Synergetic Urban Landscape Planning in Rotterdam
Liveable Low-Carbon Cities

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Synergetic Urban Landscape Planning in Rotterdam

Liveable Low-Carbon Cities

Dissertation

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By

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This dissertation has been approved by the promotors

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For Anouk and Ruben

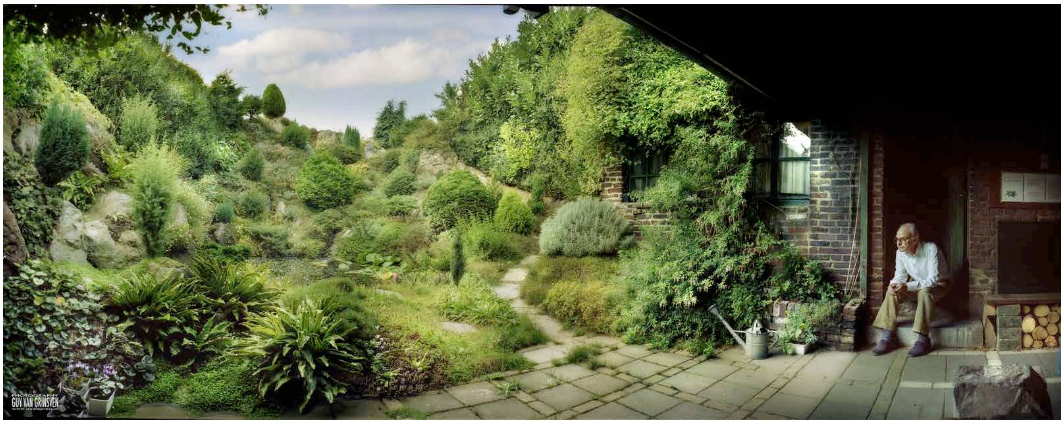
Preface

This preface was written because I wanted to give some background to the research. It is not a stand-alone item, but rather part of a journey of exploring inter-connected areas of interest which started many years ago and has now reached the point of this PhD regarding Synergetic Urban Landscape Planning in Rotterdam.

It was 1977 when our mothers allowed us to cross the street with our small bikes. We were about five years old when new grounds could be explored in the village of Amby in Maastricht, and so we did. As one of my friends mentioned the existence of a nearby secret garden with mountains, waterfalls, fish and birds, this was something we had to see.

When opening the garden door, we were mesmerized by the little fairy tale landscape with rocks, plants and water. Several species of evergreen gave depth and cohesion and made it a special and harmonious place. Streamlets and waterfalls came from little gorges, and water tumbling over rocks found its way to a central pond in the garden. Vertical cliffs were clothed with ferns, mosses, Solomon's Seal and rare plants such as *Ramonda* and *Haberlea*. As I later learned from Tony Hall of Kew Gardens, for Ber Slangen (the designer and owner of this garden), the key priority was to create an overall effect of being in the mountains. It didn't matter if this was achieved by planting easy-growing local ferns or choice rare species. In this garden, you really did experience the mountains – Ber Slangen had created a magical atmosphere in his own back yard.

As a student in landscape architecture at Wageningen University, some 15 years later, my question was: How can such a garden be designed? How can the secret to its success be utilized in other designs? Very telling was the quest of the late John Ormsbee Simonds, celebrated American landscape architect. With fellow students, he had spent years looking for the essentials of the world's most renowned gardens in Japan, China, Tuscany in Italy, France, England, and so on. What are the secrets to all these gardens? Was it just the lay-out, the geometry, order, unity and intricacy, or was there more? Somehow, Simonds and his colleagues felt that the essential essence of these places had eluded them. Many years later, whilst he was sat in a woodland with sunlit trees, motionless air fragrant with Hay fern, purple foliage, and squirrels searching for acorns, Simonds writes that 'an old familiar tingling went through me, a sense of supreme well-being, and an indefinable something more.' It gave him the same sensation he had felt in some of the gardens years earlier. The secret lay not in the design or lay-out of the gardens, but rather what one experiences there! They were planned experiences.



Rock Garden Ber Slangen in Maastricht, The Netherlands (Photo by Guy van Grinsven)

Moving on, I was not only interested in the design. In fact, Ber Slangen's garden – like a landscape – was in a sense the outcome of a process that evolved over many years. I was interested in what happened there – the ecology, the metabolism, daily maintenance, new areas being planted, the management, future planning, the visitors. What principles was it based on? In this garden, as well as in its adjoining house, nothing was thrown away. Organic material was recycled, nutrients retrieved, old furniture taken apart for its basic components, rain-water was collected from all the roofs, stored in the pond and used. In a way, this was a miniature form of sustainable land-use and synergetic planning. How could certain principles be scaled up? Or how could certain conditions be created and designed in other projects, such as parks and other urban landscapes?

More principles about sustainable land-use planning and landscape architecture and its connections, I learned in Wageningen, when dealing with natural water cycles and environmental challenges of industrial pig-farming in the Gelderse Vallei. When dealing with such issues, it felt almost perverse to apply landscape architectural knowledge for aesthetics only and not link it to restoring life functions in this area.

Working in Amsterdam, and after that for the City of Rotterdam, my interests broadened to consider cities or urban landscapes – the public realm, parks and urban ecology – and how the city is used.

John Ormsbee Simonds (1983) writes that the most pleasurable aspects about cities, throughout history, have not derived from their plan geometry, but have resulted from the essential fact that, in their planning and growth, the life functions and aspirations of the citizens were considered, accommodated and expressed. 'To the Athenian, Athens was infinitely more than a pattern of streets and structures. To the Athenian, Athens was first of all a glorious way of life'. How can this be applied to modern cities – and not for a few decades only, parasitizing on finite resources, but in a sustainable and liveable low-carbon way?

In this PhD research, I explore some basics in dealing with the urban landscape system of Rotterdam, its flows, functions, areas and actors. I hope it provides a good basis for future research, design and planning experiences, but above all that it offers the possibility of habitable low-carbon cities with a high quality of life.

Reference

Ormsbee Simonds, J., (1983). Landscape Architecture: A Manual of Site Planning and Design, McGraw-Hill, New York.

Acknowledgements

Such as a beautiful landscape is the result of processes involving many actors, so is my PhD. Therefore, I am very grateful to my family, friends and (former) colleagues who helped me to get through this process successfully.

Firstly, I would like to express my gratitude to my mentor team: Andy van den Dobbelsteen for his confidence to recruit me in a time when sustainable urban energy plans were never heard of, for his enthusiasm, knowledge and energy. Dirk Sijmons for his inspiration and for getting me into the landscape architecture unit at the Faculty and Steffen Nijhuis for his supervision, advice and help to structure my work.

I am indebted to the late Ber Slangen, who taught me the basic principles of gardening and seeing things in a larger perspective and so much more. I am grateful to Tony Hall (Kew Gardens) for his longtime friendship and sharing his knowledge. Both of them gave me the confidence to choose to the path I believe in.

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Summary

In this PhD research, the major environmental challenges of our time, such as climate change, sustainable energy transition and scarcity of resources, are approached from a spatial, landscape-architectural perspective. The goal is to accelerate the transition to liveable, low carbon cities. The focus of the research is at the local scale and attempts to turn challenges into opportunities for a better quality of life and living environment. Since 1857, when Frederick Law Olmsted combined the construction of two large drinking water reservoirs for the city of New York with the design of a beautiful park, these types of assignments are part of a landscape architect's job. At that time, the issue was to solve the problem of drinking water while now we are concerned about solving the combination of very diverse and different flows. This renders the assignment more complex but certainly no less landscape architectonic.

As part of this research, many functions, flows, areas and actors in the urban landscape system of Rotterdam have been studied. This research focuses on the development, design and testing of new approaches to strengthen existing urban qualities and to tackle problems in such a way that positive effects for other functions (synergies) arise at the same time in order to improve the quality of life in cities.

The themes researched are:

1. Water and climate change: storm water challenges and water in the city (such as flooding) and how these might provide opportunities for a better environment
2. Energy transition: exchange of residual flows of heat in order to achieve a more sustainable energy supply.
3. Urban agriculture and nutrients: urban waste flows of phosphorus and urban agriculture as related to liveability.

All these themes could also be investigated per sector and that is often what is done, however this research looks at their inter-connectedness and the possibility to promote synergies.
For this, it is important to know what kind of synergies can be achieved and for whom. As a result, planning for synergies in a structured way is possible. Landscape architectural, urban ecological and governance theories are used to extract building blocks and to set up a so-called Synergetic Urban Landscape Planning (SULP) approach. This is an integrated approach that allows us to explore, imagine and plan synergies so as to accelerate the transition to a liveable, low carbon city. During the research

process, SULP has continuously been reinforced by incorporating the results of the separate studies on water, climate, energy, urban agriculture and nutrients. Synergetic urban landscape planning forms the bridge between CO_2 and liveability goals on the one hand, and principles for sustainable urban development on the other. This research and this approach was fed with, and strengthened by, the results of separate studies on water, climate, energy, urban agriculture and nutrients.

To test this approach, SULP building blocks were used in the inner city of Rotterdam. Possible densification and greening strategies were built together with stakeholders. This has resulted in a plan for the various components such as water and energy, which greatly improved multiple liveability aspects of the inner city and reduced CO_2 emissions per capita. These results were also used to further develop the SULP approach such as the development of the 'Smart City Planner', based on the principles and indicators of sustainable cities, an assessment tool linked to Geographical Information Systems (GIS). This tool can be used to assess the sustainability performance of neighborhoods as well as to plan for synergies.

This research contributes to sustainable urban development and emphasizes the role of landscape architecture in this regard as it provides synergies within urban metabolism (flows in the city). It also leads to closer cooperation with other disciplines. New approaches have been developed through SULP some of which have already been successfully applied, for example the 'Rotterdam Energy Approach and Planning' (REAP) as well as the 'Smart City Planner'. Approaches that accelerate the transition to a liveable, low carbon city!

Samenvatting

In dit proefschrift worden de grote milieu-uitdagingen van deze tijd, zoals klimaatverandering, duurzame energietransitie en schaarste aan hulpbronnen, benaderd vanuit een ruimtelijk, landschapsarchitectonisch perspectief. Het doel is te komen tot leefbare steden met weinig CO_2-uitstoot. De focus ligt op de lokale schaal en probeert bedreigingen om te buigen in kansen voor het verbeteren van de leef-en omgevingskwaliteit.
Sinds Frederick Law Olmsted in 1857 de bouw van twee grote drinkwaterreservoirs voor de stad New York combineerde met het ontwerp van een prachtig goed functionerend Park, zijn dit soort opgaves onderdeel van het takenpakket van de landschapsarchitect geworden. Ging het destijds om het oplossen van het probleem van één stroom, namelijk drinkwater, tegenwoordig gaat het om een combinatie van zeer diverse stromen. Dit maakt de opgaves complexer, maar zeker niet minder landschapsarchitectonisch.

Voor dit onderzoek zijn daarom vele functies, stofstromen, gebieden en actoren in het stedelijk landschapssysteem van Rotterdam bestudeerd. Dit onderzoek is gericht op het ontwikkelen, ontwerpen en testen van nieuwe benaderingen om bestaande, stedelijke kwaliteiten te versterken en problematieken zo aan te pakken, dat er tegelijkertijd ook positieve effecten voor andere functies ontstaan (synergieën), om zo de leefbaarheid in de steden te verbeteren.

Onderzochte thema's zijn:

1. Water en klimaatverandering: uitdagingen op het gebied van (regen)water in de stad, zoals wateroverlast en droogte.
2. Energietransitie: uitwisseling van reststromen van warmte om te komen tot een duurzamere energievoorziening.
3. Stadslandbouw & nutriënten: stedelijke afvalstromen van fosfor en stadslandbouw in relatie tot leefbaarheid.

Al deze thema's zouden ook sectoraal onderzocht kunnen worden en dat is wat meestal gebeurt. Echter, in dit onderzoek wordt gekeken naar hun verwevenheid en de mogelijkheden om winst te halen uit hun synergie.
Hiervoor is het belangrijk te weten wat voor soort synergieën er te behalen vallen en voor wie. Vervolgens is het mogelijk te onderzoeken hoe je deze gewenste synergieën op een gestructureerde manier kunt plannen en ontwerpen. Theorieën over

landschapsarchitectuur, stedelijke ecologie en bestuurskunde leveren bouwstenen op voor het opzetten van een zogenaamd 'Synergetische stedelijke landschapsplanning' (SULP). Het is een integrale aanpak om synergieën te verkennen, te bedenken en te plannen, om zo de overgang naar een leefbare CO_2-arme stad te versnellen. SULP is gedurende het onderzoeksproces steeds opnieuw versterkt door de uitkomsten van afzonderlijke studies over water, klimaat, energie, stadslandbouw en nutriënten in de aanpak te verwerken.

Synergetische, stedelijke landschapsplanning vormt de brug tussen CO_2- en leefbaarheidsdoelen aan de ene kant en principes voor duurzame stadsontwikkeling aan de andere kant.

