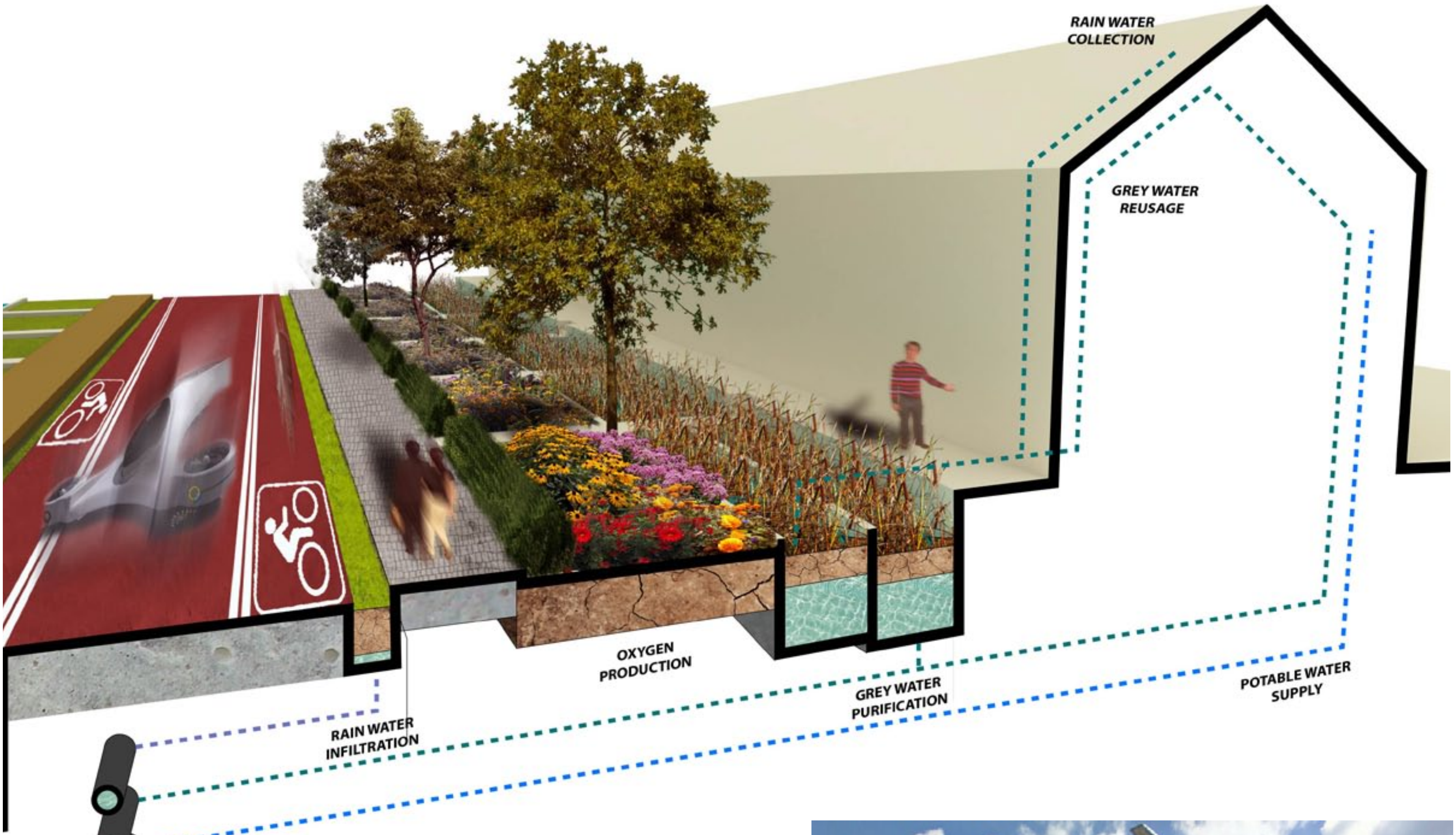



**fig. 9.12**
Plan of the water network

**fig. 9.13**
water cycle





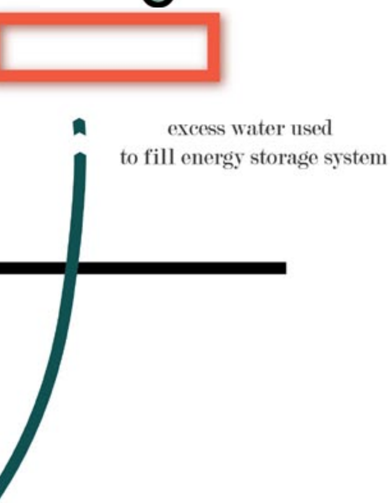
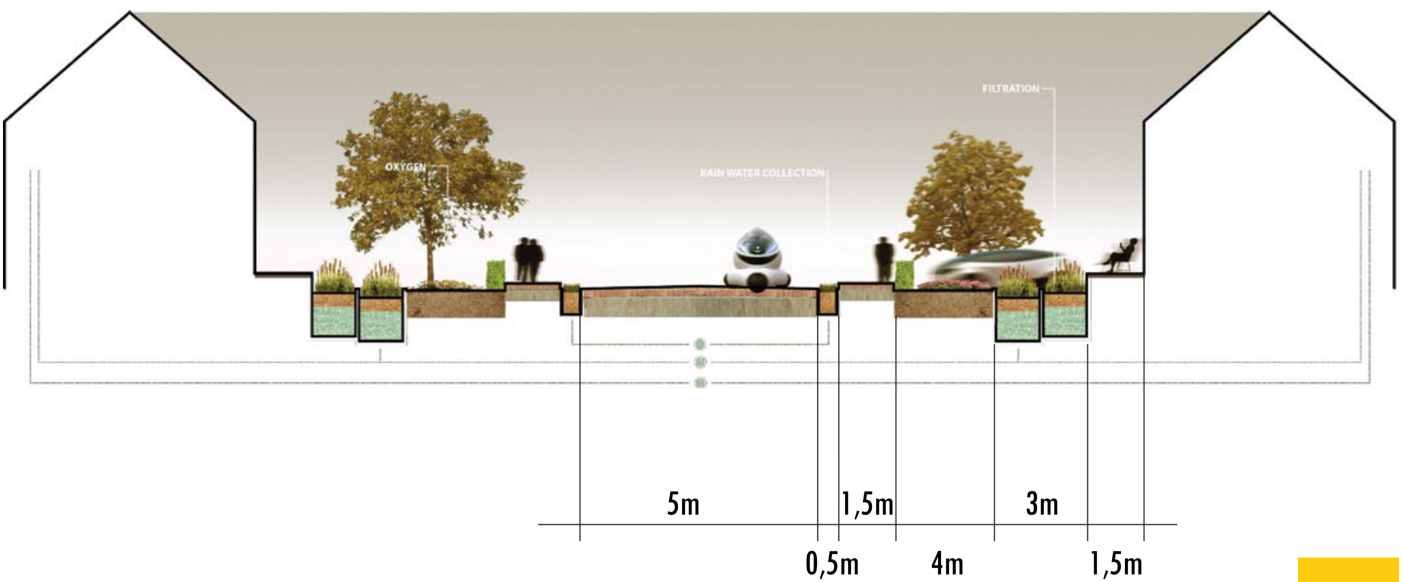




**fig. 9.14**
capture and filtration system for households on the main axis

before (rigt)

after (above)

section (bellow)



# Food

As part of the added value guidelines food production is viewed as important and embedded into the structure of the district. In order for the design to be grounded in the ecosystem services of the site it must explore its potential for providing food for its inhabitants in a sustainable way.

food integrated

A multilayer strategy for food production is put in place, based on intensive vertical greenhouse agriculture but also more decentralized engaging platforms made to directly link people to their food. The actual potential of this system will be elaborated upon in later section, for not what is important are the separate strategies (fig. 9.15).

Most of the produce will be supplied from the vertical greenhouse system, which is as mentioned in the section describing the water system, linked to water cycles and provided with water resources.

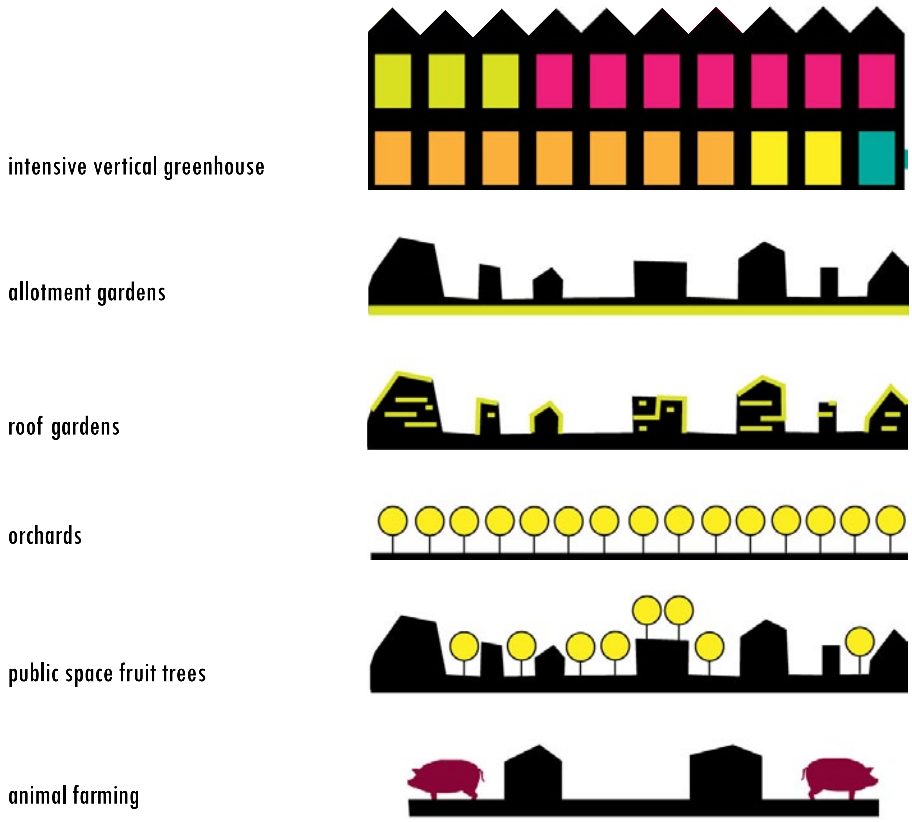
Allotment gardens are also implemented at the immediate outskirts of the district, to both produce food for individual consumers and provide a platform for social interaction and direct engagement with the food.

Herb gardens are proposed for green roofs and garden as well as balconies, and in this way, inhabitants can grow small scale herbs for individual use.

Urban orchards are implemented in several centralized locations offering besides an important source of fruit a platform for social interaction and community gathering in the historical sense. Also fruit trees are planted along roads or in public spaces as well as private gardens as so forth.

As a final potential, individual animal farming is also explored for a few courtyards which have that potential. This is mainly in farmyards or individual detached houses.

**fig. 9.15**
strategies for food provision



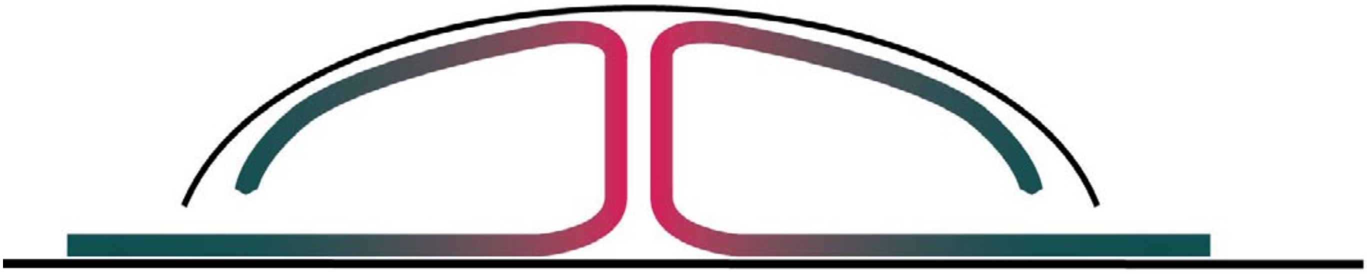


**fig. 9.16**
natural air circulation process visualized in the summer

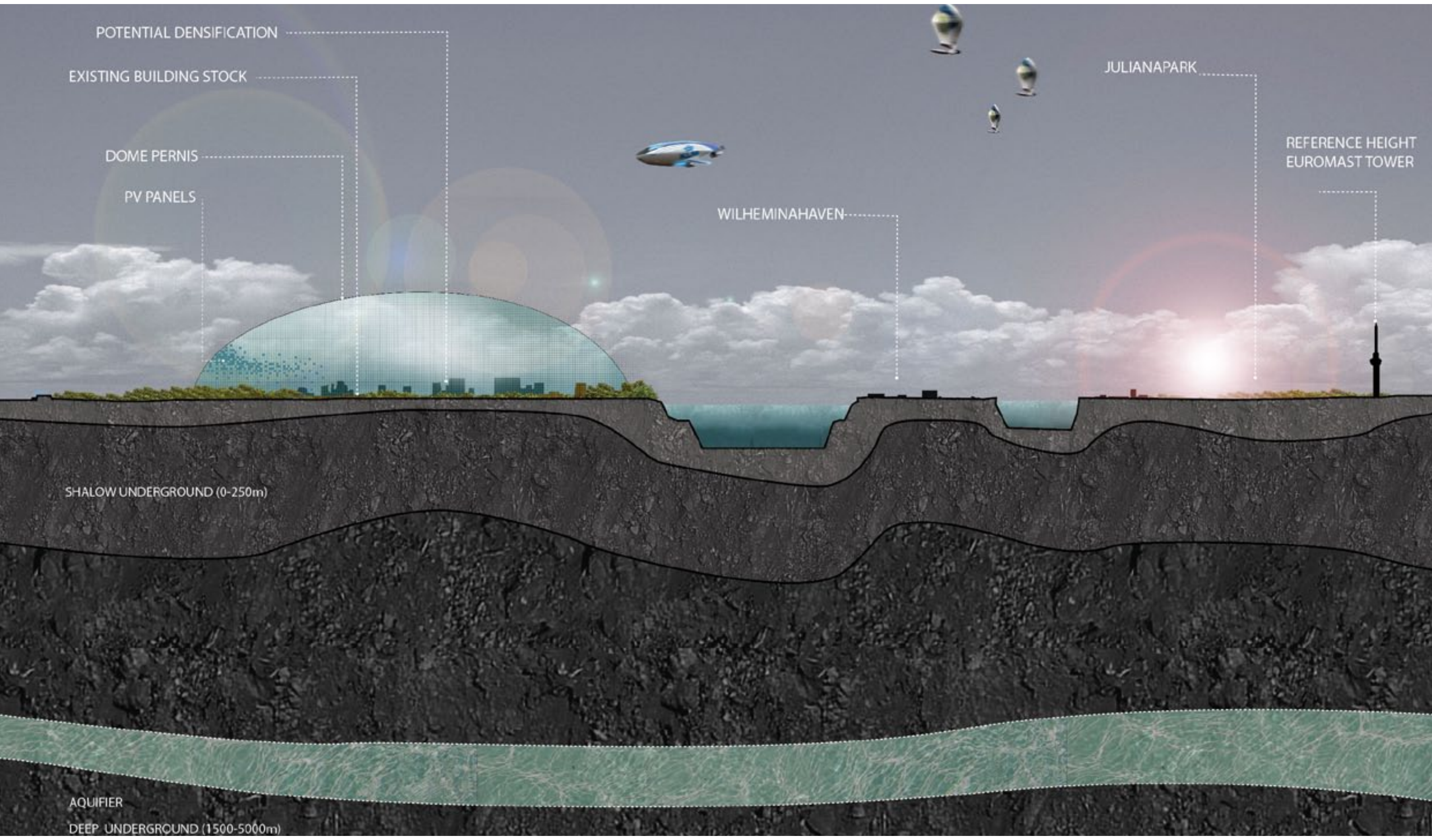
## Air Circulation

A final aspect investigate in terms of potentials is air quality and ventilation. For the purpose of encouraging natural ventilation the lower section of the dome can be opened in the summer and therefore natural convection processes can occur. At the same time this would re-engage the inner dome with the outside environment and mitigate the barrier effect imposed by the dome allowing for interaction between inner and outer environments fig. 9.16).
For the purpose of improving air quality, plants are chosen according to their capacity for oxygen production and carbon sequestration.

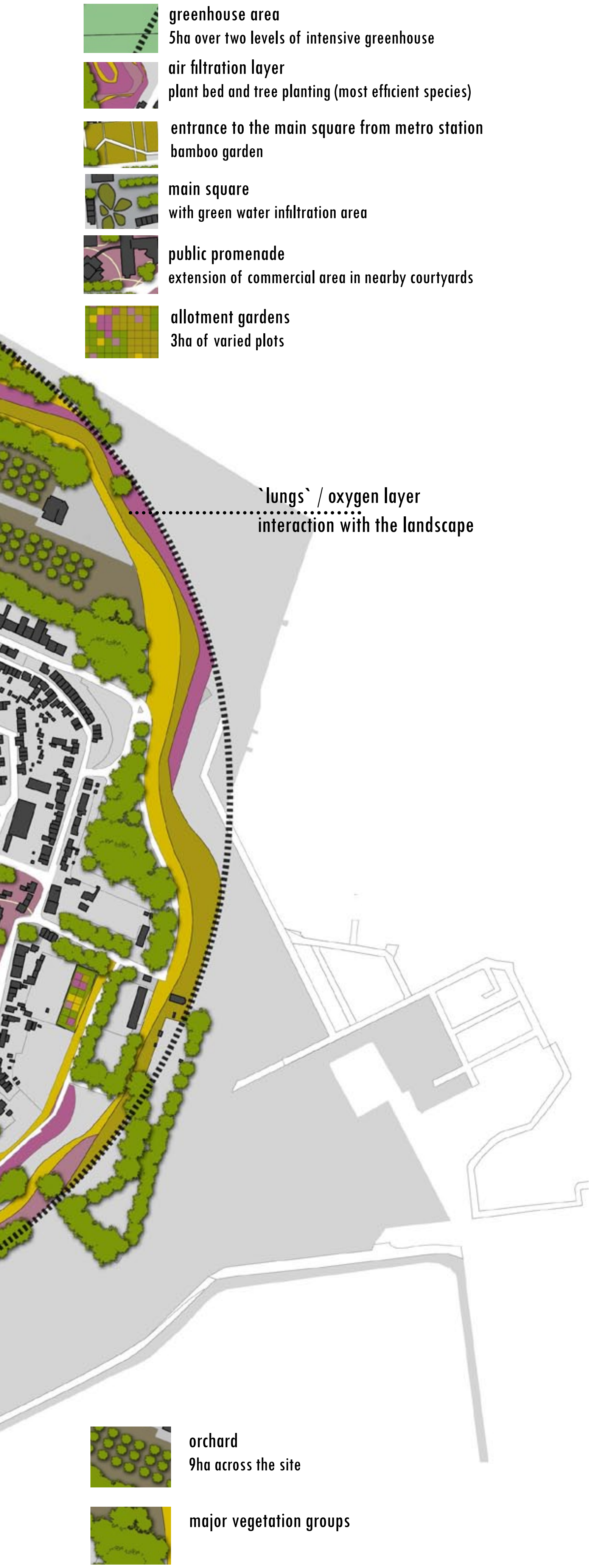
## Plan

The resulted design proposes a dome of 700m in diameter and 300m in height covering the district of Pernis which would be opened (at the base, all around) in warm days and closed in cold days . The existent landscape and spatial structures identified in the landscape are strengthened and different strategies for food provision and water management implemented. Special care is given to the edges in terms of framing the design as well as being a platform for interaction with the outside environment.

**fig. 9.17**
visualization of the design proposal




200m
orchard
energy storage basin
entrance parking
water storage for agriculture
greenhouse agriculture
allotment gardens
constructed wetlands separate purification
household grey water finltration
rainwater filtration
entrance parking
N




main transit route:

linking the two main entrances and outer car parking areas


outer ring:

farmyards and mixed use linking all major outer functions


commercial and activity axis:

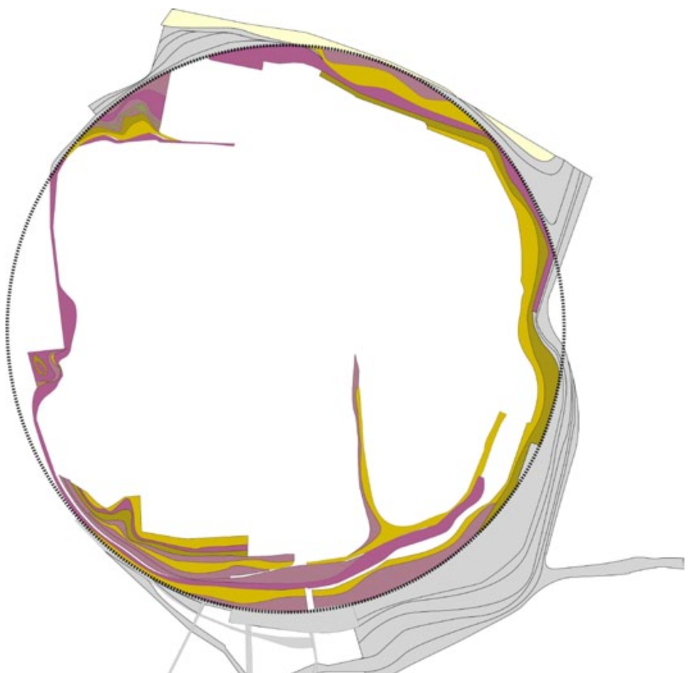
linking the metro station with the centre and with the park

**links**
Ulmus/betula pendula/ quercus rubra

**accents in April/May**
Periwinkle
Moss Phlox

**macro scale major species**
Ulmus/Betula pendula/ Quercus rubra/Fagus silvatica/Tsuga canadensis/Tsuga martensiana/Accer

**accents in August/September**
aster
jupiter's beard
lobelia
liatris



**accents in October/March (air filtering for the dome)**
gerbera jamesonii
hedera helix
dracaena marginata
chrysanthemum chrysantema
arecaceae
selected based on NASA, 1989 (study on plants capacity to filter air)