Om deze aanpak te testen, zijn SULP-bouwstenen gebruikt in de binnenstad van Rotterdam. Samen met belanghebbenden zijn mogelijke verdichtings- en vergroeningsstrategieën opgesteld. Dit heeft geresulteerd in een gedegen plan voor de verschillende onderdelen, zoals water en energie én hun samenhang, waardoor diverse leefbaarheidsaspecten van de binnenstad sterk konden verbeteren en de CO_2-uitstoot per inwoner kon dalen. Deze uitkomsten zijn tevens gebruikt om de SULP-aanpak verder te ontwikkelen. Zo is op basis van principes en indicatoren van duurzame steden de "Smart City Planner" ontwikkeld: een meetinstrument gekoppeld aan Geografische Informatiesystemen (GIS) . Deze kan gebruikt worden om buurten te meten op hun duurzaamheidsscore, maar ook om mogelijke synergieën beter te plannen.

Dit onderzoek naar de ontwikkeling van SULP draagt bij aan duurzame stadsontwikkeling en benadrukt tevens de rol van de landschapsarchitectuur. Daarmee levert het niet alleen synergieën op binnen het stedelijk metabolisme (stromen in de stad), maar leidt het ook tot nauwere samenwerking met andere disciplines. Dankzij SULP zijn nieuwe benaderingen ontwikkeld, waarvan enkelen al met succes zijn toegepast, zoals de 'Rotterdam Energie Aanpak en Planning' (REAP) en de 'Smart City Planner'. Benaderingen die de overgang naar een leefbare, CO_2 -arme stad versneld mogelijk maken!

PART 1 Introduction

1 Introduction

§ 1.1 Background

Whereas slightly over ten per cent of the world population lived in cities in 1900, in 2013 this was already 53 per cent and it is expected to increase to 70 per cent or higher (of an estimated 9 billion world population), by 2050 (McCarney, 2013). With the increase in population, as well as the average level of prosperity, the resulting use of natural resources and fossil fuels and the negative consequences thereof (e.g. the emission of pollutants and the strain on nature, agricultural lands and biodiversity) also increase. So, at a time when climate change has become an established fact, there is a larger number of people demanding more from Erath's decreasing usable surface, with a decreasing amount of available raw materials (Tillie, 2012).

The natural world, including human living environments and the economy, is under threat. Many authors recognise that the so-called 'take make waste' manner of doing things in the past 200 years has been extremely destructive to our global ecological systems (Doppelt, 2008). Due to global warming, local ecosystems are under threat but also, 'for the first time in history, climate change threatens the entire world, and humans are the dominant cause. Global warming is the ultimate issue of sustainability. Although few people as of yet, seem to grasp this, it will be the defining issue for all of humanity for decades to come' (Doppelt, 2008).

In fact, in the late 1980s my former geography teacher Mr. Aussems, had already pointed out scientific papers discussing the risk of increased levels of CO_2 but in general there was absolutely no attention paid to this. As Dutch journalist Karel Knip wrote in 2009, 'Only ten years ago scientists were able to prove that the earth is quickly warming up as a result of a greenhouse gas effect strongly influenced by humans. In 1995, one could say there was a probability, and before that it was not more than a hypothesis. Until 1980 there was almost no attention for greenhouse gasses. Nowadays global warming is commonly seen as the biggest problem humanity is facing' (Knip, 2009). The Paris COP21 Climate Treaty has sealed the international consensus on the urgency of action.

Although cities create economies of scale and offer opportunities, we have not been able to create prosperity without adversely affecting our living environments (Wackernagel, 1996). And these effects can be seen around the world. An increasing number of city-dwellers are faced with problems connected to this. This applies to cities worldwide, with problems ranging from air-pollution, health, flooding and social issues.

A drastically changing environment has consequences and affects all life. Loss of ecosystems is not just a problem for people loving nature, as it provides us with resources and materials such as gene pools for cultivated crops, sources for medicine, delivery of water where we need it and storage where we do not, as well as an ability to absorb pollution (Walker, 2008).

So, in an increasingly urbanised world, with a growing population, emerging economies and the threat of global warming, the need for research and expertise to come up with sustainable, renewable, economically sound and equitable solutions in cities is drastically growing. A lot of research is required in order to understand how cities can grow, how to transform their existing layout, what interventions need to be made, how citizens should transform their way of life and how cities should develop.

Turning challenges into opportunities (Greef et al., 2005; Tillie et al., 2007) and making a transition to sustainable communities is therefore essential. A world where it is possible to create prosperity with a positive effect on our living environment while also restoring degraded ecosystems (Newman, 2008; Doppelt, 2008) is an enormous task. Decisions and actions at the local and regional levels can contribute to this to a great extent. But what does this mean specifically for a city? And how to approach this quest? As each city has its own dynamics, where to step in? How can we influence processes and develop sustainable communities with a good quality of life, not only here and now, but also elsewhere and in the future (Tillie et al., 2014)? It is about improving the sustainability performance of cities whilst linking to the broader goal of sustainable development addressed by Brundtland (1987).

Viewing cities as urban ecosystems might provide clues as it offers a range of existing and new insights but above all, offers a way of thinking that can link different disciplines or silos such as traffic planning, energy provision, public space and technical urban water issues and have added value, not just to ecological, but also to economic, social and cultural aspects.

Although a lot of research has been undertaken since the term ecology was coined by Haeckel in 1866, many questions remain unanswered or new insights have only recently been discovered. The inter-connectedness of disparate elements such as human activity, soil, oceans, climate and CO_2 levels in the global ecosystem is very complex. Interesting in this respect is that in 1948 Vogt had already written about this inter-connectedness and by way of example, appeared to predict Hurricane Katrina in New Orleans.

"Drastic measurements are required. Foremost we have to change the way we think. If we don't want to perish, we have to remove every selfish thought that we live alone; We live in a global society where the life of a farmer in Indiana, USA, can't be separately seen from a Bantu tribesman in Africa; We pay for yesterday's mistakes and create tomorrow's. Today's white bread can cause a dike breach in spring and flood New Orleans" (Vogt, 1948).

Addressing CO_2 and positive inter-connectedness or planning for synergies in urban landscape systems are the next steps.

§ 1.2 Object of study

Cities are responsible for 30-40% of CO_2 and other greenhouse gas emissions, and if the emissions connected to the goods and food used in these cities are added, the number is even higher. In Europe, the approximately 100 metropolitan regions are responsible for about 75% of the European greenhouse gas emissions (Metrex, 2008). Also, worldwide, cities and metropolitan regions are responsible for approximately 75% of the CO_2 emissions (Carney, 2009).
Cities are a big part of the problem, but also hold the key to a big part of the solution. Cities are in a position to accept local responsibility. Their capacity to act in issues such as a low carbon future and planning for synergies should be used, enlarged and supported throughout. How are we to accomplish this?

The object of study is a city that for the purpose of this PhD research is defined as an urban landscape system with legal boundaries governed by a mayor and a board of aldermen or councillors. The functions, flows, areas and actors (Tjallingii, 1992) are studied within this system.
Although systems boundaries are rarely similar to legal boundaries, the reason for this particular field of study in cities is that many people dealing with complex issues in cities (such as raising quality of life and decreasing CO_2 emissions) are faced with new challenges and are covering new ground. Often dealing with contradictory goals, investment choices, decisions in spatial planning, energy systems and liveability have

have to made on a daily basis, based on the information available, political arguments and internal or external expertise. In many cases, a good overview of these interconnected fields, is missing, which in itself leads to sub-optimal planning results. One of the problems is that there are few good systematic urban landscape planning approaches or frameworks for the transition of existing cities towards liveable, low carbon cities.

Since the 1980s a lot of research has been done at the scale of a single building regarding energy, water and material use. Energy-producing buildings have been built and even more will be built in the coming years. Before 2005 however, energy and CO_2 have rarely been part of urban plans at the higher scale of neighbourhoods, districts, cities and regions. Additionally, energy and CO_2 are much more abstract than classical themes in urban planning such as water, infrastructure, public space and housing. Low carbon and energy principles need to be linked to urban landscape planning principles so as to make energy and CO_2 a more defining theme in urban planning. However, solely focussing on a low-carbon future can possibly result in environments with a lower liveability or quality of life ,or that prohibit people choosing a low-carbon option. A wider set of goals including liveability is a necessity to reach a low carbon future as well as planning for synergies.

In a comparison two buildings, where one lacks direct sunlight, fresh air, green and windows with a view, and the other has all these qualities, McDonough & Braungart (2002) write, 'in fact, this (second) building is just as energy-efficient as the first, but that (quality) is a side effect of a broader and more complex design goal, which is: to create a building that celebrates a range of cultural and natural pleasures sun, light, air, nature, even food – in order to enhance the lives of people who work there'. It is this broader and more complex design goal that can offer the required quality. In other words, solutions for CO_2 reduction should contribute to a better city in other fields as well as encouraging synergies. So, the broader research goal is to create a liveable low-carbon city with a high quality of life. To take the next steps some crucial terms are defined below.

Urban landscape systems

The overall approach of this research on synergetic urban landscape planning and liveable low carbon cities, is a holistic one, using some in depth studies on urban landscape planning as related to water, energy and nutrients.

As Zonneveld (1995) states in a landscape ecological perspective, 'in philosophy and science holism is considered as the opposite of reductionism'. The systems approach can be considered as the scientific counterpart to the philosophical concept of holism. Portugali (2011), Roggema (2012) and Stolk (2015) explain about systems in earlier work at the faculty of Architecture and the Built Environment at TU Delft. A system can be described as an entity with interrelated and interdependent parts. There are structural as well as functional relations. A system is made up of a structure defined

by its parts and composition. Inputs, processing and outputs of information, energy, and materials are all an apect of a systems behaviour. A system coexists with its environment and in an open system interacts with other systems. It is defined by its boundaries and it is more than the sum of its parts or subsystems (Bertalanffy, 1968, Zonneveld, 1995, Wikipedia 2017). So, in fact, there is a kind of heterosis effect or synergies are taking place. Bettencourt (2010) and West (2017) also show this relation in urban systems, although the effects of increasing the number of relations in the urban system, cannot all be labelled as synergetic as also crime rates and other negatively experienced outcomes increase.
As many authors (Tjallingii, 1992, Zonneveld, 1995 Alberti, 2009) propose, systems and also urban landscape systems can be classified according to form (patterns, areas), structure (infrastructure), function, process (flows) and actors (stakeholders). Throughout this PhD research the focus will be on these aspects. Urban landscape planning will be used to influence courses of action aimed at changing existing situations into preferred ones (Simon, 1996)

Urban landscape planning

Urban landscape planning can be defined as landscape architecture applied to the urban environment. The definition of landscape architecture according to the International Federation of Landscape Architecture (Nijhuis, 2015) is:

"A profession and academic discipline that employs principles of art and the physical and social sciences to the processes of environmental planning, design and conservation, which serve to ensure the long-lasting improvement, sustainability and harmony of natural and cultural systems or landscape parts thereof, as well as the design of outdoor spaces with consideration of their aesthetic, functional and ecological aspects."

Laurie (1986) mentions that the definition of the profession has varied over the years in an attempt to match its goals with problems and needs of society. In this research, the urban environment seen as an urban landscape will be prevalent. Nijhuis (2015) acknowledges three principle knowledge areas in landscape architecture: landscape planning, landscape design and landscape management. According to Nijhuis (2015)

"Landscape planning is concerned with the long-term development and preservation of natural and cultural landscapes by the development and implementation of strategic goal-oriented concepts and allocation of types of land use. Landscape design is concerned with form and meaning, the development of design principles and the organisation of a physical, functional and aesthetic arrangement of a variety of structural landscape elements to achieve desired social, cultural and ecological outcomes'"

Urban landscape planning is used in this PhD research to answer questions of liveability, low carbon urban developments and the exploration of synergies in urban landscape systems.

Liveability & quality of life

Liveability can be broadly defined as the well-being of a community. It represents the characteristics that make up a place where people want to live now and in the future VCEC (2008). The quality of the living environment is closely linked to liveability. As described by Van Dorst (2005) VROM (2001), a good environment suggests that 'residents, business owners and users of public space perceive their living environment as recognisable, pleasant, clean and attractive, so they want to live, work and stay there'.

Low carbon & CO_2 neutral

When planning for low-carbon cities, the goal is to have net zero-carbon emissions or even have a negative carbon footprint. In other words extraction of CO_2 from the atmosphere. Concepts related to a low-carbon city include CO_2 neutral, energy neutral and climate neutral. These are all different concepts that indicate a similar endeavour (Gommans, 2012). Due to global efforts to reduce CO_2 emissions, the operational definition used in this research will be CO_2 neutral. "CO_2 neutral is the situation in which after one year of measurements, the fossil energy use (and related CO_2 emissions) within the defined territory is a maximum of zero, total energy use in not more than all the energy supplied to the system from renewable sources " (BuildDesk, 2007).

Synergy

Synergy in this research refers to the interaction of two or more agents or forces so that their combined effect is greater than the sum of their individual effects (Freedictionary, 2017). It can also be described as the action of two or more substances, organs, or organisms to achieve an effect of which each is individually incapable (Morris & William, 1991). As such, integrated design comes close to this and there are certainly integrated designs that have synergies however, there are crucial differences. Integrated design is defined as combining or coordinating separate elements so as to provide a harmonious, interrelated whole (Dictionary, 2017).