**accents in May/June**
Aquilegia vulgaris
Clustered Bellflower
Creeping Gypsophile
Moss Phlox

**accents in Jully/August**
sedum
Harebell Campanula
levender

**fig. 9.18**
moving edges

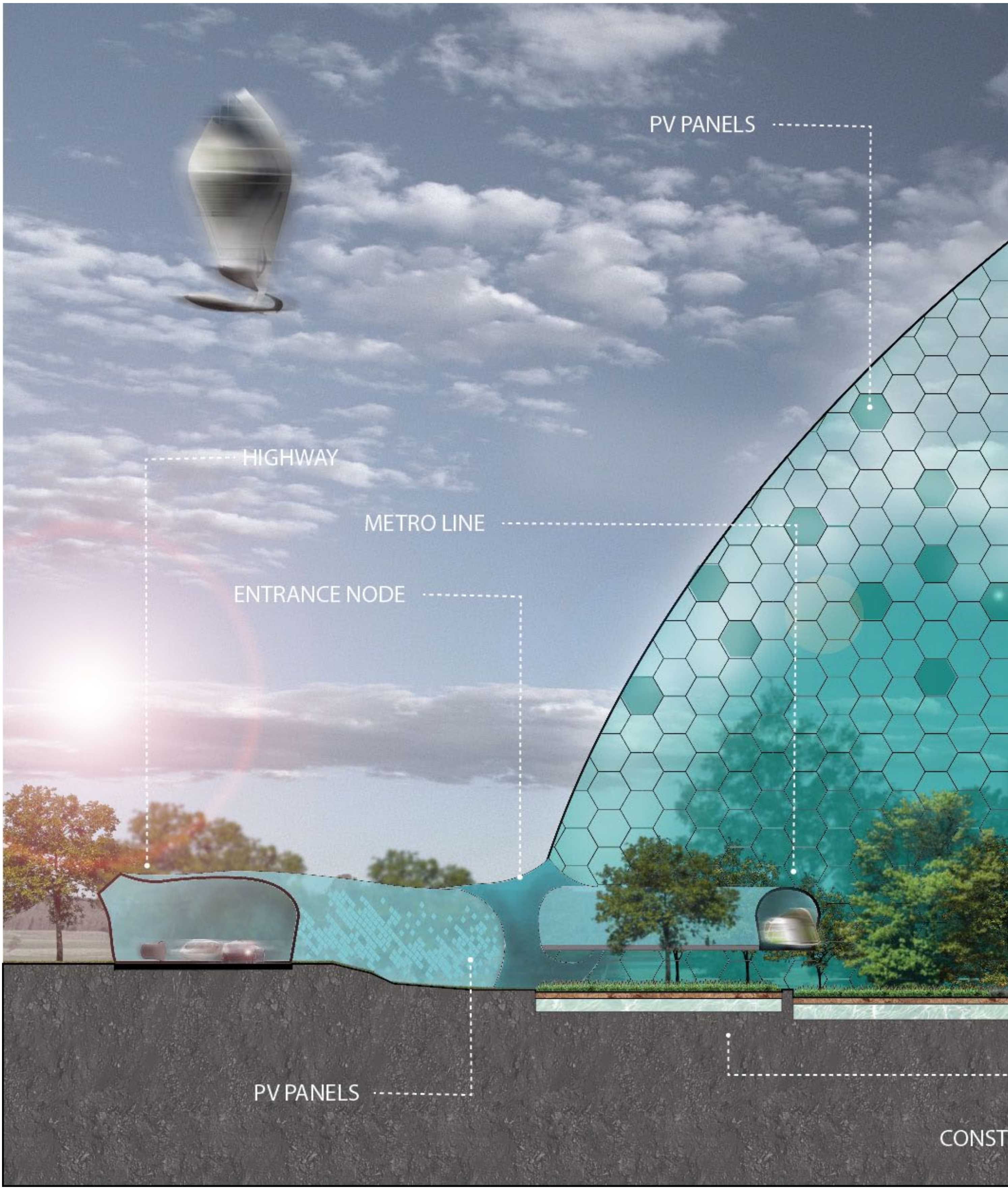
# Moving edges

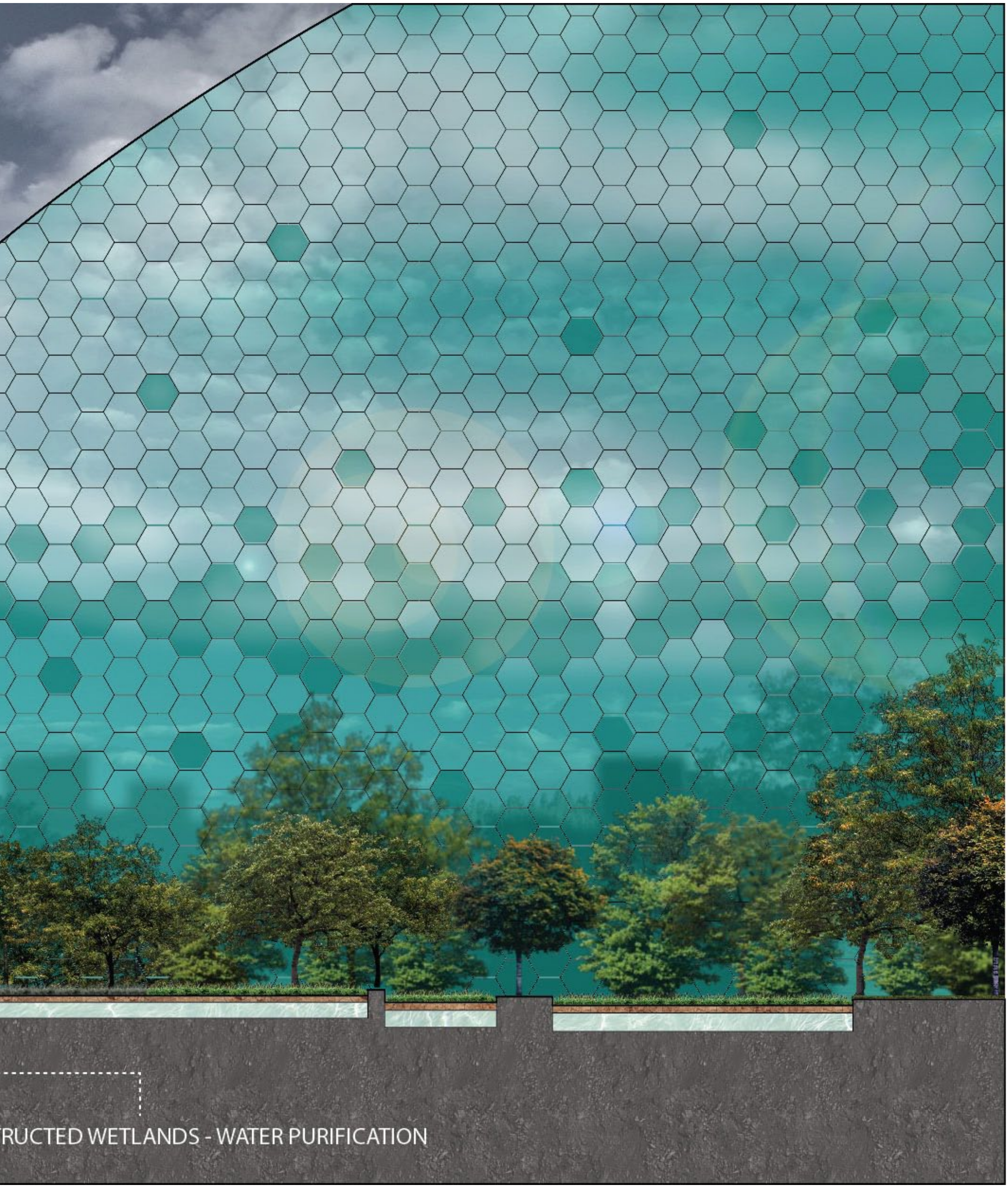
The concept of Movable edges is introduced in order to address the issue of the barriers, and enclosure that the dome creates. This barrier is perceived as being a very hard, strong edge and has a big impact on the way inhabitants interact with and perceive the outer environment.

In order to address this issue the strategy proposed is that of "blurring" the perception of the edge. Therefore the outer "belt" of the district is extended inside using the same formal language and being split into different landscape sections. These are planted with different species of vegetation which gets activated (flower beds blooming in different months/ deciduous vs. coniferous etc.) in different times of the year engaging people's perception of the edge in different location all the time and mitigating the effects of the strong edge.

Major connection In the network are constantly "activated" (April to October) while the outer edges shift gradually from the edge within (May to September). Afterword's species inside the dome get "activated" and can bloom from November to January due to the constant temperatures. Inside vegetation is chosen by its ability to filter air and produce oxygen. Green macros structure is patched with gerbera, hedera helix, chrysanthemum for their ability to filter air pollutants (NASA, 1989). In each stage a series of special plant species are chosen apart form the normal green macro network. These are not meant as main green structure but rather as accents.

**fig. 9.19**
urban incubator -image of the dome, with the wetlands system as well as infrastructure connection node



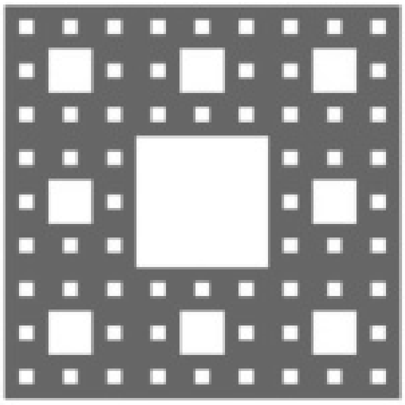

RUCTED WETLANDS - WATER PURIFICATION

# Constructal densification

Once this barrier is put in place, town expansion can no-longer function by the same parameters. Instead of an outward extension in the landscape, it would have to occur inward within the climate of the dome.

Therefore a clear strategy needs to be put in place the would allow for densification in such a way that it maintain green space percentages in the district, as well as its livability. This automatically implies no high rise constructions. Instead a constructal law based densification strategy is structured.

**fig. 9.20**
the Sierpinzky carpter 100% passive volume
source: Salat et al., 2011



We have established in the second chapter the that according to constructal theory, flow patterns should evolve according to fractal geometry (Bejan, 2010). The question is how does that relate to buildings. Salat bring forth the issue for passive volume of buildings, which, in order for the building to be energy efficient has to be as high as possible (Salat, Bourdic, & Nowacki, 2010). The passive volume of a building is considered the inside surface roughly 6-7m from the exterior wall. He gives puts forth the Sierpinzky carpet as a potential solution to raising passive volume of buildings.

The inspiration of the fractal structure is taken and applied to a site in the district of Pernis. The area is composed of modern housing apartment just 2 stories high. In total 100 homes are located in the site. It is low density and if densification strategies are to be discussed places similar to this would be the main focus areas.

The densification strategy is phased in 3 stages ( 2020, 2030, 2050) and each stage takes the Sierpinzky carpet approach by maximizing contact surface with the environment in a different way than the approach it come after (fig 9.22 and 9.23) . At the same time areas in between the densification blocks become gardens (roof) and considerably increase the amount of green (fig 9.24 and 9.25).

In short this strategy can take the housing number from 100 to roughly 450 and green surface from 6500m2 to 10150 m2. In this way a process of introducing complexity back into the urban fabric is described. Lack of complexity is according to Sallat the main issue of our current cities, and it's a big contributor to energy consumption (Salat & Bourdic, 2011).

**fig. 9.21**
satellite image of the site
source: google earth

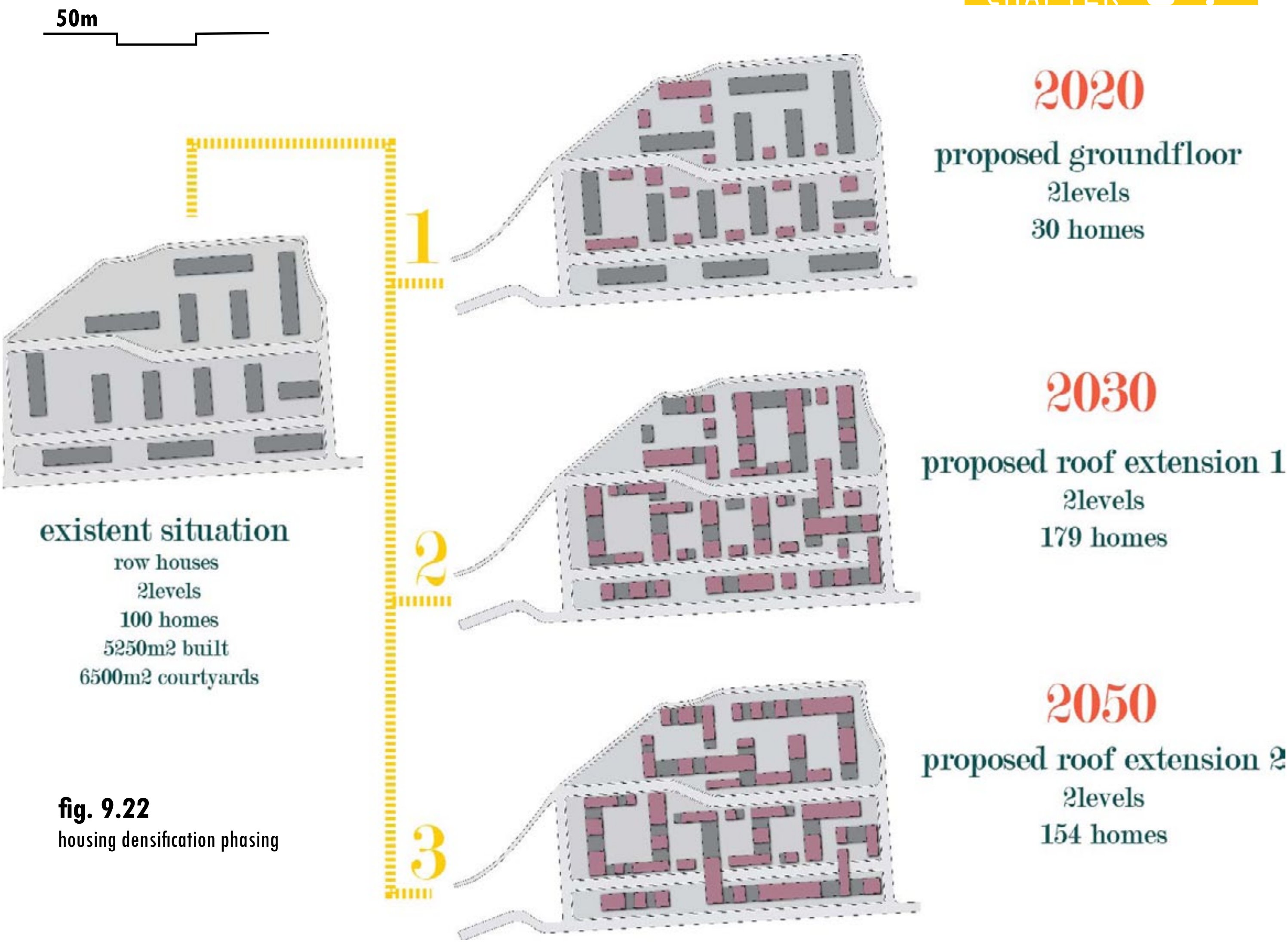
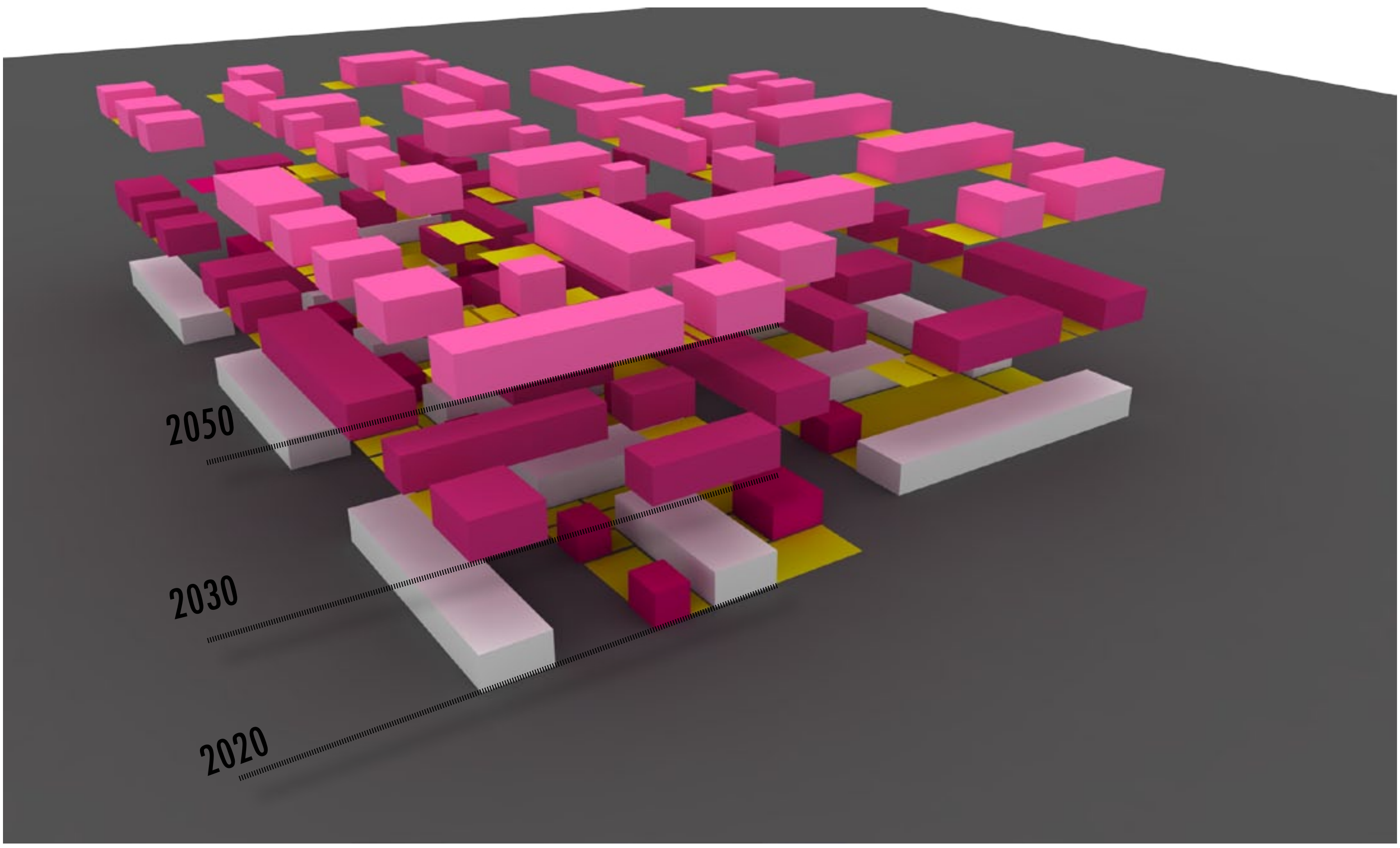



**fig. 9.22**
housing densification phasing

**fig. 9.23**
3D model of the densification layers



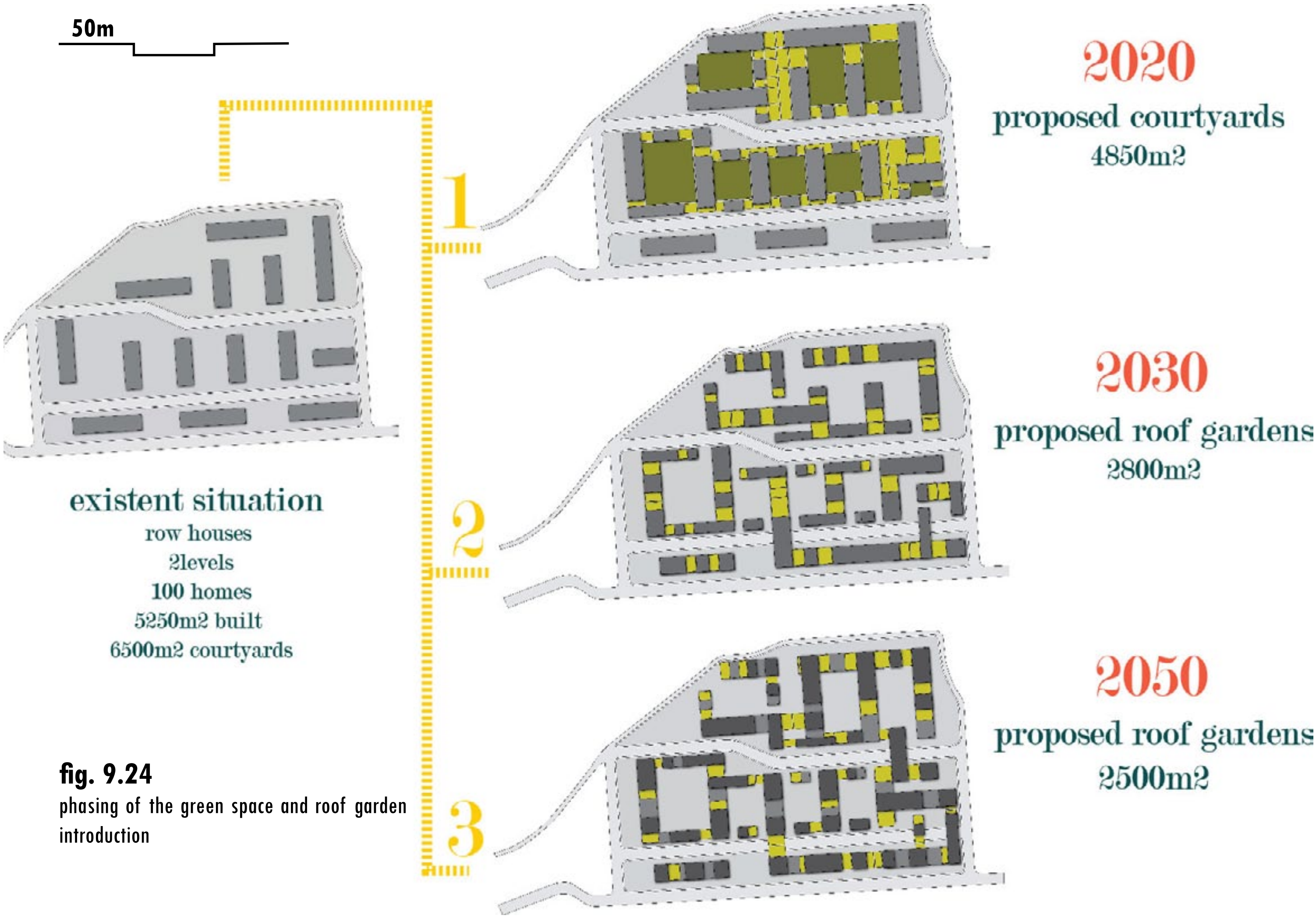
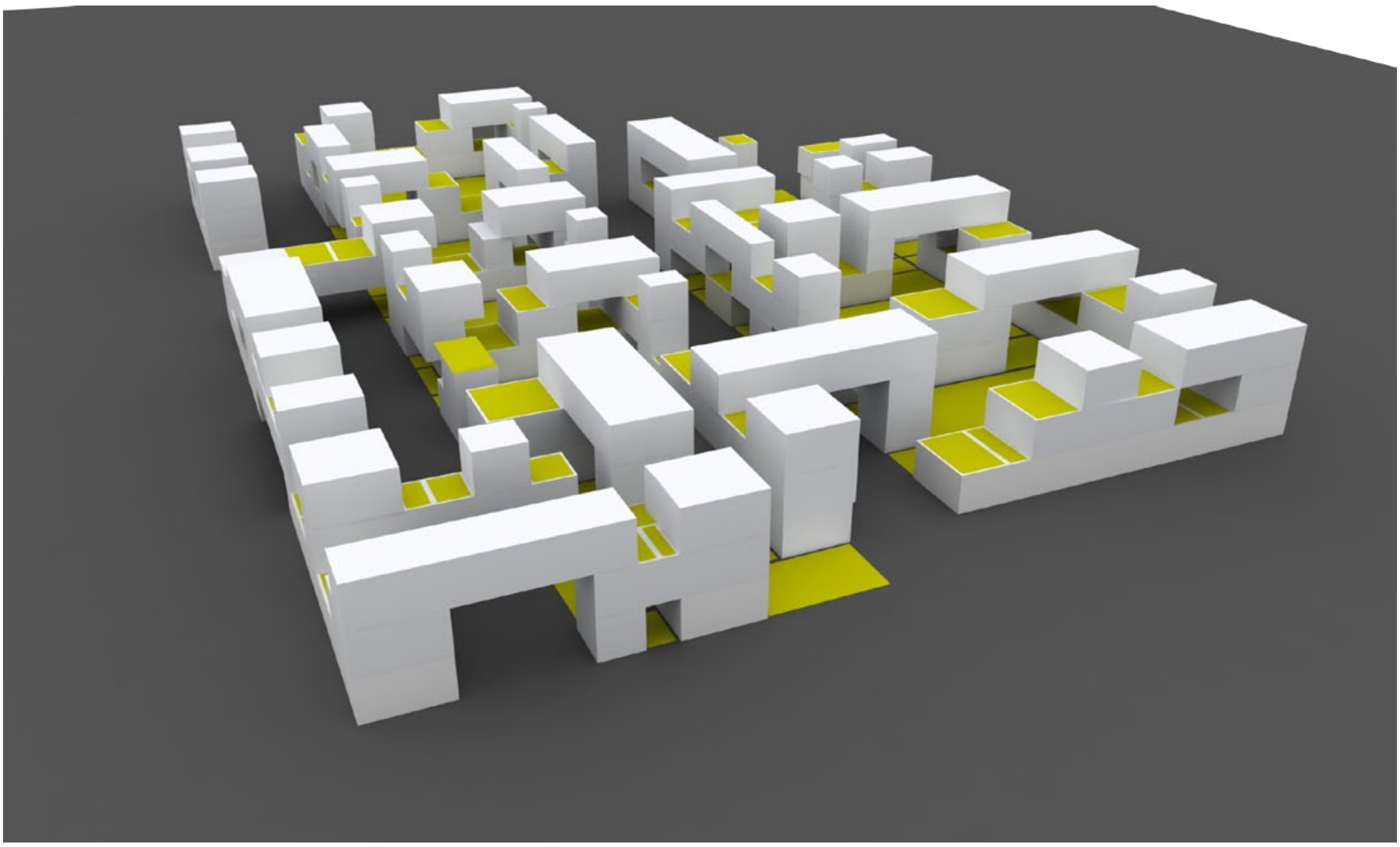



**fig. 9.24**
phasing of the green space and roof garden introduction

**fig. 9.25**
3D view of the resulted geometry



The proposal needs to take into account potential shading issues that arise from such a approach and for that shadow simulation are run in order to optimize the design.

Shadow simulations are run for Winter and Summer days, taking into account morning, noon and evening sun positions and visualizing the impact on shade. The major conclusion from this test is the limitation in terms of number of levels. Even is structurally possible no more than 4 additional levels should be inserted, otherwise shading issues can arise.

The end result is visualized in terms of plan view. The block are ca be a very dynamics housing area in which greens pace and architectural variety are introducing a level of complexity and vibrancy back into the city.
Car traffic is discouraged and therefore courtyards, gradually become soft water infiltration areas for semi/public use rather than hard parking lots. Also pedestrian links with the macro infrastructure are inserted with several public space areas at different points.