§ 1.3 Research objectives and research questions

Research objectives

The background describing environmental urgencies in urban landscape system and the lack of a framework to plan for synergies, lead to the following

This research aims to develop an approach for the transition to a liveable low carbon city and explore potential urban synergies to improve quality of live. What approach for urban landscape planning can be developed to achieve this?

Even when an integrated approach is foreseen, a lot of planning is still focused on separate sectors. A synergetic planning approach that serves different aspects of quality of life as well as city services will be helpful to also render cities more sustainable. The Urban Ecology discipline is one of the angles used in this research as a basis to build a framework for synergetic urban landscape planning.

This framework can be used by all those involved in working on sustainable and liveable, low carbon cities from a spatial perspective, such as urban policy-makers, landscape architects, urban planners and other related practitioners.

The main objective is to develop an integrated approach to urban landscape planning for the transition towards a liveable low carbon city and for exploring potential synergies to improve quality of life. So, the primary research question can be formulated as what such an approach or approaches might look like, how it might work and what building blocks it consists of?

To reach this main objective, secondary research questions are formulated per chapter and can be found in the thesis outline.

Consequently, these questions are applied to the context of the city of Rotterdam, as an urban landscape system.

Research questions

Primary research question one: what is a possible urban landscape planning approach to help transition to a liveable, low carbon city

I How should we link the urban flow of thermal energy to urban planning while making use of heat waste flows to reduce carbon emissions?

II What are the built environment's energy (heating) requirements in the city as well as its related CO_2 emissions?

III What is the potential for renewable energy in the city?

IV What are the spatial/technical concepts for tuning demand and supply of heat and cold in cities?

V What stakeholder based energy scenarios might be possible in the city and how can we define them?

Primary research question two: what is a possible approach for synergetic urban landscape planning (SULP)?

VI **Functions**: What elements should be part of a conceptual model for a sustainable city with the goal of developing an approach to urban landscape planning, for the transition towards a liveable, low carbon city as well as exploring potential urban synergies to improve quality of life?

VII **Flows**: How can we deal with urban storm water flows to prevent flooding, improve water quality as well as develop synergies with other functions and city services to improve liveability ?

VIII **Flows**: How can we deal with (heat) energy flows and develop synergies with other functions and city services to improve liveability.

IX **Flows**: How can we deal with urban phosphorus flows and how to develop synergies with urban agriculture and liveability.

X **Areas**: What are potential densification / greening strategies as well as a stakeholder based urban agenda, that improves the quality of life / liveability of the area as well as its sustainability performance? How can this be measured and enhanced using urban data?

XI **Actors**: How was urban ecosystem governance incorporated in local policies and projects and what role, actors such as the local government and inhabitants played in planning, designing and maintaining these goals.

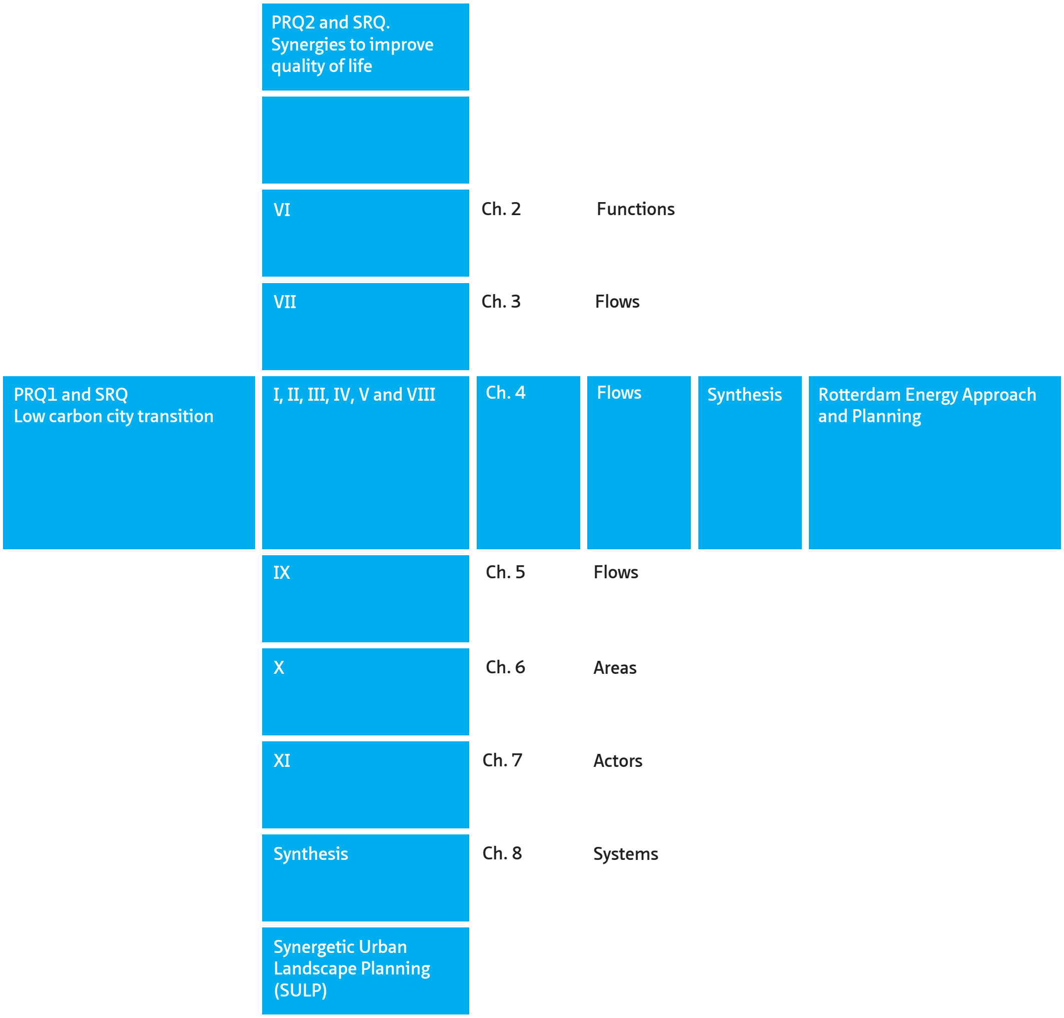

FIGURE 1.1 Interlinkage of the two main research questions, related chapters and key elements.

§ 1.4 Relevance and Scope

Relevance

This PhD is part of the scientific work carried out to support the abatement of global warming by developing an approach for the transition to liveable low carbon cities and the exploration of synergies to improve quality of life.
As energy plays a crucial role in our world, it is surprising to see that energy has rarely been an integral part of global urban planning traditions. Energy and related greenhouse gas emissions have been studied at the built level, but it is at higher scales that there is a lack of knowledge. A lot of new ideas are to be expected by combining the technical world of energy with the creative world of urban landscape planning; landscape architecture. Cross overs from the perspective of energy, urban water systems, nutrients and other processes emerge when planning for synergies.

Final products & contribution to science

Scientific results: the outcome of this PhD will provide insight into how data on energy and CO_2 as well as planning principles and stakeholder involvement can be used and translated in synergetic urban landscape planning and policymaking to improve quality of life in cities. This will allow energy and CO_2 to become a major theme in urban landscape planning while improving quality of life.
Practical result: with the knowledge gained, combined with existing approaches, a new approach will be built. This can help provide insight into the effects of various planning choices concerning liveable low carbon cities as well as synergetic urban landscape planning and its guidance thereof. The approach(es) should be easy to understand and flexible in use. It should be a bridge between CO_2 and liveability goals on one hand and urban landscape and sustainable development principles on the other.

Boundary conditions

Although the object of study is urban landscape systems and in particular, the urban landscape system of Rotterdam, this research will not focus on the systems approach itself. This research will focus on a few subsystems and parts of Rotterdam. These subsystems are those linked to water, energy and nutrients within the area of Rotterdam as well as associated city actors.

This research is about energy consumption and CO_2 neutrality in the built environment at the neighbourhood- and city scale. Other greenhouse gases are not the main focus. Separate buildings will be used in this research but the main focus is from the building

scale up to the level of neighbourhoods, cities and city regions.
Apart from chapter four, which covers CO_2 calculations, mapping and scenario planning there will be few CO_2 calculations as all other chapters' deal with low carbon issues in an indirect – albeit no less important – way. As Maarten Haijer noted 'In my view the climate crisis is also a crisis of imagination. If you do not picture a world without CO_2, you continue to be ruled by fear. Designers have the role to imagine the unthinkable. To me images are a very important concept: you have to think through images on the unprecedented future. Those images can structure what we do' (Galama, 2016).
The second part of this research deals with exploring synergies. Improving urban qualities that benefit a low carbon urban system (in)directly, such as low carbon effect due to recycling nutrients, having a safe living environment or improved circumstances for bike use. These are often the intended synergies when planning for different challenges.
In this research, the exploration of potential synergies in urban landscape planning will be more descriptive than analytic. However, outcomes of analytical research from other sources are sometimes used.

§ 1.5 Thesis Outline

This PhD thesis consists of five parts: 1. Introduction 2. Research approach 3.Urban landscape flows 4. Urban landscape strategies (-areas and actors-) 5. Synthesis and outlook
There are eight chapters including the introduction. In chapter two, urban ecology, landscape architecture and governance are used to build a methodological framework including the framing of functions and indictors for a sustainable and low carbon city. In the following chapters three, four and five, the research studies water, energy and nutrients from a flow and urban metabolism perspective. Chapters six and seven show the practical approach in areas involving different actors. Each step can use the outcomes and approaches of the previous steps and evolve from there. An overall synthesis will be made in chapter eight and an outlook will be given for a follow up [Figure 1.2].

A bridging text between each chapter links the specific issues at hand with the main line of this research. This format is also used by (Roggema, 2012).

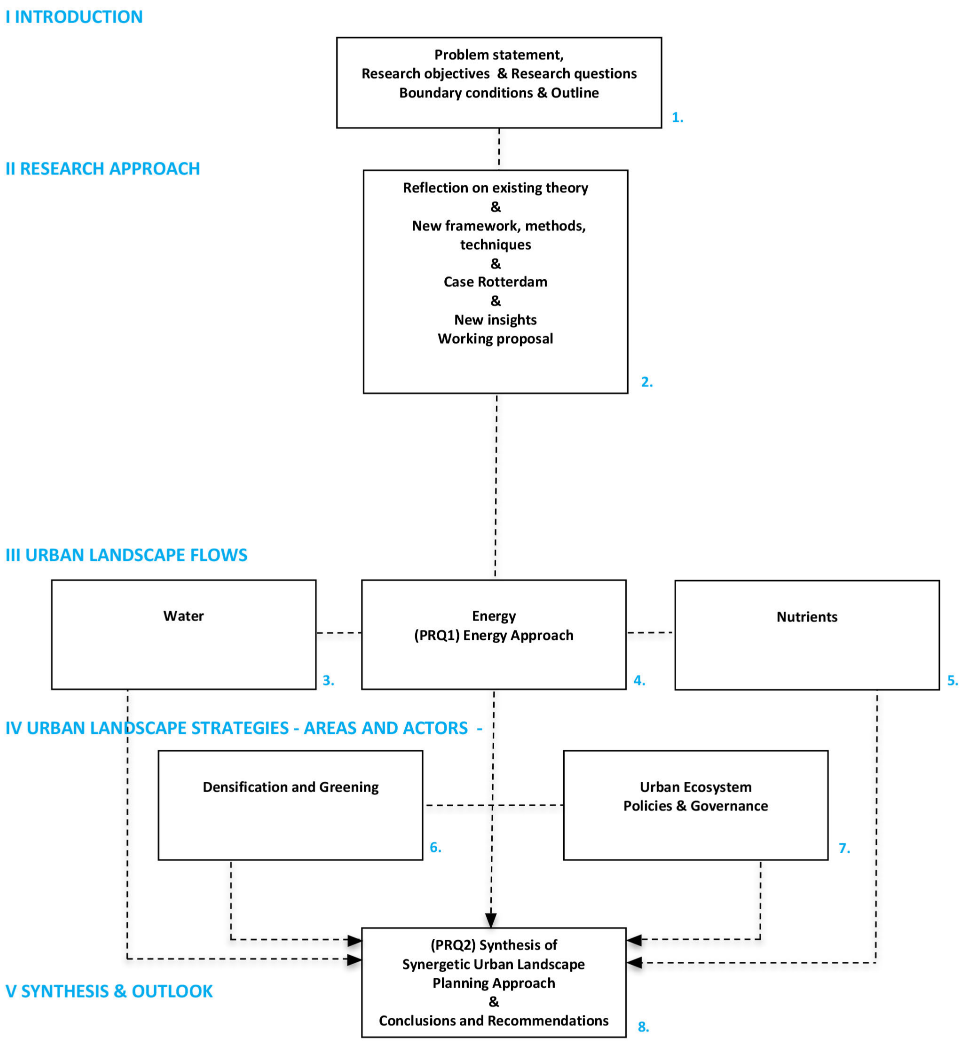

FIGURE 1.2 Thesis outline

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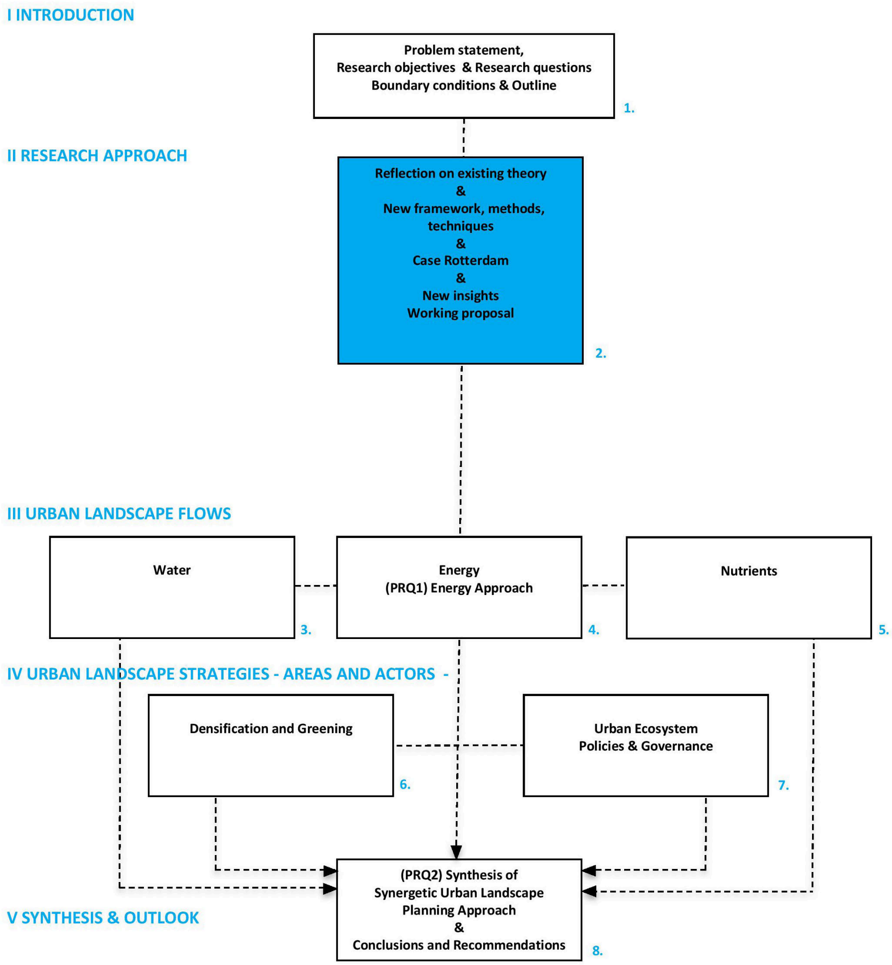

FIGURE 1.3 Bridging one to two

Bridging one-two

In chapter one, the playing field of this research was defined while zooming in on the background, boundaries, objectives, and research questions. Throughout this PhD thesis, Urban **systems, functions, flows, areas** and **actors** are aspects that play a crucial role. The methodology will be elaborated on in chapter two.

Chapter two can also be related to urban **functions**. A methodological framework is created using theories, methods and techniques that were studied in urban ecology from the perspective of ecology. Theories such as 'Cities As Urban Ecosystems' and the Ecopolis strategy provide a good overview of different aspects as well as bridge the gap between landscape architecture and spatial planning. These theories provide support to taking a closer look at landscape architectural and planning frameworks such as Swarm Planning.

While working on projects in practice it became clear what many authors and practitioners have already stated: one of the biggest components to fulfil **urban functions** is the **actors**.

The use and application of principles of urban ecology, landscape architecture, spatial planning and governance in practice was very valuable and helpful in the selection of elements to be used in a conceptual model and the methodological framework. This produced and supported the line of reasoning and research throughout this thesis.

PART 2 Research approach

2 Methodological framework

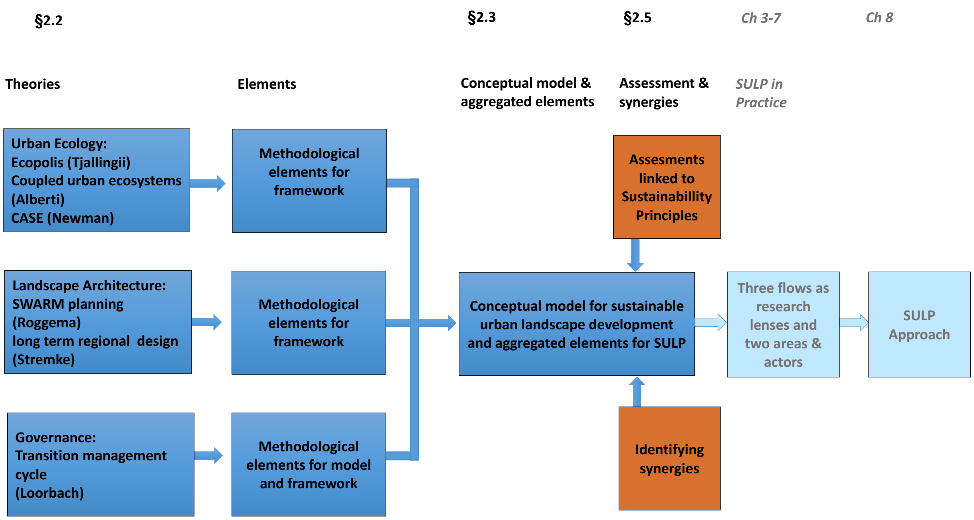

FIGURE 2.1 Outline chapter 2 and follow up in other chapters

Note in advance

In Paragraph 2.3.1, (adapted) pieces of text are used from a double peer-reviewed conference paper at SASBE 2012 and an online paper with Public Sector digest in 2015

- *Tillie, N., Kouloumpi, I., Dobbelsteen, A.van den (2012), City Rankings and urban performance tools to help accelerating sustainable development in cities, SASBE2012 Sao Paulo*
- *Tillie, N., Heijden R. van der, (2015), Rotterdam's smart city planner: using local and global data to drive performance, Public Sector Digest London Ontario: https://www.publicsectordigest.com/article/rotterdam's-smart-city-planner-using-local-and-global-data-drive-performance*

§ 2.1 Introduction

This chapter presents the methodological framework of this research.

The main research question is:

What is a possible framework for urban landscape planning for the transition towards a liveable, low carbon city and he exploration of potential synergies to improve quality of life?

Quality of life can be divided into spatial, environmental, socio-economic and economic issues and synergies between them. As it is a broad topic to address, in this thesis it will be approached from the perspective of the ISO37120 standard: city indicators for city services and quality of life.

Different theories will be studied, relevant elements will be extracted, and new insights will be added to existing theories with the goal to formulate different elements for a synergetic urban landscape planning (SULP) approach, which can be applied to real cases in cities worldwide [Figure 2.1]. For performance measuring, the SULP approach is linked to sustainable development principles and internationally standardised performance indicators on city services and quality of life as well as to local performance indicators.

§ 2.1.1 Research method

Cities, or urban landscapes are complex systems (Stolk, 2015). They are all unique. Among many other elements they differ in:

- Phase of transition;
- Phase and topics of addressed challenges;
- Potentials;
- Political context;
- Historical geographical context;
- Location, topography;
- Climate;
- Social-economic and cultural aspects.

Because of these differences as well as the broadness of sustainability topics, different approaches and frameworks with a modular set-up are studied; this also aligns with the argument of Roggema (2012). Modularity introduces flexibility and allows for elements or building blocks to be used in another context or framework.
As we are looking for potential synergies between spatial, environmental and socio-economic functions, models will be used from these three different angles. First, from an urban ecological perspective, this angle focuses on the environmental aspect. From this perspective the Ecopolis strategy (Tjallingii, 1995), 'the integrated framework for coupled urban ecosystems' (Alberti, 2009) as well as 'Cities As Sustainable Ecosystems', the so-called CASE model (Newman & Jennings, 2008) will be studied. The spatial aspects are approached from a landscape architectural and spatial planning perspective, Swarm Planning (Roggema, 2012) and the 'methodological framework for long term regional design' (Stremke, 2012) theory is used. The socio-economic domain in this thesis comes forward mainly through performance studies on quality of life. However, a crucial aspect in synergetic planning is stakeholder involvement and governance (Roorda, 2012; Tillie, 2012a). From a governance perspective, transition management (Rotmans, 2008; Loorbach, 2010) is used.

Elements from these different frameworks and theories will be used and tested in various forms in the next chapters. Through this, day-to-day urban challenges in existing urban areas will be addressed. In order to do this, a case study city is selected. After applying and testing, the results will be used to synthesize a synergetic urban landscape planning (SULP) approach for a low carbon city in chapter eight.

§ 2.1.2 Case study city

In order to work towards a SULP approach the selected elements and methodology needs to be tested in a city in existing projects. For this research, the city of Rotterdam, in the Netherlands is used as a case study. The case study city is selected on the basis of a few parameters:

- Easy access to the city, data, projects, stakeholders and policymakers;
- A city that is going through a transition to deal with climate change, energy challenges, as well as socio-economic issues;
- A city that is active in dealing with challenges and has a tradition in urban planning and can be an example for other cities;
- A city that links to small and medium-sized cities (up to 200,000 inhabitants) as well as to megacities (more than 10 million);
- A city that is active in international networks on sustainable development topics such as food, energy and water, and that provides a platform for further development.

Rotterdam applies to all of these parameters and it has been very valuable to work there.
In the past years, seven vision documents combined with action plans were produced in Rotterdam covering a number of urban systems, flows, and sustainability principles. These vision documents range from an overarching city vision in 2007 to a vision on urban green, climate adaptation, densification, urban agriculture, public space and energy.
In addition, three long-term vision documents were produced within the context of the International Architecture Biennale Rotterdam (IABR2005, 2012, 2014). Other plans related to the metropolitan region or provincial or national level. Furthermore, there were several plans implemented such as the renewal of the Museumpark in Rotterdam. All projects are related and used in this PhD thesis. The author was involved as a landscape architect and, in most cases responsible for project content.
Another valuable project initiated by the author, and fed into several vision documents was the European Interreg IVC project called MUSIC (Mitigation in Urban Areas Solutions for Innovative Cities), in which the governance model of transition management was linked to spatial models and tested with stakeholders in five different cities. Different experiences in this work have led to key elements to strengthen existing frameworks such as the use of city data and mapping tools. Outcomes of this will be covered in chapter six.

Before discussing the research done in Rotterdam in chapters three to seven, a theoretical study of existing theories and frameworks will be presented to create an overview of relevant existing work as well as extract elements for a conceptual model and methodological framework and later on for the SULP approach in chapter eight.

§ 2.2 Theoretical background: three perspectives

Sustainability is the direction of the proposed urban transition in this thesis. As Bossel (1998) describes, sustainability in an evolving world can only mean sustainable development! A definition of sustainable development often quoted from the Brundtland report of the UN: "a development that meets the needs of the present without compromising the ability of future generations to meet their own needs". (Brundtland, 1987). A more recent definition is "Sustainable is everything future generations want to inherit, use and maintain" (Kristinsson, 2012).
Within the wide framework of sustainable development, an urban ecological, landscape architectural and governance perspective will be discussed.

§ 2.2.1 Urban ecological perspective

Forman (2014) defines urban ecology as the interactions of organisms, built structures, and the physical environment, where people are concentrated. Until recently, urban ecology has been predominantly approached from an ecological perspective. Alberti (2009) called for other professions and research angles to enrich the urban ecology domain. Because the main goal is to help cities transition to sustainable cities using the model of cities as urban ecosystems, landscape architecture becomes a key domains.
A main question in urban ecology related to the previous statement is: what is the role of humans in urban ecology? Forman (2014) discusses that "it seems wiser to maintain and further build on the core strength of ecology, with its basic focus on plants, animals and microbes. Sister disciplines and professions will welcome and use principles developed by a strong urban ecology". This might raise some questions about where humans stand in relation to nature. This debate, as Forman (2014) formulates, "A human-as-inside-or-outside-of an ecosystem discussion is endless (McDonnell and Pickett, 1993; Alberti et al., 2003; Head and Muir, 2006)".
From the perspective of a purely natural environment or conservation of these areas

without 'direct' human influence this is a most valuable approach. From a landscape architectural perspective in non-urbanised areas, this approach is the cornerstone for restoring and maintaining ecosystems, and gaining a better understanding. However, in urban landscapes, which are more influenced by humans, more knowledge is needed to not only understand relations, but also design and anticipate for them. Sijmons (2014) specifically states that humans are part of nature and he uses this perspective to approach these phenomena, using urban metabolism (Sijmons 2014; Tillie, 2014). Also, Alberti (2009) argues that taking the standpoint of accepting humans as part of the ecosystem might gain new insights; she discusses the concepts of cities as hybrid ecosystems and mentions that

"urban ecosystems are not different from other ecosystems simply because of the magnitude of the impact humans impose on ecosystem processes, nor are they so removed from nature that ecosystem processes become only a social construct in themselves. If we conceptualize such systems purely in ecological or human system terms, we limit our ability to fully understand their functioning and dynamics (Collins et al. 2000, Alberti et al. 2003)."