**fig. 9.26**
constructal densification - plan of the area in 2050

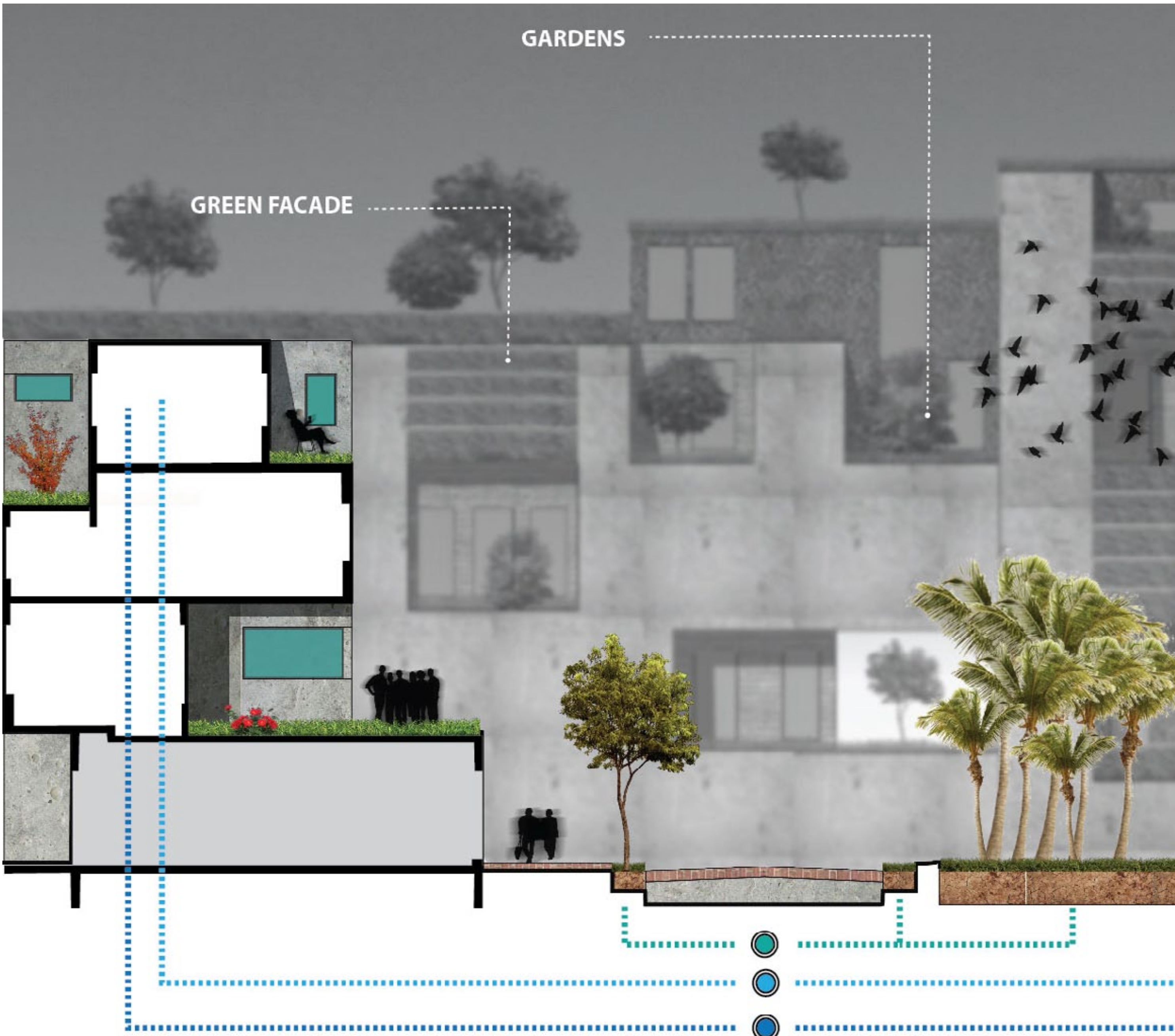
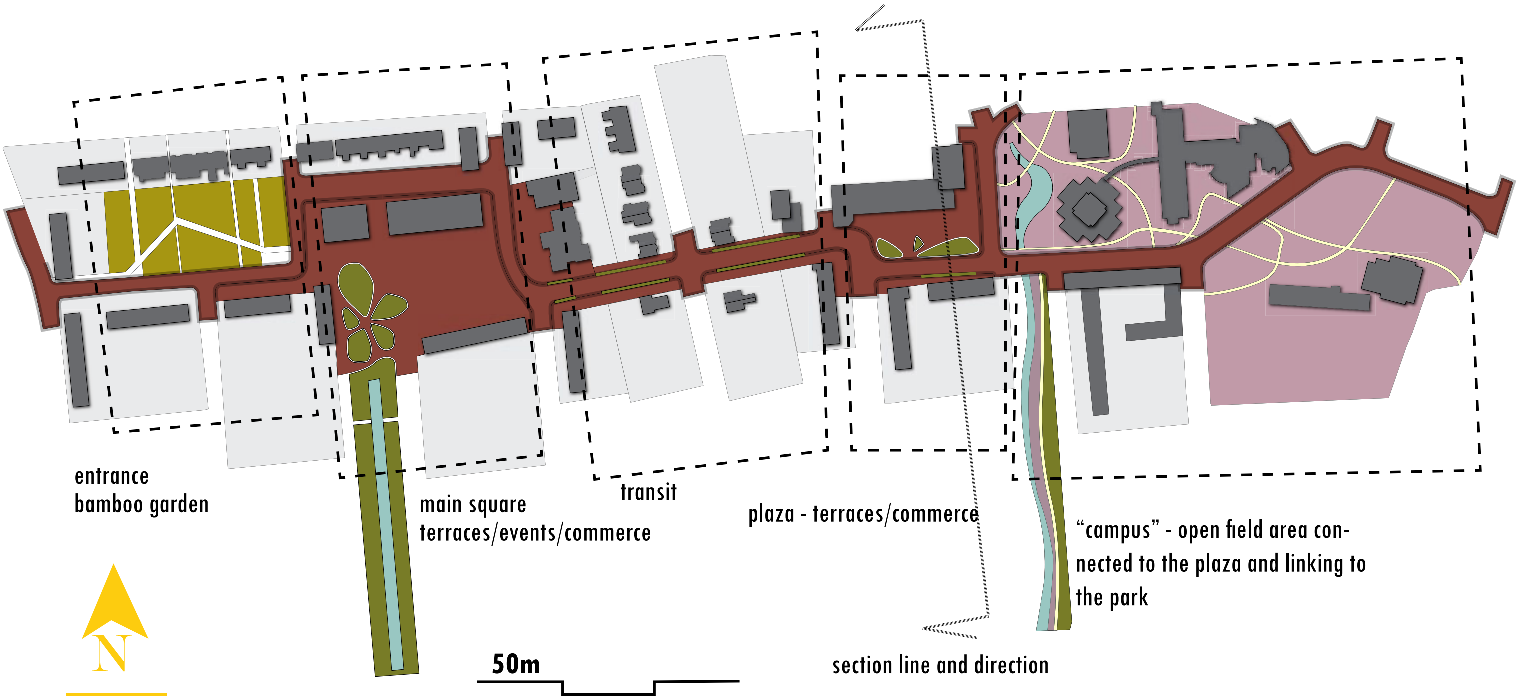
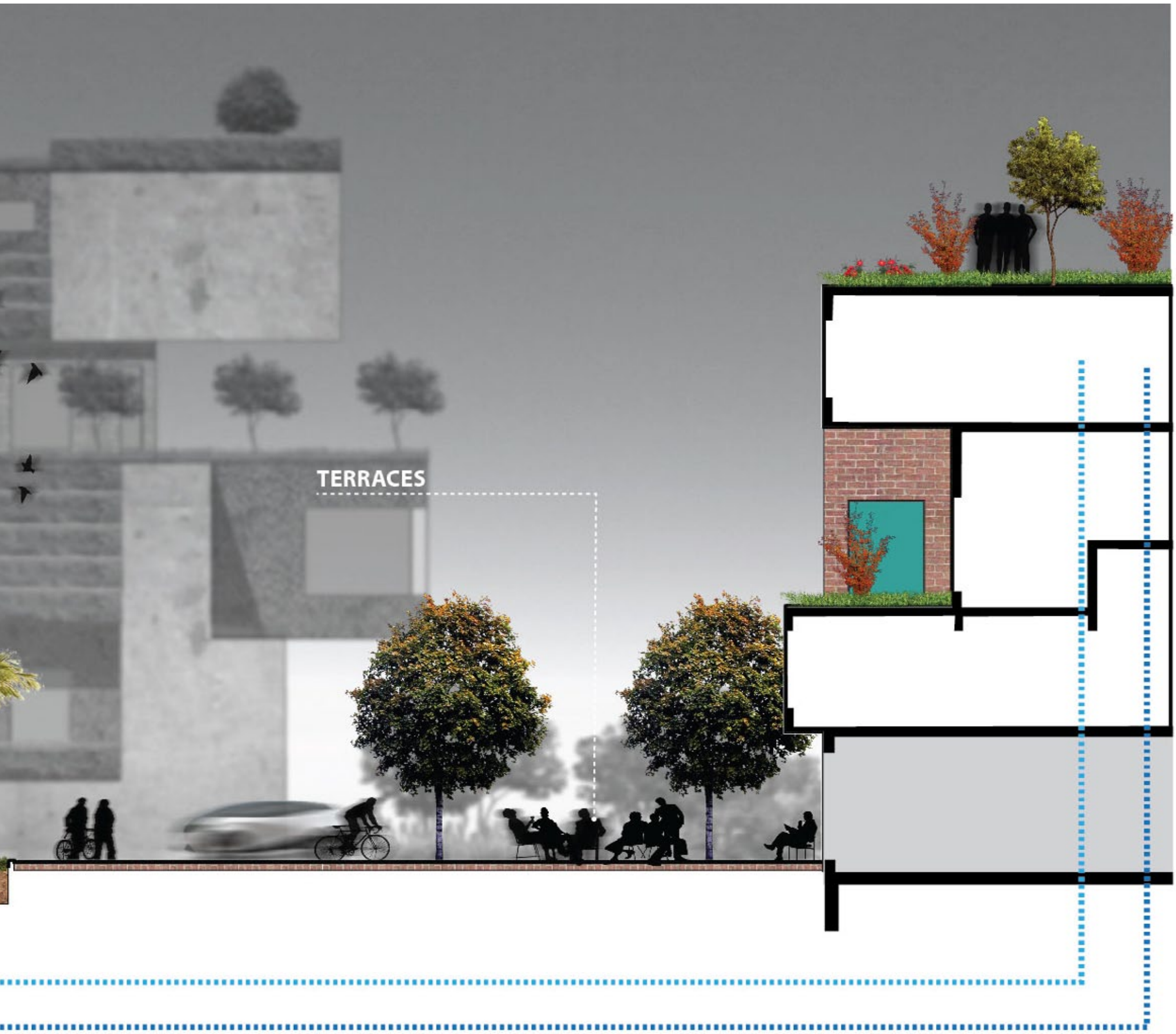



**fig. 9.27**
public space - section of plaza with water infiltration and collection system and green roofs and facades within the densified surrounding areas






## Strengthening the spatial structure

As part of the major structure defined in the plan of the dome, the commercial activity axis, was a major contributor to the spatial structure and identity of the place. It linked the entrance by metro to the entire district and therefore should be structured in such a way that it supports pedestrian and transport influx as well as providing a vibrant and yet remain grounded in the scale imposed by the district in terms of public space size, and activities.

A series of "chambers" are proposed, which sequentially link the space in different moments while maintaining the relatively "small" scale image and giving it coherence.
One of the plazas is detailed in terms of section, showing potential densification and roof gardens, around a central plaza with "surprising" vegetation and infiltration areas.

**fig. 9.28**
interactive /adaptable experience : rendering of the main square during Queen's day
INTERACTIVE SKY
possibility of projection on the dome's surface


HOME GROWN

# 9.5_ Carrying Capacity; Design in Numbers

As with all interventions that are trying to ground themselves in the ecosystem services of the site, carrying capacity is very important (Pulselli & Tiezzi, 2009). Therefore, the maximum potential in terms of energy, water managements food provision and inhabitant density are explored and energy systems optimized in order to obtain the clearest image possible on the potential of this type of intervention.

## Thermal potential

As with the intervention on the inner city, this structure has the same parameters when discussing energy potentials. The big difference is in the size of the space that needs heating in the winter. At the same time, the surface harvesting solar thermal energy is considerably larger, making for allot more heat being collected. As an estimate there are roughly around 65ha (fig 9.30) of surface facing the sun at a good angle for solar thermal collection. At an average of 5.3W/m2 (fig 9.29) the system has the potential to store and use for the winter enough heat to influence the dome temperature by 2.75 C in the winter coldest days.

2.7 degrees

650.000 x 5.3 W/m2 =3.445 kW
3.445kW x 24 x 365,25 = 30.198.870 kWh/year = 30,2 GW = 0,12 PJ

with a leakiness of 1,5W/C/m2
dome radius = 700m and dome area = 153 ha =1.530.000 m2

overall leakiness 1,5W/C x 1.530.000 = 2.295 kW/C

with an average of 200 days needing heating

2,295 kW x 24 x 200 =11.016.000 kWh/C/year = 11GWh/C/year

This means that 30GWh is enough to influnence the inerior temperature of the dome with 2.75C in cold days.
This is not enough to provide a constant environmental temperature that would not require extra heating use in the households, and therefore additional opportunities should be explored

## PV Potential

If from the 65ha facing south we cover 18ha (fig 9.30) with PV panels at a conversion rate of 200kWh/m2 then the total electricity potential is estimated at 36GWh.

30.000 households

With the current electricity consumption rate per household this energy can provide enough for almost 29.000 households, and if we assume a decrease in consumption due to the thermal benefits of the dome it can even generate for more.

intermitency storage

Furthermore this electricity can be stored in the provided energy storage basin to address the intermitency issue. Using Kaplan turbines energy can be stored at a efficiency rate of 70 to 90%. Thus assuring constant energy supply.

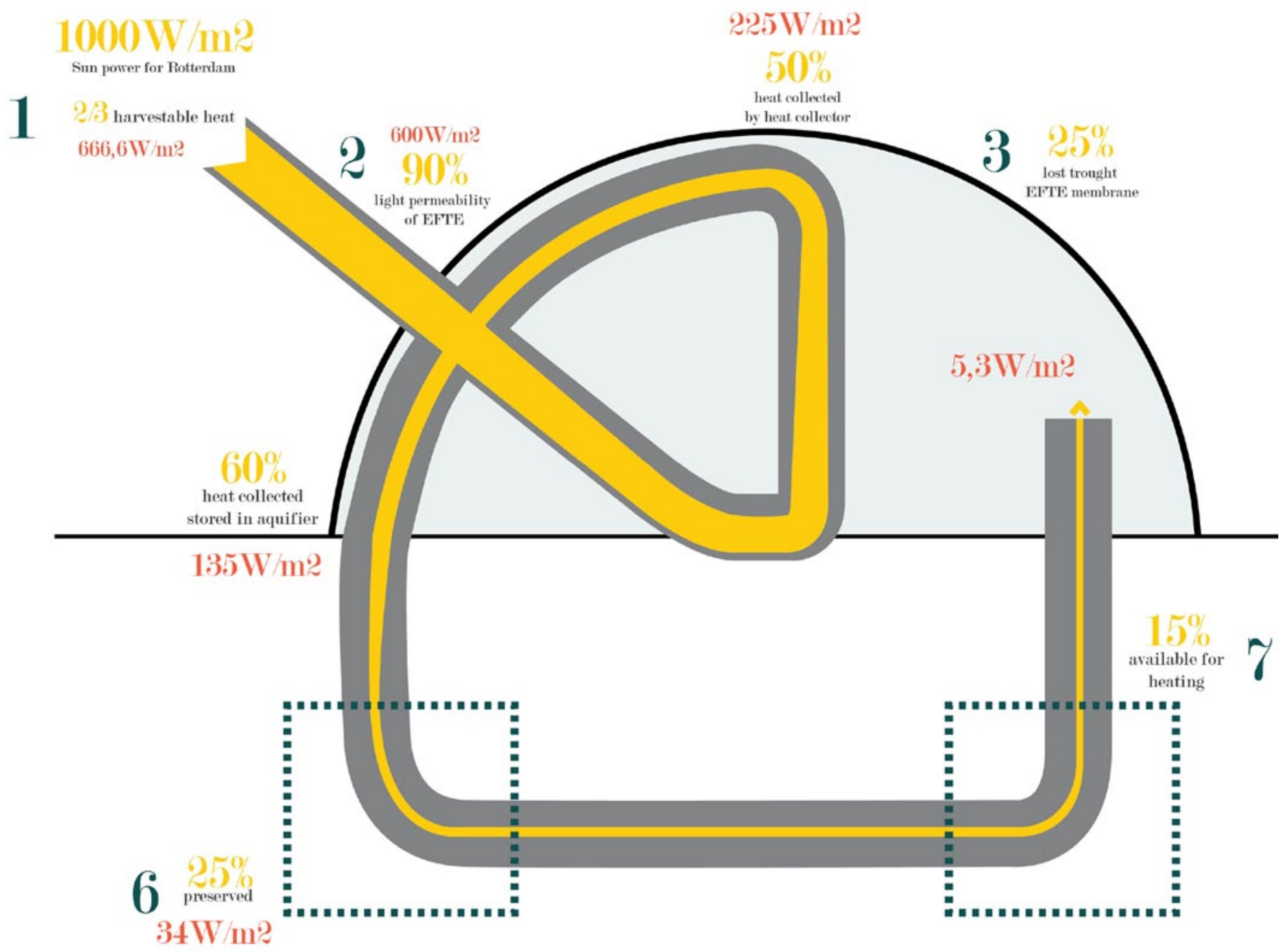
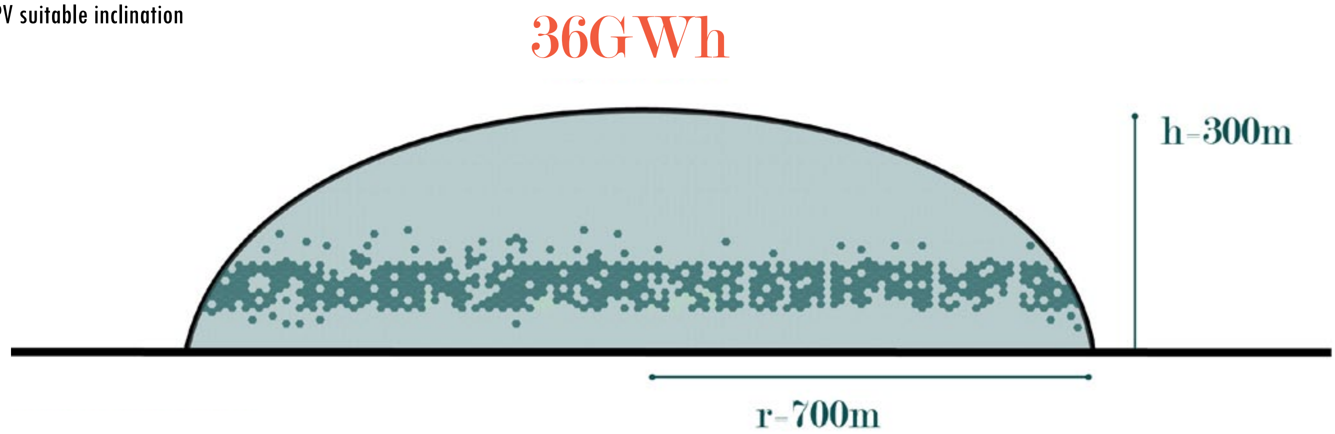
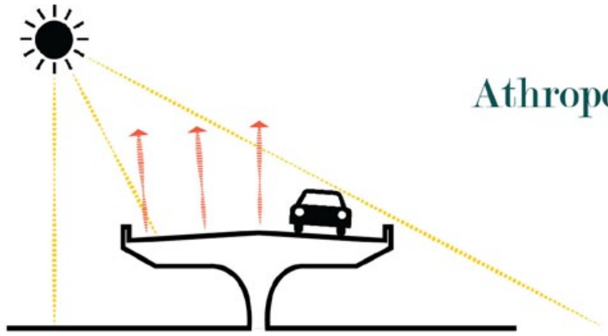