As a result we would also limit ourselves in identifying valuable synergies between these systems. Landscape Architecture is one of the disciplines well positioned to generate a connection and combine the natural as well as human aspects.

Newman & Jennings (2008) share Alberti's viewpoint but approach the 'cities as ecological system model,' as Forman (2014) frames it, from a more social and governance perspective. The ecosystem viewpoint they use for cities is also "an inclusive one that sees humans as part of local socioecological systems from bioregions to biosphere. The focus is on relationships and processes that support life in its myriad forms, especially partnerships and cooperation".
Also, Tjallingii (1995) links these aspects. Flows such as water, energy and food are studied in the Ecopolis strategy, this is referred to as 'the responsible city'. Areas are called 'the living city' and include the provision of quality to urban areas for different people and lifestyles (social diversity) as well as a variety of other forms of life such as plants and animals (biodiversity). Tjallingii states that the Ecopolis cannot be achieved without the partnering of citizens and other stakeholders; 'the participating city'.
Alberti (2009) points out that only recently, various disciplinary approaches have been combined to study the interactions between complex human behaviours and ecosystems functions in urban ecosystems, and the concept of ecosystem functions has been expanded to include human and ecological components. "Urban ecosystems consist of several interlinked subsystems – social, economic, institutional and ecological – each representing a complex system of its own and affecting all the others at various structural and functional level."

An integrated framework is proposed by Alberti (2009) [Figure 2.2].

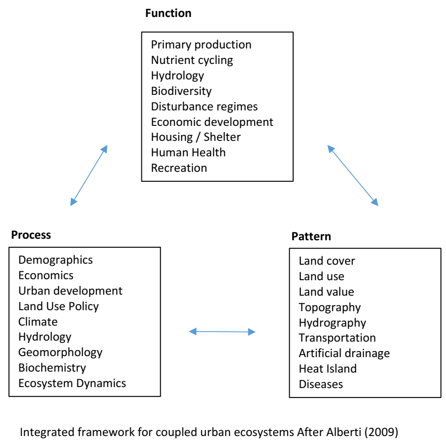

FIGURE 2.2 Integrated framework for coupled urban ecosustems after Alberti (2009)

Newman & Jennings (2008) describe the concept of 'Cities as Sustainable Ecosystems' (CASE). They state:

"Cities are viewed as ecosystems in themselves, with materials, energy, flows, and complex information systems like any other ecosystem. The city-as-ecosystem approach is a useful way of viewing city dynamics, but the idea of CASE goes further by examining the lessons from sustainable ecosystems to address the unsustainability of current city ecosystems. It offers solution to our current predicament and provides a framework for action and ecological restoration within the city and its bioregion."

A crucial step is to create a local urban performance tool that links to an international context. One needs to be able to identify shortcomings, challenges and opportunities before restoring can begin. As such, this is one step further and requests the definition

and filtration of principles of which some are applicable to this research.
Forman (2014) underpins that for understanding an urbanised area and its urban ecology, the models used need to be spatial. This links the 'pattern' element in Alberti's (2009) proposed framework **[Figure 2.3]** to landscape architecture. Patterns of abiotical, biotical and anthropogenic factors touch the basis of landscape architectural theory and environmental design (Kerkstra, 1976; McHarg, 1969). As in McHarg's layer approach, mapping is in this respect a fundamental analytical tool.
Forman (2014) mentions that maps are models in itself. Next to the Greenbelt model, Urban to rural gradient model and others, the City as an ecological system model (CASE) can also be classified as an urban form model. The CASE model which according to Forman (2014)

"goes well beyond specific ecosystem characteristics to provide a broad multi-dimensional approach for understanding an urban area (Alberti, 2008; Newman and Jennings, 2008). The model may include: principles of form and function, diversity, adaptiveness, inter-connectedness; resilience, regenerative capacity, symbiosis, holism, systems interaction between parts; processes, complexity, hierarchical and context factors; flows of energy material and information (Grimm et al., 2000); city-shaping relative to transportation patterns; self-organisation (zero waste, self-regulating, resilient/self-renewing, flexible) (Bossel, 1998); and ecological succession. This array of characteristics of course represents a wish list of recommendations for future study and modelling."

This wish list actually puts the CASE model in a wider research agenda, which is too broad for this PhD thesis alone. The question that will be focused on here, is: what and how this can be used in this thesis to plan for sustainable development and promote additional synergies?
One of the leads taken from this literature review is to assess city services, functions and processes. Also to study spatial issues and how they are interrelated with these services, functions, and processes, in order to come up with an urban landscape planning agenda which provides for synergies for a SULP agenda. However, as synergies are not just spatial and are often hidden in unknown combinations, opportunities or stakeholder's minds, it is crucial to involve stakeholders on spatial, environmental, economic, and socio-cultural aspects. A long-term stakeholder-based vision and a governance model are helpful within this. In the next two paragraphs, the landscape architectural (urban landscape planning) and governance framework will be discussed.

§ 2.2.2 Landscape architectural – urban landscape planning– perspective

To (re)build cities as sustainable ecosystems and find out what approach to follow, urban ecology is approached from a landscape architectural perspective. These two worlds meet at connected integrated themes [Figure 2.3]. These connected integrated themes are key to potential synergies. A simple example is the design of parkways to structure a city and regulate its water functions on a large scale while also make it accessible for biking and walking. This can be designed in a very technocratic way using concrete quays or making use of natural elements such as soft water edges providing gradients for other forms of life.

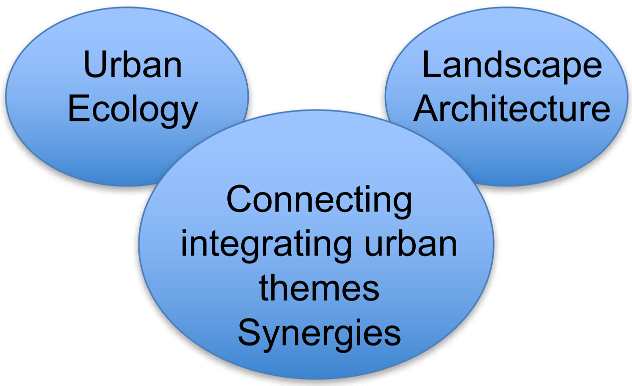

FIGURE 2.3 To (re)build cities as sustainable ecosystems and find out what apprach to follow, urban ecology is approached from landscape architectural perspective. These two worlds meet at connected integrated themes.

Existing landscape architectural and planning frameworks

To connect these integrated themes and ultimately look for synergies, it is important to connect these themes to a larger framework. From a planning perspective, a number of planning frameworks are available, such as the 'Layer approach' by Frieling (1998). Meyer & Nijhuis (2016) place this 'Layer approach' in a tradition that came from the 1970s, since they noted: 'landscape architects and urban designers have tried to conceptualize mutual relations between different processes using a 'layer approach'— where substrate, infrastructures and land-use patterns are regarded as different urban layers with different speeds of change — based on the theories and methods of Braudel (1966) and McHarg (1969).' Frieling et al., (1998) define three layers for different timeframes or 'rhythms'. Roggema (2012) extends this approach in his Swarm Planning theory to five layers and introduces different scales and time horizons.

Another influential approach in landscape architecture is the 'framework model' ('Casco-concept' in Dutch), developed by Kerkstra & Vrijlandt (1990, 1991) and Sijmons (1991). The 'framework model' is a regional design approach based on designing strong frameworks for sustainable landscape development. As Meyer & Nijhuis (2016) describe,

"An important basic premise of this model is to deal with time, uncertainty and (shifting) responsibilities based on the physiology of the landscape. The framework model strives to create a pattern of inter-connected zones in which long-term, sustainable conditions for 'low dynamic functions' (such as nature reserves) are provided, as well as envelopes: expanses of land in which dynamic functions, such as urbanization, recreation and agriculture, can flourish."

The breakthrough project of this model was the winning entry of the EO Wijers competition, Plan Stork (Plan Ooievaar) (De Bruin et al., 1987).
Two more recent frameworks will be discussed below. In paragraph 3.5.1 and 3.5.2 more existing planning frameworks and approaches are discussed in relation to water.

Five-step approach

In his methodological framework for long-term regional design, Stremke et al. (2012) five-step approach gives an overview of building blocks and combines components of earlier studies from design-oriented planning to spatial planning and landscape architecture. The five-step approach [Figure 2.4] can form a basis from a spatial perspective and create the main research objective focused on spatial interventions and impact. However, the governance as well as potential synergies needs to be addressed more.

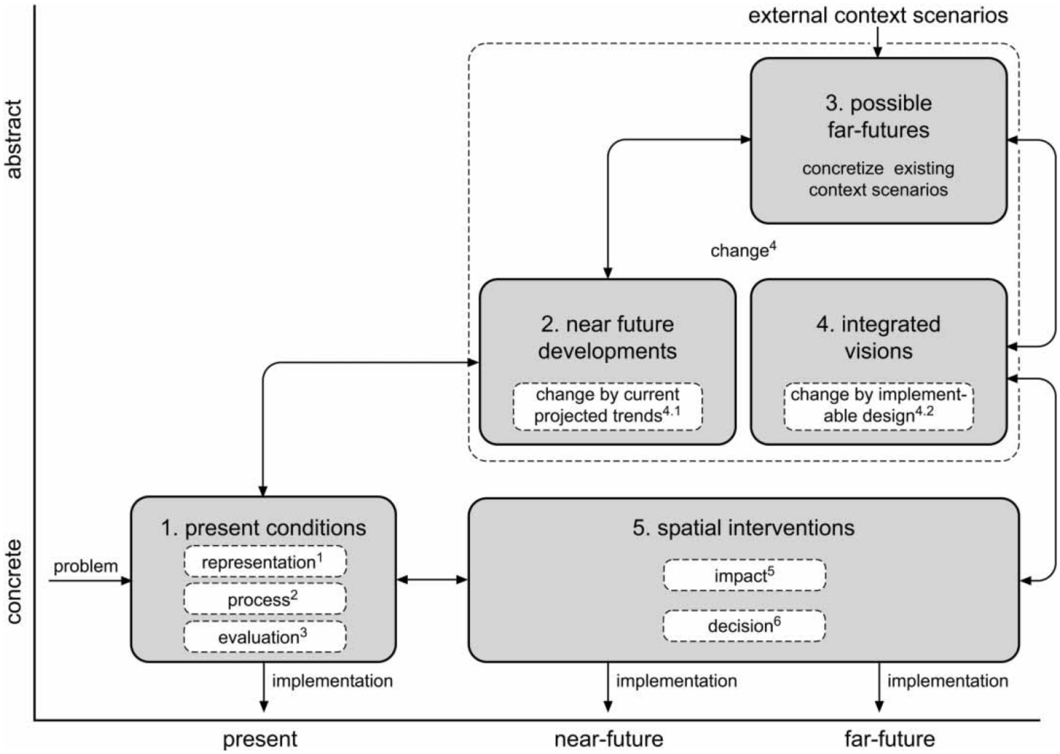

FIGURE 2.4 Five-step approach (Stremke et al., 2012)

The five steps in the five-step approach are as follows: analysing present conditions; mapping near-future developments; illustrating possible far futures; developing integrated visions, and identifying spatial interventions. It also has the elements of a classical iterative design process, going back and forth between phases and scales. However, this framework should be strengthened with a governance framework. The involvement of a wide range of (specific) stakeholders is a crucial part to identify synergies and make them useful for sustainable development and synergetic urban landscape planning.

Swarm Planning theory

Roggema (2012) introduces the Swarm Planning theory [Figure 2.5], which enables a spatial system to reach a higher adaptive capacity to adapt to new sudden changes in circumstances or environments. Natural disasters or effects of climate change may involve such changes.