**fig. 9.29**

source:by the author


**fig. 9.30**
PV suitable inclination





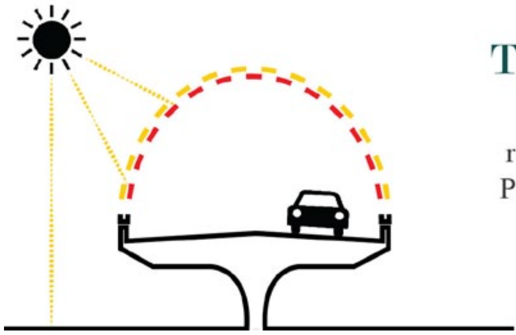




**fig. 9.31**
Motorway membrane

## Residual heat potential

residual heat from Shell (6PJ)

For exergetic optimization the use of residual heat sources is also important. One major source of residual heat is the Shell refinery adjacent to the district. The refinery generate yearly 6PJ of residual heat for which the municipality is trying to find uses (Municipality of Rotterdam, 2012). This energy source would be more than enough to keep the dome at a constant 16C temperature year-round. However the system would not be sustainable if such a large part of its energy supply would rely on residual sources form an industry which is predicted to disappear in the future.
Therefore further potentials are investigated.

heat from highways

One that stands out is the potential for harvesting residual heat from the nearby infrastructure. By applying a similar "dome" concept on highways as well as asphalt collectors we can harvest heat from nearby infrastructure and use it to heat up the dome. The concept has been researched under the frame of the sustainable highway and its potentials quantified (Movares, 2009). Among potentials for PV implementation and eve kinetic energy, which can be added value for the intervention, the thermal energy potential of 1km of highway is enough to heat 2400 homes (Movares, 2009). At a consumption rate of 0,00825 GWh/home/year this would mean roughly around 20Gwh/ km/year of heat coming from highways.

The nearby motorways can easily provide about 5-6 km for covering and harvesting heat, and would therefore be able to generate about 100Gwh/year of thermal energy. Furthermore this action would considerably decrease the amount of heat released in the atmosphere by traffic and infrastructure networks.

# Food provision

Food provision potentials are also quantified in order to assess the potential of the intervention to feed its inhabitants. Based on research by Doepel Strjkers Architects in collaboration with Wageningen University and TU delft we can generate a surface need per capita for all the food groups, assuming a intensive vertical greenhouse system (Doepel Strijkers Architects, Tu Delft, Wageningen University, 2009).

The following food spatial footprints are estimated citing studies by NASA (Doepel Strijkers Architects, Tu Delft, Wageningen University, 2009).

vertical greenhouse

In our case the intensive greenhouse system is covering 5ha outside the dome in a two level layout. The most space consuming and demanding food types are grown here. Wheat and dairy (soy replacement) taking up the most space in the greenhouse, with vegetable, fruits and finally fish (Tilapia) following. These 5ha of greenhouse can generate yearly 235kg worth of vegetable/capita, 210 kg/capita of starch 30kg of dairy replacing soy, 50kg of vegetables and 24kg of fish meat. With a space need of 20m2/cap for generating the minimum food diet for a person, the 5ha double stacked can produce for 5000 people the minimum required.

additional measures

In order to produce for a more balanced diet additional space is used in the design. Therefore fruit is mostly provided from outer sources like urban orchards (9ha) and public space planted fruit trees (3ha). Also additional quantities of vegetables are provided in the allotment gardens (3ha) and overall estimated 2ha of roof gardens for herbs.

Additionally as an exercise and awareness raising intervention 500 pigs can be raised over 1ha of space spread within the individual households and farmyards. All these interventions can provide 80% of the necessary food intake for people inside. However if diets remain the same in terms of meat consumption the goal of providing for the future is unlikely to be achieved. The remaining 20% of the food need is accounting for 60% of the space need for production (Laorga & Sheane, 2011).

The proposed food system can provide for 5000 inhabitants with meat being imported largely form outside. However if fully meat supply would be replaced by Tilapia fish the system could provide for as much as 3 times this number, reaching a capacity of 15.000 inhabitants without any import.

**fig. 9.32**
Spatial need for food production
based on DSA, TU Delft, &WUR, 2009

| Food group | kg/cap/year | | Example crop | kg/m² | # stacks | Harvests/year | Total kg/m² | Edible | Edible kg | m²/cap |
|---|---|---|---|---|---|---|---|---|---|---|
| Starches | 219 | 110 | Super-dwarf wheat | 4.0 | 5 | 3.8 | 77 | 33% | 26 | 4.3 |
| | | 110 | Potato | 5.0 | 5 | 3.0 | 75 | 45% | 34 | 3.2 |
| Fruits | 73 | | Orchard, grown in public places | | | | | | | |
| Vegetables | 110 | 36 | Lettuce | 5.5 | 5 | 14.0 | 386 | 45% | 174 | 0.2 |
| | | 36 | Sweet pepper | 6.0 | 5 | 2.5 | 75 | 45% | 34 | 1.1 |
| | | 36 | Tomato | 9.6 | 5 | 3.5 | 168 | 45% | 76 | 0.5 |
| Proteins | 73 | | Fish (Tilapia) | 42.2 | 1 | 2.0 | 84 | 40% | 34 | 2.2 |
| Dairy | 37 | | Soybeans | 0.7 | 5 | 3.5 | 12 | 40% | 5 | 7.4 |
| | | | | | | | | | Total | 18.9 |
| | | | | | | | | | Total rounded up to include infrastructure | 20.0 |

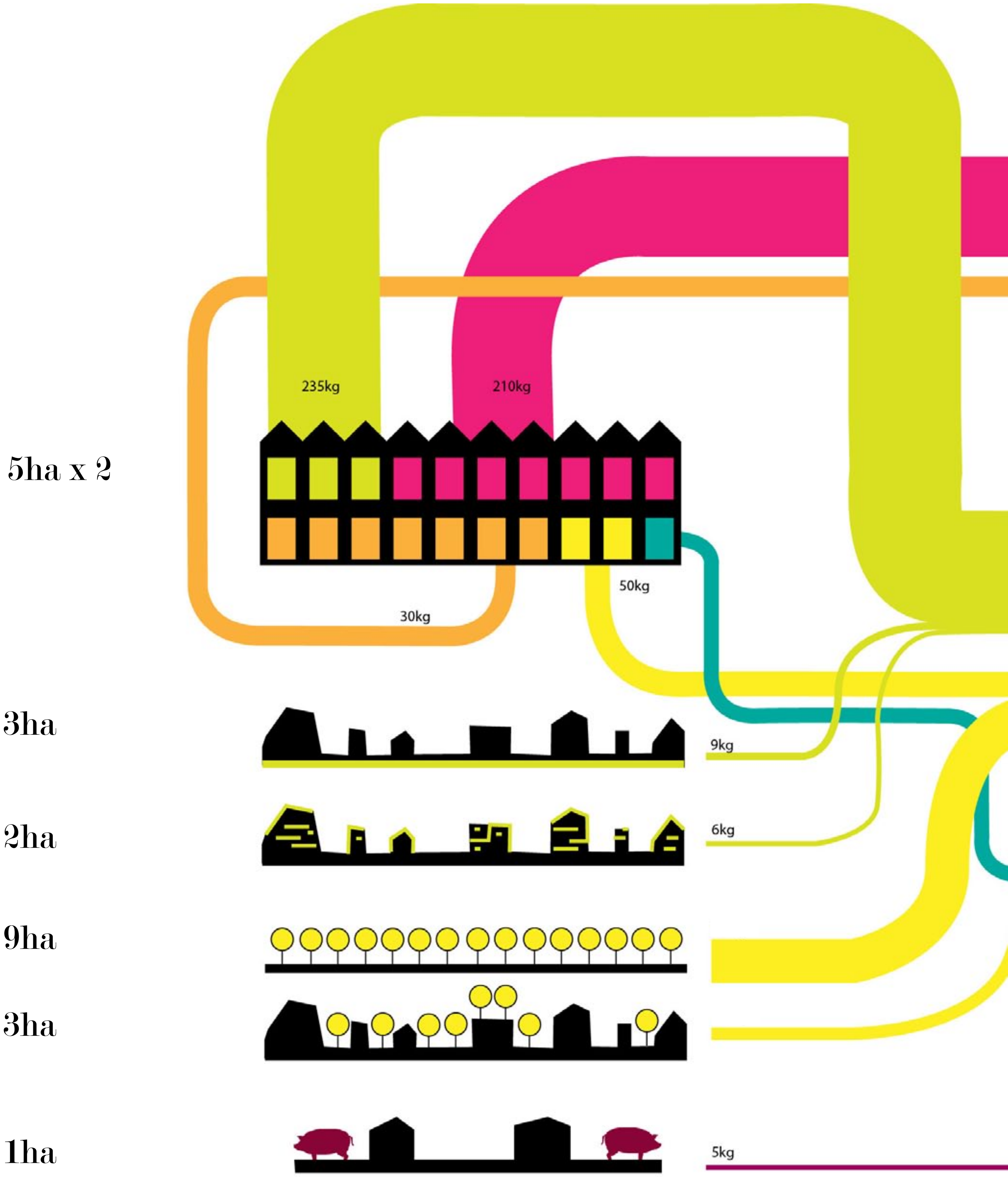
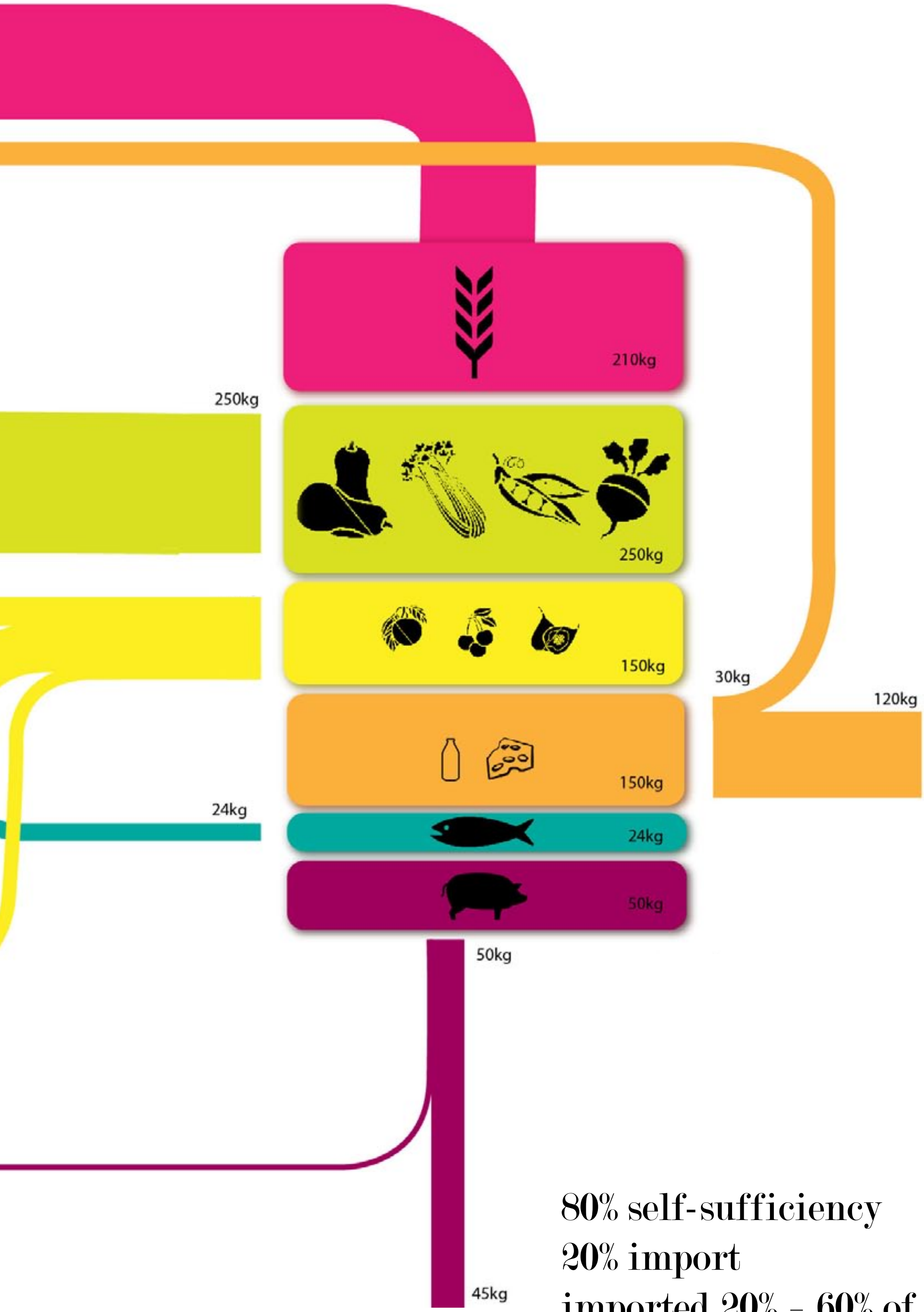