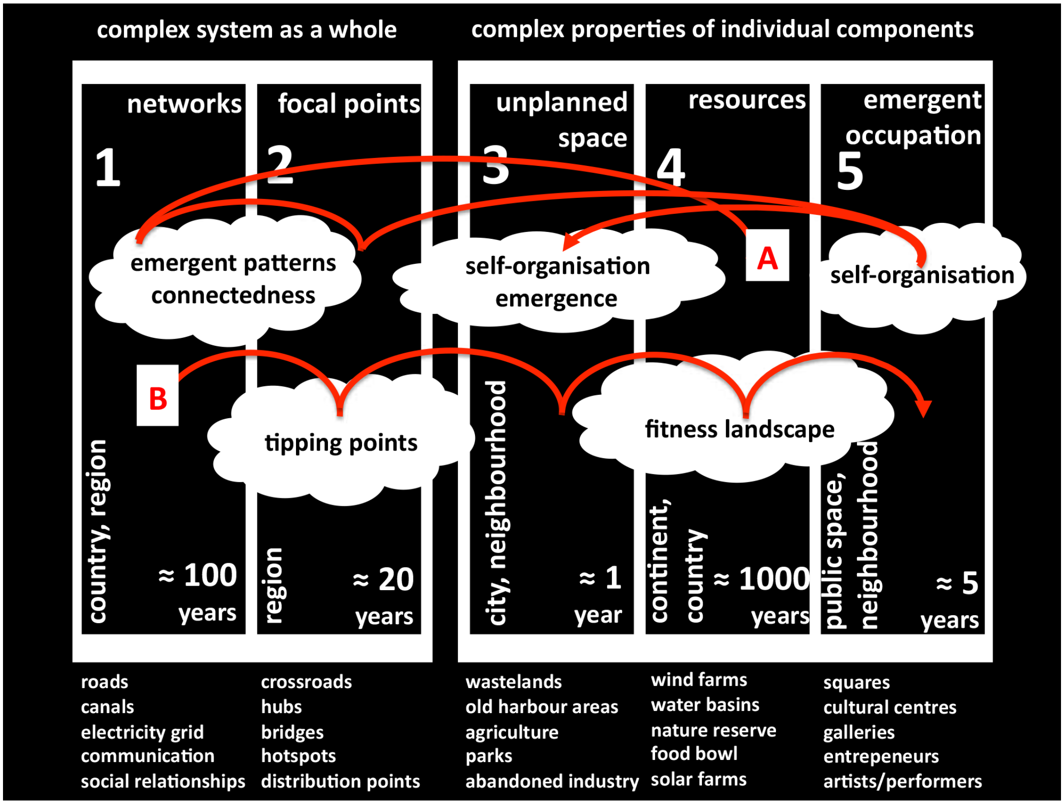

FIGURE 2.5 Swarm Planning (Roggema., 2012)

Related to urban landscape systems

Roggema (2012) uses two levels of complexity that are distinguished by Portugali (2000), the city as a whole and its complex individual components. Different components of the urban landscape system are described and can be seen as complex adaptive entities. Together these systems can self-organise and essentially act as a whole system and by doing so develop -in case of a crisis - into a higher level of adaptive capacity. What is important is that adaptive properties are attributed to the different components.

Areas (patterns, forms, structures)

Furthermore, the five layers are distinguished and coupled to time horizons belonging to each layer and scale as shown in [Figure 2.5]. Related to this, Roggema (2012) mentions

‘Climatic trends, which are seen as developing over a long period and at larger scales are downscaled to dimensions that are closer to current development needs and the context institutions operate in, the preferred domain of spatial planning. The Swarm Planning Framework fills up the gap between the ‘long-term-large scale’ climatic trends and the short term-small scale of the majority of spatial planning practice.’

Roggema points out that the networks and focal points (1 & 2) are important as they can influence the whole system while unplanned space, resources and occupation patterns (3, 4 & 5) mainly have an impact on ‘complex behaviour’ on the level of individual elements.

Processes (flows)

Urban landscape systems are approached with complexity theory, Roggema (2012) links this theory to complex adaptive processes, such as *emergence, self-organisation*, the *fitness landscape, connectedness* and *tipping points*. Also, the spatial elements that are part of one or more layers are coupled. To link this theory - which is successfully tested in projects – to urban landscape planning these complex adaptive processes are briefly explained in relation to the five spatial layers and its elements.

According to Roggema (2012) new (spatial) patterns can develop from networks (1) and focal points (2). Intensive used networks and, as a result nodes, lead to more connectivity or *connectedness* ,which leads to a higher probability of new patterns emerging in such a case. Especially in focal points (2) which are intense and combine certain functions, activities and events there is a possibility that they behave like a *tipping point* so the existing system will have more and more changing properties until it transits into a new system.
When there is more room for development and/or change, *self-organisation* and *emergence* is more likely to happen. A fixed spatial configuration does not offer a lot of room for change. Unplanned space (3) allows for other spatial components, actors ,or agents to come in. The probability of self-organising processes taking place in those situations is very high.
In the Swarm Planning theory, the fitness landscape is largely related to natural resources (4) linked to the ecological system. This provides the basic conditions of a landscape where processes such as soil formation takes place over a long period of time. Resources such as clean water, clean energy, nutrients & food thrive in a stable environment as natural processes take place. It is also linked to self-organising processes in unplanned space (3) as well as emergent occupation patterns (5). Both can change conditions rapidly and turn into chaos and crisis, and force a system to transit into a new one. Roggema (2012) mentions "Changes happen very slowly in

these systems until the system no longer can function properly. At that moment, the system jumps to a new state where it can operate in a stable way. The continuous search for this most optimal stable state is called fitness landscape." Interaction between functions, a wide range of spatial elements and people may lead to new occupation patterns (5) In many cases being the network focal points they self-organise into new patterns.

Throughout this thesis different aspects of the aforementioned frameworks are used. In the next paragraph stakeholder involvement and governance will be explored.

§ 2.2.3 Governance and institutional perspective

The main input for this research comes from the MUSIC Interreg IVC project in Rotterdam, in which governance played a crucial role. This project was initiated by the author and was part of this PhD. When looking at the five cities in the MUSIC project, it was discoveredthat available low-carbon techniques were not a lot being applied in the city. Aditionally, a merely technical approach was often not successful at that moment.

Lehmann (2010) notes: “With all this technological progress, we should not lose sight of the fact that a key component in any society’s sustainability is more than its carbon footprint. The future of our societies is not just merely a technical matter of finding eco-friendlier energy solutions, but a question of holistic social sustainability and healthy community.”
The city of Rotterdam concluded that societal change and involvement of citizens and other stakeholders was necessary. To accelerate and spark change in multiple layers of society and ignite new projects, the transition management model of Rotmans (2008) and Loorbach (2010) was introduced in the MUSIC project cities: Rotterdam, Gent, Ludwigsburg, Aberdeen and Montreuil.
Loorbach (2010) points out 'governance processes based on transition management had been developed in various sectors and regions over the past 10 years'. These are designed to create space for short-term innovation and develop long-term sustainability visions linked to ‘desired societal transitions’. For several challenges in the city – in fact applying sustainability principles - this was done.
Meadowcroft (2005) describes transition management as follows:

"First, the theory has a modular structure, with several elements being combined to produce the whole. Particular components include: the image of the transition dynamic with the distinct stages of the transition process; a three level analytical hierarchy of 'niche', 'regime' and 'landscape' that provides a framework for understanding transition processes; a basket of future oriented visioning devices (goals, visions, pathways and intermediate objectives); a practical focus for activities (arenas and experiments); and a broad 'philosophy of governance' that emphasizes decision-making in conditions of uncertainty, and the gradual adjustment of existing development pathways in light of long term goals."

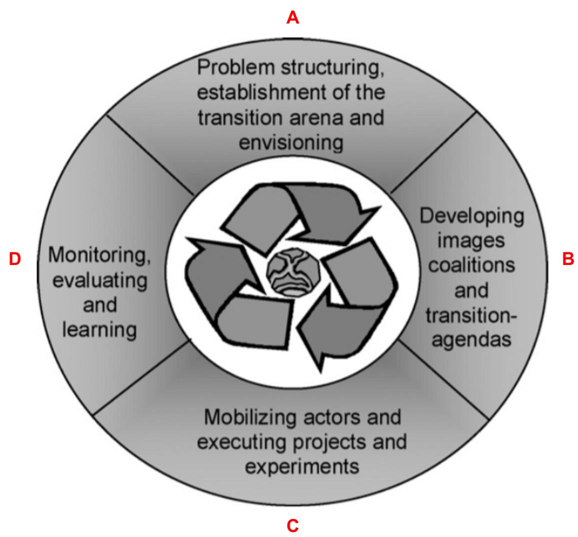

FIGURE 2.6 Transition management cycle after Loorbach (2010)

Steps in transition management

In the guidance manual for the MUSIC project (Roorda et al., 2012) note: "A central instrument in this approach is the transition arena, a setting that provides an informal but well-structured space to a small group of change-agents from diverse backgrounds (businesses, government, research institutes, citizens)." This is organised in such a way that it helps to build a group of ambassadors that are inspired to go beyond current interests and daily routines. The participating change agents engage in a series of meetings to jointly develop a new and shared visionary story, which they can directly link to their own everyday practice. The arena group has a temporary character and subsequently works on structuring a transition challenge (phase III) [Figure 2.7 & Table 2.1], drafting visionary images (phase IV) and developing transition paths and a transition agenda (phase V). The outputs guide the search for strategies to transform existing structures, cultures and practices and to realize new projects, collaborations and experiments. The transition management cycle [Figure 2.6] can continue to fine-tune this process.

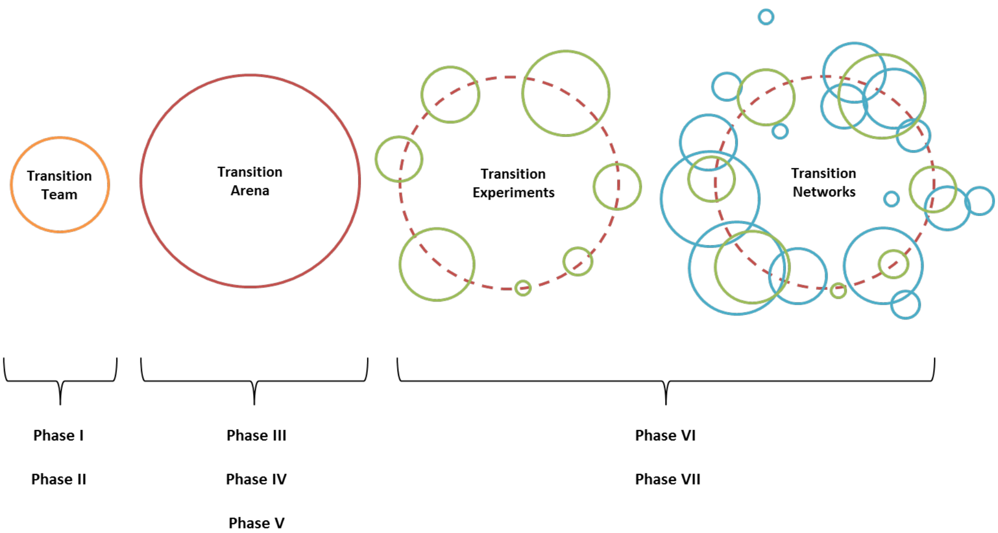

FIGURE 2.7 Different phases in transition management after Roorda et al. (2012)

PHASE		PROCESS STEPS
I II	Setting the scene for Transition Management Exploring dynamics in your city	The Transition Team is formed to drive the TM process and start to explore the cities dynamics (takes about 3-6 months)
III IV V	Framing the transition challenge Envisioning a sustainable city Reconnecting long term & short term	The Transition Arena group is formed and engages in a series of meetings to jointly structure the transition challenge, draft visionary images and develop transition paths and a transition agenda (takes about 6-12 months)
VI VII	Getting into action Engaging & anchoring	Effort is put into dessеminating the vision and transition agenda; initiating actions in line with the vision (transition experiments); and engaging more actors and netwoks.

TABLE 2.1 Phasing and process after Roorda et al. (2012)

As transition management offers a prescriptive approach toward governance as a basis for operational policy as well as actions; it also helps to embed local policies. By taking sustainable development as long-term goal it is a normative model that perfectly fits to the basic sustainability principles discussed before. As Loorbach (2010) puts it, "as it is through scientific and societal debate in several projects and cities that the thinking and practice of governance for sustainable development advances." The MUSIC project outcomes helped to fine-tune this framework from a data, geo-informational and spatial perspective.

Aggregated elements from the aforementioned theories and frameworks form the building blocks for the methodological framework or SULP approach. But first a conceptual model needs to be built in coherence between the three different perspectives urban ecology, landscape architecture and governance.

§ 2.2.4 First extractions for follow up

As described in these three perspectives, different elements are used throughout this thesis and used in the follow up of this methodological framework. Crucial elements that will be continued are, the integrated point of view and, using design and planning as well as a multi-disciplinary approach. Several overlapping frameworks in all presented perspectives use this. For clarity the different angles from Ecopolis strategy (Tjallingii, 1995); **Flows** (urban ecology), **Areas** (urban landscape planning) and **Actors** (governance) are used to structure this thesis.

§ 2.3 Conceptual model for sustainable development

After studying the urban ecological, the spatial, and the governance frameworks the questions rise: how are they interrelated? What is the relation to sustainable development? And how can these be structured thematically? An advantage of this thematic structuring is that principles and indicators can be linked to the methodological framework and set up a performance measurement system. Bossel (1998) mentions in his theory on constructing a system of indicators for sustainable development six essential parts of the anthroposphere are defined: Individual development, social system, government system, economic system, infrastructure system and environment & resource system [Figure 2.8]. As defined before, not all systems will be covered in depth although all of them are directly or indirectly related. For example, on the economic system Slangen (1960) states 'in essence, economic life is an endeavour to reduce the welfare shortage with limited resources' it links to improving quality of life.