**fig. 9.33**
Food supply network and potentials




80% self-sufficiency
20% import
imported 20% = 60% of the spatial footprint

# Densification potential

The constructal densification method described in previous chapter has the demonstrated potential to add on average around 333 new households in every area of similar characteristics with the one analyzed. After a quick spatial analysis of the area based on the initial housing typology analysis elaborated, a total number of 14 areas with similar numbers of households and overall surface are found. It Is also important to mention the households all have very similar typologies.

Therefore considering the initial potential of 333 extra households per area, this would take the potential densification to
14 X 333 = 4662

At a household occupancy of 2 people per household this means a potential densification of roughly 9000 inhabitants. Added to the currently 5000 this would take the district at a number of 14.000 inhabitants.

Comparing the surface of the district with Rotterdam Inner city, the density of 14.000 would be the equivalent of 44.000 inhabitants in the Inner-city (currently there are 30.000)

**fig. 9.34**
densification potential

# Energy Flows and Material Cycles

By implementing the mentioned strategies of harvesting energy as well as ‚making use of closed cycles in terms of waste (burning household waste/ using GFT waste to produce biogas etc.) we can think in terms of the energy and mater system and asses its sustainability. The system is thought out for 5000 households and 10.000 inhabitants, and is trying to provide energy and resources for household use as well as commerce and transport (fig 9.36).

The energy system is thought in such a way that it results in should result in self-sufficiency. At the current rate of electricity supply vs. consumption that is not possible. Mainly because of the high electricity need of the greenhouse sector (34GWh - number based on DSA, WUR, & TU Delft,2009). Thearefore if we require food production for 10000 people an extra 17GWh should be imported or other conversion techniques incorporated. Main proposed electricity sources in the current system are PV panels on top of the dome (36GWh) as well as a 25% coverege with PV of 5km of the domed motorway (7.5GWh based on Movares,2009). Also excess biogas is converted to electricity and generates an extra 0,51GWh (fig 9.35).

Gas is relatively easily supplied by digesting GFT waste form households (30% of total waste output based on data from CBS) along with animal manure fro mthe 500 pigs (500 tons based on BIG, 2004) and human slurry 500 kg/cap (BIG,2004) (table 9.35)

| | | | | | TOTAL SUPPLY |
|---|---|---|---|---|---|
| **ELECTRICITY SUPPLY** | PV ON THE DOME<br>36WHh (18ha) | PV ON MOTORWAY<br>7.5GWh (5Km 25% cover) | BIOGAS CONVERSION<br>0,51GWh | IMPORT<br>17GWh | **60,5GWh** |
| **GAS SUPPLY** | HOUSEHOLD GFT<br>2GWh (1620 tons) | HUMAN SLURRY<br>0,26 GWh (5000 tons) | | | **2,26GWh** |
| **HEAT SUPPLY** | COLLECTED FROM DOME<br>68,78GWh (after storage loss) | RESIDUAL MOTORWAY<br>103GWh (5km) | BURNING HOUSEHOLD WASTE<br>94,5GWh (2340 tons) | | **266GWh** |

| | | | | | | TOTAL USE |
|---|---|---|---|---|---|---|
| **ELECTRICITY USE** | HOUSEHOLDS(5000)<br>6,05 GWh | GREENHOUSES (10ha)<br>34GWh | COMMERCIAL (10.000m2)<br>1,5GWh | CARS (4000)<br>4,56<br>(6000km/p/year) | UTILITY<br>2GWh | **50GWh (due to storage loss)** |
| **GAS USE** | HOUSEHOLDS(5000)<br>1,65GWh | CONVERT TO ELECTRIC<br>0,51GWh | COMMERCIAL<br>0,1GWh | | | **2,26GWh** |
| **HEAT USE** | HOUSEHOLDS<br>42GWh | GREENHOUSES<br>114GWh | DOME HEATING<br>110 GWh | | | **266GWh** |

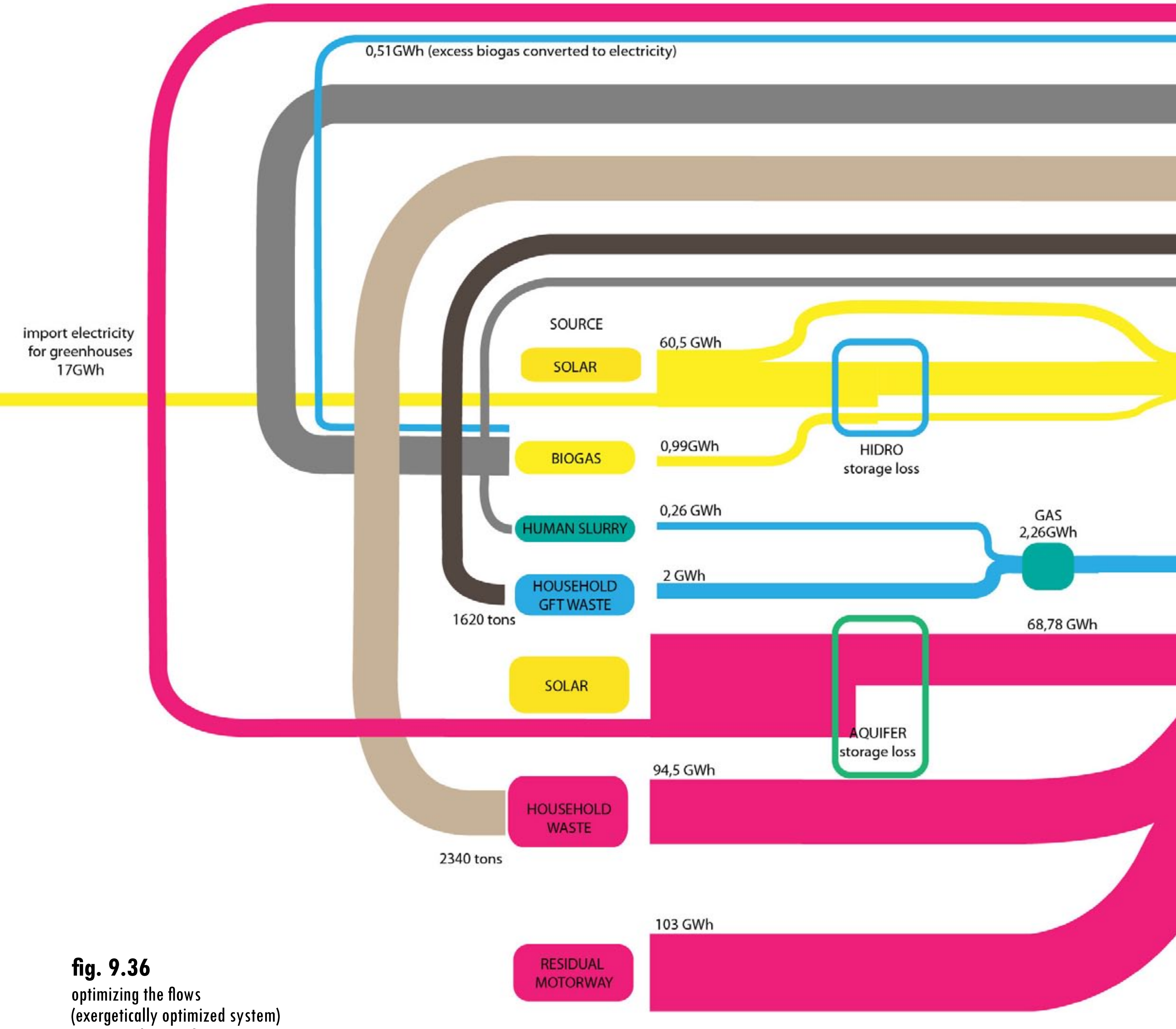
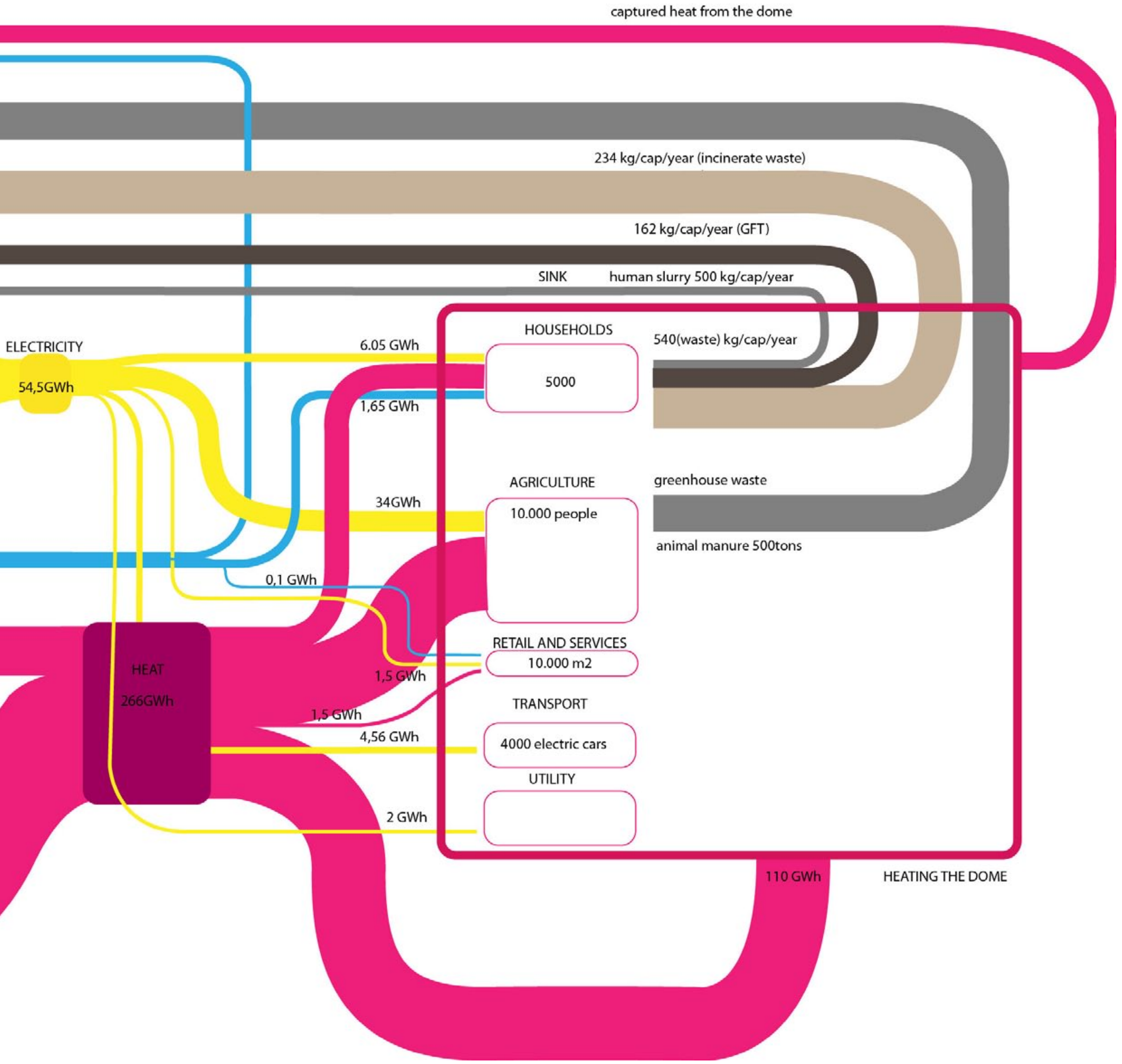



**fig. 9.36**
optimizing the flows
(exergetically optimized system)
energy and waste flow systems

Burning the household waste from 5000 households can generate as much as 95 GWh of heat which combined with the 100Gwh from motorways and the total of 68,78G GWh of solar thermal stored heat we get a total number of 265 GWh of thermal energy to use for heating in the winter. If we asses its capacity to heat the dome itself to levels which would eliminate energy usage in households (450GWh needed)

This is the situation calculated for current population levels, but what is interesting is that, as density grown inside it becomes more feasible to heat the dome instead of individual households. Therefore when density levels reach the projected 14.000 inhabitants it starts being more appealing to heat the dome instead of individual households.