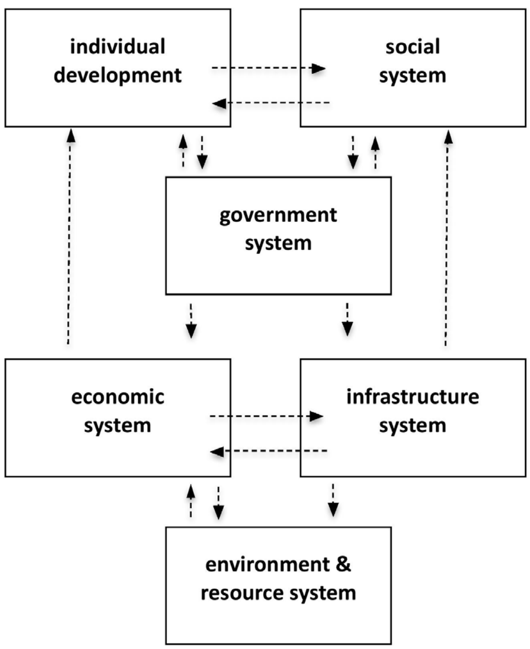

FIGURE 2.8 Major relations of the six sector subsystems of the total regional system after Bossel (1998)

Another important part is the use of indicators. They are crucial in a baseline study to measure progress but also to identify problems, for a better understanding of urban areas and, to answer questions such as: What functions need to be (better) provided for? What processes need to be adapted or what patterns need to be changed to improve? And what synergies can be introduced? In other words, it is crucial to guide the synergetic urban landscape planning process and improve the sustainability performance. Aggregated elements from Alberti (2009) [Figure 2.2] and Bossel (1998) [Figure 2.8] are integrated in a conceptual model [Figure 2.9] for sustainable urban development. The conceptual model will be used as a guideline.

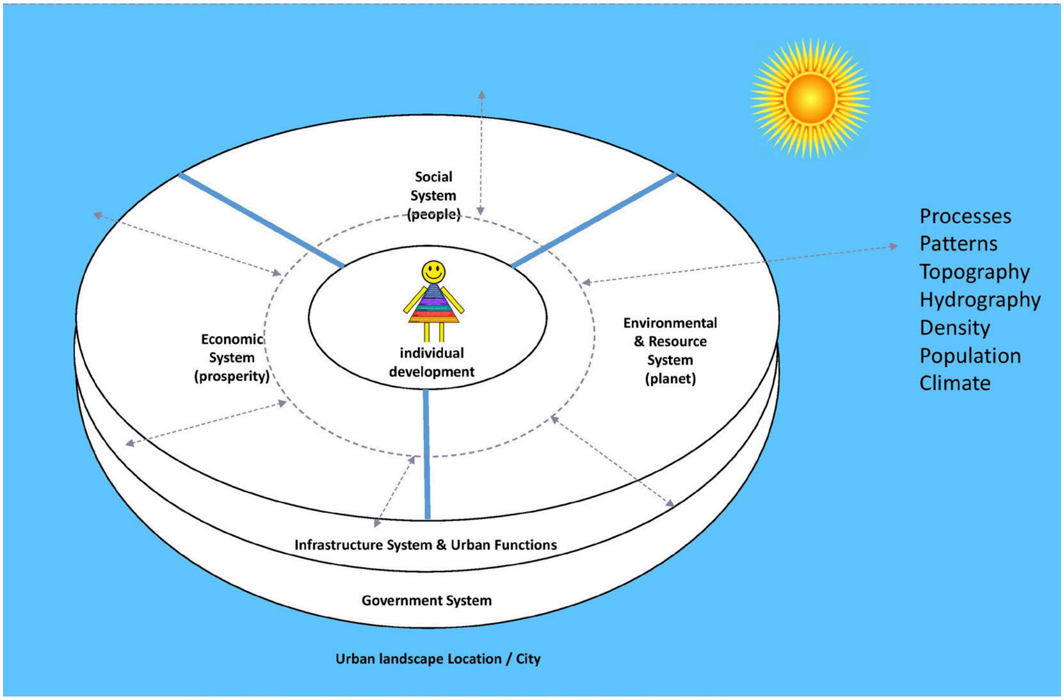

FIGURE 2.9 Conceptual model for sustainable urban development. Aggregated elements from Bossel (1998) and Alberti (2009) show interrelations betreen urban landscape systems functions and patterns.

The next step is to explore principles, indicators and performance tools.

§ 2.3.1 Performances and sustainable development principles

Due to changing leadership and changes in policy focus it is not rare that long-term visions are made every few years or simultaneously but for different challenges in different sectors without synergetic effects. As such each new long-term vision (and its connected policies and projects) is an opportunity to steer the city's transition pathway towards a sustainable one. To have inter-connectedness between these long-term visions, policies and implementations, it is fundamental that these are based on underlying principles about sustainable development and related issues.

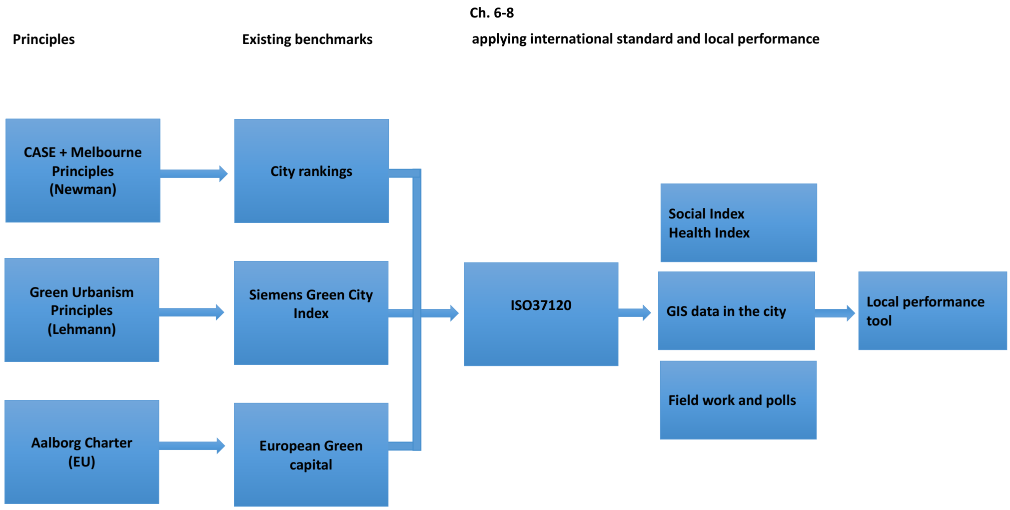

FIGURE 2.10 From sustainable urban development principles to using indictors in the SULP approach.

Principles

In the description of the City as an ecological system model Newman and Jennings (2008) uses the 'Melbourne principles'. These principles were developed at an international charrette in Melbourne in 2002. Later on, local governments at the Earth Summit in Johannesburg.endorsed them. The principles are used to set goals and guide the processes in cities and range from vision making, to partnerships, and how to model cities on ecosystems.
With the Green Urbanism principles, Lehmann (2010) focuses more on the role of urbanism and planning itself and mentions:

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'While urbanism is about to reach a 'tipping point' in regard to its carbon emissions and material waste, urbanism will only ever be green, if we base all urban design and planning on holistic and measurable principles to change unsustainable practice.' As such, measurable principles and use indicators on sustainable development is a crucial part of this PhD research.

There is overlap between ISO37120 standard (see next paragraph) and sustainability principles that can be used in this thesis [Figure 2.11]. There are more sets of sustainable development principles such as the Hanover Principles and the Aalborg Commitments. For this study, the latter one has been included. The Aalborg Commitments were the result of the 4th European Conference on Sustainable Cities & Towns in Aalborg in 2004. The purpose of the event was to develop a common understanding of sustainability, and as a consequence to develop a framework to be used at the local level that would better articulate how to embed sustainability across municipality sectors. The Aalborg Commitments were agreed on and, so far, have been signed by more than 700 mayors from across Europe.

There are more sets of principles which can be used such as the eco system services from an urban ecology perspective (Bolund, 1999). In a global urban landscape perspective, the UN Sustainable development goals have a wide-ranging effect. These were established in 2015 with a view to create a more sustainable world by 2030 (WCCD, 2017). This will be elaborated on. more in chapter eight.

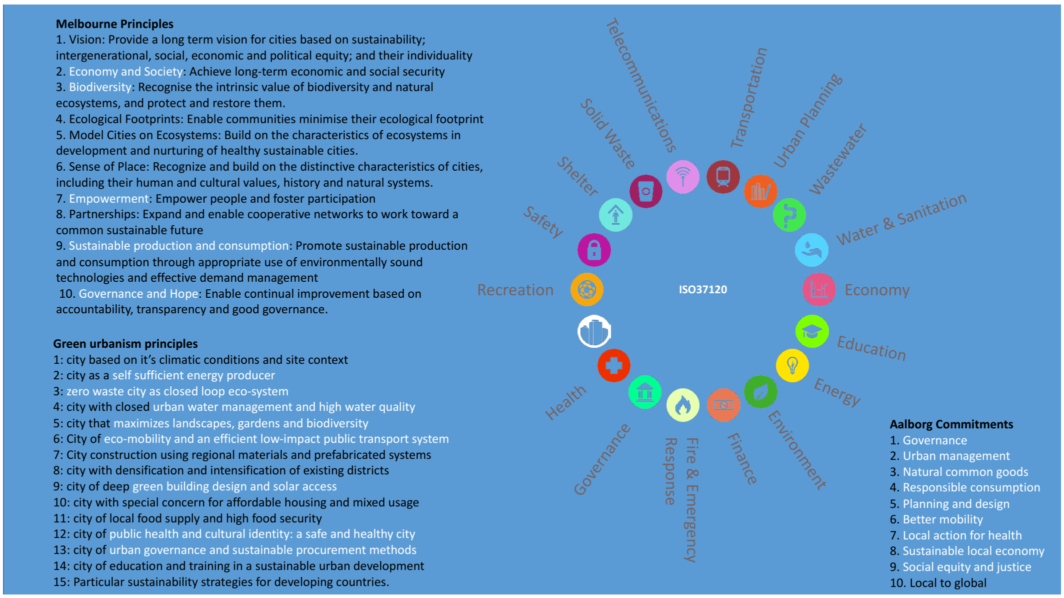

FIGURE 2.11 Highlighted principles can directly be measured using the ISO37120 indicators divided into 17 themes.

Existing indicator systems

Many cities share the goals of becoming prosperous and environmentally friendly. They look to create a high quality of life for their citizens. A transition to a sustainable low-carbon city is part of that. However, a critical question is: how can these goals be accomplished and how can they become self-sustaining? One of the steps a city can take involves leveraging city data and Geographical Information Systems (GIS) to create informative stakeholder information and to develop efficient planning processes for the city.

Sassen (2012), Katz (2013) and Barber (2013) write about the growing importance of metropolitan regions and cities in the global context. Until 2014 (start of ISO37120), it was almost impossible to find high-quality, verifiable data at a city level. Benchmarking can be very helpful for regions, cities, and neighbourhoods to understand the urban system better, to diagnose challenges, and to see where specific improvements are needed. This process can be approached in several ways – both by interacting directly with local citizens by talking to them and interviewing stakeholders as well as by collecting established (as well as new) data about specific issues.

Like a student concerned about a mediocre grade in school, a city should be concerned with its own performance – as well as where it appears in (inter)national rankings. To make these benchmarks useful for improving policies in the City of Rotterdam, available rankings and benchmarks were studied [Table 2.2] (Tillie, 2012).

To collect criteria for the usefulness of rankings in accelerating sustainable development in cities, professionals were interviewed working for the cities administrations of Rotterdam and Almere in the Netherlands. Also, organising meetings about the use of city rankings in cities as well as meetings about entering the competition of European Green Capital were very informative and provided a lot of data. This study builds on earlier studies on urban performances such as Benner et al. (2010) and Roorda et al., (2011).

	RANKING	SOURCE	YEAR	SCOPE
Worldwide	Quality of Living, global city rankings	Mercer	2010	Worldwide Quality of Living
	The Economists's World's Most liveable cities	The Economist	2010	Worldwide, uses Mercer data
	Global Cit Indicators Program	Global City Indicators Facility	2010	Not a ranking, but a broad indicator set developed for global comparability of city performance and knowledge sharing
USA	US sustainable cities	Sustainlane	2008	USA, 50 most populous cities
	Smarter cities	Natural Resources Defense Councils	2008	US cities >250.000 inhabitants, broad range of sustainability factors
	50 Greenest Cities	Popular Science Magazine	2008	US cities >250.000 inhabitants. Main categories: electricity;transportation; transportation; green living; recycling & green
Canada	Sustainable cities Report	Corporate Knights	2010	17 Canadian cities, in three categories by size (small <250.000, medium and big >250.000)
	GreenApple Canada SMART Transportation Ranking Report	The Appleton Charitable Foundation	2008	Canadian cities benchmarked on sustainable planning and mobility
Europe	European Green City Index	Siemens/Economist Intelligence Unit	2009	30 European capitals or major cities focussed on green urbanism and energy
	Smart cities - Ranking of European medium-sized cities	TU Vienna, University of Ljubljana & TU Delft	2007	Europe, 70 medium-sized cities (50.000 - 200.000 inhabitants)
	European Green Capital Award	European Commission	2009	Based on submissions from cities who want to take part in this competition. The competition is focussed on environmental, spatial and social economic parameters
	Urban Audit	Eurostat	2007	No ranking, but a collection of comparable statistics and indicators for European cities
United Kingdom	Sustainable cities index	Forum for the Future	2009	UK, 20 biggest cities
The Netherlands	Local sustainability benchmark	COS Nederland	2009	Dutch cities mainly based on the implementation of people, planet, prosperity parameters

TABLE 2.2 City rankings and urban performances studied (Tillie, 2012)

Although there are several worldwide rankings, the geographical scope of the rankings is mostly restricted to one continent or even one country. As it is difficult to gather information of many cities in a limited timeframe only a number of cities are selected for the rankings. This means that the cities that are not included are often not valued or undervalued.