Therefore the desired approach is heating individual households and other functions and using the remaining heat to raise the temperature of the dome, while after higher densities are reached heating the dome itself. This of course is in case of desired independence from residual heat from Shell. The residua heat can be used as a bonus but due to the great impact of the dome intervention it should not rely on the residual heat from industry in order to be justifiable.

# 9.6_ Discussion on the incubator

As a short end reflection on the design, it is impossible to ignore the impact on people and on the landscape, such an intervention would yield. When discussing people's preferences and desires in terms of their landscape, similar qualities come up. People like a tidy landscape (Nassauer, 1994), and generally prefer optimal conditions in terms of maintenance, temperature microclimate etc. Whether actually providing all this will be considered beautiful or even ethical is up for discussion. But I consider it worthwhile investigating.

However, the main goal of the research is exegetical optimization, an in this sense the proposal delivers a feasible system which not only provides energy and resources but it can do so in the future as well. The main benefits of this being that regardless of the developments outside the system it can continue to provide basic needs for its inhabitants (energy, water, food), in a undiscriminating way. Of course such an intervention has enormous implication on ethical, social, cultural, political, economic and technological layers, each bringing forth its own set of challenges and arguments and they will be addressed in the end discussion.

If we reflect on guidelines, principles and goals, with regards to the resulted design, the main points of conclusion would be:

thermal

Exergetic optimization of the thermal energy flow by introducing the dome, can yield self-sufficient urban structures given the suitable population densities. Of of its major points of attraction is the potential for undiscriminating provision of free, ecosystem services grounded, energy.

water

Water storage and climate proofing is possible in a way that it also introduces filtration systems and precipitation control for the structure. All this in a robust way which is adaptable to change in precipitation levels as well as inhabitant numbers.

electricity

Electricity supply can be achieved for high population numbers (30.000 households) if we do not factor in food production. In order to provide a fully self sufficient system that provide food and powers its own agricultural sector additional interventions are needed. (wind turbines, PV fileds etc.).

food

Food provision is also achievable for certain population numbers. The calculated systems provides 80% of the demand of 10.000 inhabitants (2 times current population), and could be producing 100% of the demand if meat consumption if replaced with alternative sources. In this way the system could produce for as much as 30.000 inhabitants with extra levels added to the greenhouse area.

air

Ai quality and oxygen supply become of importance when discussing such interventions and people's impact on the biosphere becomes even more relevant. Specific vegetation types are implemented for their ability to filter air pollutants and produce oxygen and the system is making use of natural convection process whenever possible.

people

Impact on people is tacked by trying to mitigate the adverse effects from within , making the structure blend into the skyline as well as a strategic approach to the edges in order to address the barrier effect which the dome would potentially have.

# PART III

# DISCUSSION

# 10 DISCUSSION AND CONCLUSION

## 10.1_ Comparative discussion

### Introduction

urbanization

The pace of urbanization has fundamentally altered the relationship between people and nature, between human settlement and the land which sports it. Moreover, the expected changes will alter these interaction even further.
The city is built on the premises that it will always receive a steady input of energy and resource which will power its functioning, while at the same time being able to face climate process and even control them.
In recent decades this has proven to be a highly unstable and fragile approach, which can collapse at any time if resource input is cut or if climate processes develop along similar patterns as they are today.

Rotterdam

Rotterdam is at the heart of all these issues, probably more so the any other city. As a delta city, it is highly exposed to climate change impacts and changes, being constantly in danger of flooding from all directions, weather sea level rise or river discharge, and recently even from its own inability to manage peak rainfall in the city.
As a city and port it is largely a product of industrial thinking and the fossil fuel economy. This makes it incremental in today's energy networks but also leave it very vulnerable to predicted resource depletion. Furthermore, as a landscape structure it is largely built following technocratic and industrial thinking leaving it very inapt to dealing with today's problems.
This context is seen in the research as an opportunity for reinvention. The reinvention of the city itself, of its metabolism, of the way it relates and is conditioned by its surroundings and of the way people are part of the urban fabric.

The research is aiming at framing this change in parameters which are vital for tomorrow's city. Energy efficiency and even self-sufficiency; resource independence; and climate robustness are vital components of that city, but at the same time is has to be able to grow. It is insufficient to provide an answer for today's population . We have to think far into the future if today's solutions are to be relevant tomorrow as well. This challenge is not easy and the solutions are not always pleasant, or even acceptable.

RQ

The starting point in terms of research question is: Can exergetic optimization of energy and matter cycles yield an attractive urban structure that provides ecosystem services and supports human life, activity and growth?

This is tackled by first shaping in a systemic way a se of principles and guidelines which would inform  the future designs:

1. The most important goal is energy efficiency as understood by SLT (second law thinking).

systemic guidelines

2. The solution revealed by a thermodynamic approach is molded in order to improve microclimate and address the goals of climate proofing

3. Potentials for added value are explored: renewable energy supply or even energy self-sufficiency; potentials for food provision or even food self-sufficiency.

artificial microclimate

The framing concept (that of the geodesic dome and artificially controlled microclimate) is applied in two ways on different sites of different scales, and explore different potentials an their implications on energy, climate and people.

erosion

In the case of the inner-city a more bottom up approach is considered in which interventions of block level eventually reshape the urban fabric. This is proving challenging for a number of reasons, spanning from morphological differences between a street pattern shaped by speed and traffic and a block morphology shaped by forces of nature. The approach can touch upon most of the issues raised by the research question but is still in need of multiple testing and implementing and requires a more deep interdisciplinary approach.

incubator

In the case of the incubator concept, the approach is more obviously top down but at the same time it tries to encourage a bottom up development of the site (framed by the major guidelines). Here the challenges  raised by the research question in terms of energy and mater, and even growth are easier to quantify and achieve. At the same time it raises a more prominent ethical and social challenge, grounded in the nature of the intervention. This is tacked by a number of strategies and approaches with the goal of mitigating the adverse effects, without claiming to solve them completely.

## Design Comparison

systemic design

A vital part of the research process is systemic design and systemic consideration. In fact the need for such an approach is clearly evidenced when trying to combine energy and microclimate oriented approaches.   Its feasibility is tested on current projected trends and it helps frame the main principles which guide the rest of the design process.

The two separate  takes on the approach are both following these principles and guidelines but yielding very different solutions and even results to some extent. By looking back upon their relation to the original principles and goals as well as relating them to the research question the designs can be compared and evaluated according to the original objectives.

energy efficiency

The main guideline referred to energy efficiency in terms of second law of thermodynamics.  In this sense both designs manage to reduce consumption drastically and at the same time utilize the intervention meant for energy saving as a platform for energy generation and even climate proofing and microclimate adaptation and mitigation. The very different scales approached make it hard to asses the efficiency of the systems in direct comparison, each approach having its own  optimized levels according to scale.

climate proofing

With regards to climate proofing and microclimate improvement, the incubator has the advantage of generating benefits which can be quantified for city scale. The erosion approach generates quantifiable improvements within its generated microclimate. The benefits it generates for the outer environment are difficult to demonstrate until implementation on a large enough scale, for it to impact the urban microclimate, takes place.

added value

When it comes to potentials for added value again the scales of the approaches make for comparisons to be relatively unbalanced ,especially when it comes to food provision.
Potentially one way of looking at their link would be to view food provision in the case of the erosion approach as being one of the food strategies implemented in the incubator (roof gardens). Therefore the incubator offers the potential to structure a more robust and complex food provision system, instead of a single step in the process.

morphology

Probably the most relevant comparisons between the two approaches are from morphological and social perspectives. They are taking fundamentally different takes on the existing situation, as the `erosion` approach tries to embed itself in existent urban morphology while at the same time transforming it. This is proving very difficult and resource consuming due to the large number of trials needed for optimizing the approach and guaranteeing a positive outcome. Overlapping the street morphology structured by road networks and need for speed fundamentally collides with the morphology shaped by forces of nature.
The incubator is taking a different approach on this, providing the same exergetic benefits but at the same time allowing for a preservation of the existing structures in the city, and an eventual time transformation based on the existing identity rather than a direct and fundamental change.

social and ethical

The second set of comparison criteria related to social and ethical impact can be seen as being far more advertise in the case of the dome. Although the erosion process reveals striking new shapes in urban settings, being based on smaller scale interventions, it would take numerous repetitions for the shape to have a great impact on the city as a whole, and therefore this change can be seen as more gradual, thus allowing time for people to adjust. Furthermore their close relation to the building scale makes them more resembling architectural interventions and do not alter the public space as a whole.
In the case of the incubator the impact is direct, blunt and "grotesque", and if adding upon that the issue of `closed cities` it requires creative ways of rethinking the way cities interact with the environment. It is also affects much more people. Apart from the vastly larger numbers it `houses` its visibility in the landscape, makes its impact on a social and ethical level potentially grater and therefore mitigation of these effects is attempted both from within as well as from the outside.

# 10.2_ General Discussion

question driven research

The research process underlining these approaches is fundamentally question driven and based on constant testing and adjusting. The initial main research question is not approached directly in terms of solutions but rather a suitable approach is searched.

To further enhance the process of research by design or constant testing and adjusting, after the approach is intuited, it is first tested before being applied on new designs. Therefore the systemic approach, although widely recognized as a proper scientific deign approach is tested in Rotterdam in order to asses is applicability and legitimate its usage on "already in motion" initiatives.

research by design

After this general frame is established, design can commence, based on concepts generated with systemic thinking and framed by the sites. During the actual design process constant testing and adjusting is done using simulations and research informed observations. All these processes are greatly informing the research process as a whole, and its relevance stands not just in the final product or result but in the process itself.

challenges

Probably more so than with other more conventional approaches the challenges raised by these two designs are fundamentally addressing the way we live and want to live. However, consideration is given to all major aspects and the final decision is a informed one. The main reason behind some of the choices has to do with the unique contextual situation. In the past decades, we have been used to a certain degree of stability, both political, geopolitical, economical, and even energy wise. In this context, where, all basic human needs are satisfied, beauty becomes a point of interest, and a prerequisite of all interventions. However the current developments make it likely that this stability will not last. It is in that state of instability where basic needs such as protection from the elements and energy provision are endangered when the beauty or familiarity of an intervention becomes less important, and when challenging solutions come to light.

economic and energetic feasibility

One of the major points needing addressing is the economical and energy cost of such interventions, especially when it comes to the dome. In fact the current economic context makes large investments in sustainable projects very important. Such investments generate numerous work opportunities, generating jobs and making use of excess capital. This process would be similar to post war American suburban developments, with the difference that being self sustaining it would not become unfeasible in a few decades, but rather its value would rise, and future investments in refurbishment will be minimal.

This brings us to the energy feasibility. Such a intervention would no doubt require enormous amounts of energy to built, but, at the same time, it would considerably decrease the need for energy consumption for constant renovation and repair. Our constructions have a shorter and shorter lifespan and are in constant need of renovation due to their contact with the environment. These would decrease considerably accounting for decrease in maintenance consumption in the future.

decision making

Such interventions are hard to imagine given the current decision making process and political as well as administrative and social challenges it raises. In many cases it is difficult deciding on the siting of a wind turbine and its positioning can cause loud debates. For a intervention such as the dome, it would take a extreme set of circumstances for its construction to be given any consideration. In the end, what the proposal aims at is a landscape informed investigation into the potentials and options with which our future cities are presented with. Researching the city in terms of ecosystem services and what does it take to ensure growth in a city while still remaining grounded in its ecosystem's carrying capacity, and therefore ensure sustainability. This is achieved, especially in the case of the incubator concept, and although its implementation would have a set of fundamental challenges, this research shows that a landscape approach, even in the case of extreme interventions, can influence its implementation and design in such a way that it becomes more attractive.

sustainability

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THIS THESIS FOCUSES ON REVEALING NEW WAYS OF APPROACHING URBAN STRUCTURES. BY RE-FRAMING THEIR MORPHOLOGY AND THE WAY THEY INTERACT WITH THE ENVIRONMENT IT CAN YIELD SUSTAINABLE STRUCTURES THAT CAN PROVIDE ENERGY AND FOOD, AS WELL AS BE 100% CLIMATE PROOF IN A WAY THAT CARES FOR HUMAN NEEDS AND SUPPORTS GROWTH.