Geographical, cultural and other contextual differences are not clearly accounted for. Some criteria do not match the indicators. For example, some rankings assess the topic of energy with the indicator ‘energy use per household’ or CO_2 emissions per capita, whereas others only use the ‘number of green labelled buildings’ and percentage of renewable energy.

When using the same ranking, city rankings can be useful to compare the same city over time. This gives feedback to the policymakers of the city. However, although the outcomes of the rankings are readily available the background data and information is not always available or only after payment. This lack of transparency means that on the level of the criteria there is often lack of information for policy makers in cities to improve their local policies.

A lot of rankings have overlap, deal with the same issues and use the same themes. But since the goals of rankings are not the same, the criteria, indicators and units used vary. This means that it is not possible to combine and add up ranking results. In short there was no standard available.

Although most existing benchmarks and rankings were useful for specific purposes, often several essential pieces are missing from the data or the process around it, including the following issues (Tillie, 2015):

- Feedback on city scores;
- Standardised third party verified data;
- Indicator evolution— as there was no feedback from cities on the rankings;
- Transparency on the weighing of indicators;
- Resilience/adaptation capacity indicators;
- Governance indicators;
- Use of local potentials (renewables) indicators;
- Indirect impacts of consumption elsewhere i.e. footprint analysis indicators.

The results of this study show that there are large differences between rankings, indicators vary greatly and feedback to practitioners is often weak or absent. However, there are opportunities for it to be of more value to cities if data are easier available, their assessing methods are transparent, indicators are standardised, and links to local policy-makers, politicians and media are established.
The European green capital competition is a better example but is not a ranking as such. Politicians, local policymakers and the public are involved. As policymakers collect data, they gain a good overview of cross-sectoral issues. The process is transparent and all research data and reports from all cities are available. It is possible that not the best performing city wins, but the city, that has shown the biggest improvements of the past

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years wins. Although the transparency of the process is high the judging of the criteria can be subjective as specialists in the field judge each criterion -albeit in a transparent way and for each theme the same judge is used for consistency-.
Other useful initiatives are the European Urban Audit and on a global scale the Global Cities Indicators Facility (GCIF) or even more so its ally founded in 2014, the World Council on City Data (WCCD), which addresses a lot of the earlier mentioned issues. A very important aspect, is that the WCCD implements the ISO37120 standard in cities worldwide

ISO37120 sustainable development of communities; indicators on city services and quality of life

In 2010, Rotterdam joined the Global City Indicators Facility (GCIF). The GCIF indicator set was further developed into the first ISO standard for city indicators (ISO 37120), which was launched in May 2014 (along with the World Council on City Data, WCCD).
The ISO 37120 standard, provides standardized definitions and methodologies and is based on 17 themes [Figure 2.11]. Also, cities can compare themselves through the WCCD open data portal and learn from other cities globally. These International comparisons have brought some interesting insights for the City of Rotterdam and many other cities.

Local indicator systems

In many cities, a lot of information is available at the local level. In Rotterdam next to general neighborhood data, data was available from indices for social systems and health systems. Also, yearly polls were performed. Next to this the city had 600 GIS themes available. It is quite possible that other cities do not have these data sets readily available. Fieldwork, interviews and satellite images can help there. One of the tasks is to link the (inter)national comparisons to local level and vice versa.

§ 2.3.2 Identifying synergies

Dobbelsteen et al. (2010) states the following about synergies or symbiosis: “In nature symbiosis occurs a lot. Organisms support one another, such as hippos cleansed from parasites by fish, which in their turn live of the nutrient-rich manure from hippos. This perhaps may not seem easily translatable to cities, but this kind of interaction could be superposed on the use of energy. In cities, a lot of energy is used and wasted without symbiosis.” Chapter four will describe an urban energy system that is more in accordance with intelligent organisms. Apart from the energy topic, synergetic effects can be looked for in more aspects and urban flows.

Cities and urban landscapes provide functions. Anthropogenic and natural systems guide processes and deliver services in which spatial patterns result. Systems, functions and patterns are all (systematically or not) interlinked as part of an urban ecosystem. Local performances can tell us if it is a poor or good performing urban ecosystem. The interconnection of the systems (individual, social, economic, environmental & resources, governmental and infrastructural) and successful synergies between them belong to a good performing and sustainable urban ecosystem.

Within the urban landscape systems, we can distinguish systems for energy, water and nutrients (food) (the research lenses as described in the next paragraph) but also for example: waste (water), transportation, ICT, shelter, and recreational systems. Without infrastructural systems or urban landscape systems, functions such as economic activities, education, safety, and health [Figure 2.2] cannot be guaranteed. The urban flows or urban metabolism is a precondition for an urban ecosystem. Sijmons (2014) mentions that people's access to the flows, can make the difference between life and death, or open the way to well-being. In mature cities, 'smart' arrangements of flows can determine not only a good performing urban ecosystem but also the quality of life and a good location for economic development. Having a sectoral approach on one system only (for example water) has a risk that it only brings sectoral solutions. It is therefore that the conceptual model links to all other systems such as individual, social, economic, environmental, infrastructural and governmental systems [Figure 2.8]. How can synergies and improved quality of life be planned for the challenges ahead?

§ 2.4 Research lenses for water, energy and nutrients (food)

To get a grip on this matter as well as to simplify the complexity of all interacting actors, the methodological framework is first used for three sectoral research lenses chosen for the case study city Rotterdam. From this sectoral perspective synergy effects will be explored. For instance, solutions for water should incorporate strengthening of biodiversity (more gradients), infrastructure connections (new dikes also used for biking) and recreation (ponds). If the same is done for other sectors overlapping will occur over time. The research lens approach is an important part of the exploration strategy to look for potential synergies (Tillie, 2014), but also to explore new approaches as one of the primary research questions of this research is to explore a SULP approach and link urban metabolic flows to urban landscape planning.
In this research, urban ecological themes are addressed using the environmental and resource system [Figure 2.8]. The test cases of the research lenses explore the synergies

with other systems. As such, important lenses within the environment and resource system could be issues of air (quality), energy (provision, carbon intensity, security), water (quality, safety), noise (levels), biodiversity, nutrients, food, soil (quality) and so on. Each lens can be approached differently.
The selection of the research lenses also depended heavily on the interest of the case study city used. In short, is there a main interest for these kinds of themes among many stakeholders in the city? It turned out that in the municipality of Rotterdam as well as in several other governmental bodies, research institutes, companies and local stakeholders the focus was – among many other fields – on sustainability, climate change and CO_2 reduction. The Rotterdam Climate Initiative was an important factor in this.
On the basis of the aforementioned facts a selection was made for the following research lenses:

- Water (precipitation) related to surface water quality and storm water flooding;
- Energy in the built environment: transition to a low-carbon city
- Nutrients & urban agriculture.

The first research lens will focus on water quality and safety from storm water. What is important in this study is the way stakeholders were involved. The second research lens will address heating in cities and explores a new planning approach for the energy transition in urban landscapes, transition to a low-carbon city. The third research lens focuses on nutrients & urban agriculture will explore phosphorus flows and urban agriculture in Rotterdam.

Lately these topics have full attention as they link to pressing global challenges. Romero-Lankao (2017) mentions the following about these topics:

In 2015, the US National Science Foundation issued a battle cry with a call to fund US$50 million for the advancement of research on the nexus (interactions) of food, energy, and water (FEW). This heightened level of research interest has now been matched by multiple international research calls, demonstrating that the nexus has become a powerful metaphor used to convey the interdependencies between society and natural systems on which it depends.'

In the following chapters three, four and five these three research lenses will be explored. In chapter six and seven the combined research lenses are applied in areas in Rotterdam dealing with densification and greening and scaling up and policy making.

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§ 2.5 Research design

The research design is built around the conceptual model [Figure 2.9] for sustainable urban development. In the conceptual model, the different systems mentioned by Bossel (1998) such as the social, economic, infrastructure and government system are organised in another way, conceptually exemplifying a city or urban landscape. In the methodological framework the urban landscape, its systems, functions flows, areas and actors are studied and incorporated stepwise:

1. Existing Urban Landscape (baseline): analysis of current system to identify shortcomings, challenges and opportunities which can be dealt with from a spatial perspective
2. Framing the challenges
3. Involving stakeholders and explore potential synergies, setting goals and indicators
4. Vision making and where needed developing new approaches
5. Application or simulation/scenario study
6. Planned Urban Landscape: assessing the new developments or planned ideas and improve where needed

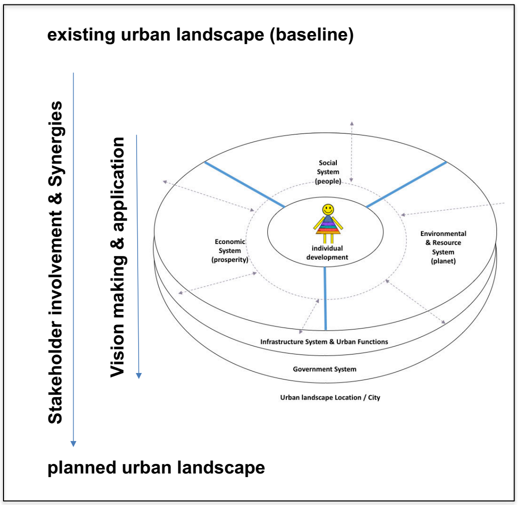


FIGURE 2.12 Methodological framework showing the relation of the conceptual model for sustainable urban development to analyse, planning an process.

Theories and frameworks ranging from sustainable development, urban ecology, governance and landscape architecture were studied in this chapter. In addition, principles and indicators are put in place.
In the following three chapters the steps of the methodological framework will be used for the different research lenses to explore potential synergies. Additionally, each chapter has its own research question and research goal to develop innovative ways of dealing with the posed challenges. There will be variation and overlap between the three chapters as they were done in different settings at different times with different stakeholders.
Lessons from all three lenses will be used in chapters six and seven and fed into the SULP approach

§ 2.6 SULP elements

Before going to the research lenses some first preliminary building blocks for the SULP approach can already be drawn based on the studies described in the previous paragraphs.
In [Figure 2.13] an overview is given of what these building blocks consist of. For this a model from the transition management, landscape architectural, and urban ecology perspective were used.

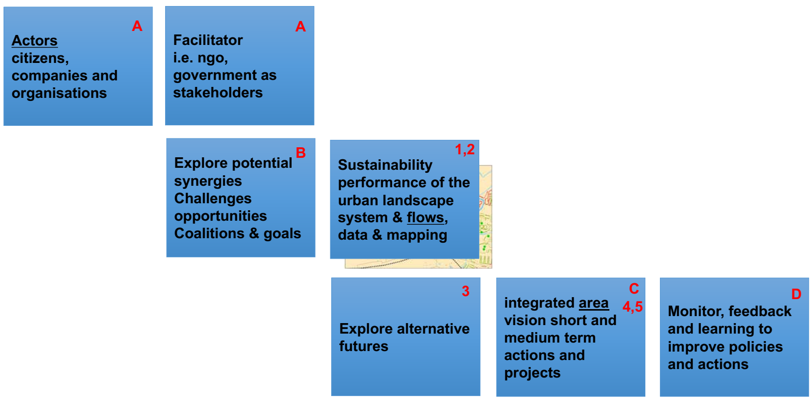
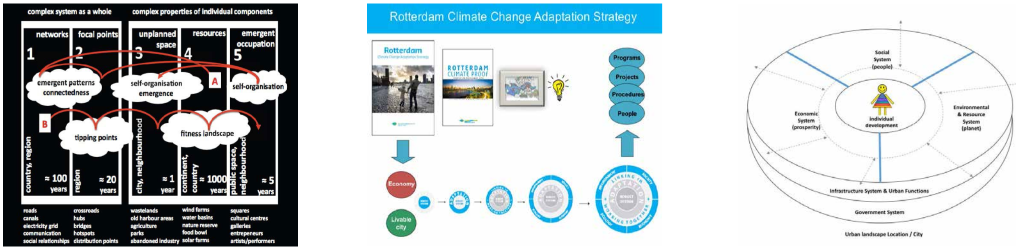


FIGURE 2.13 Preliminary building blocks for a SULP approach. A, B, C, D relates to figure 2.6. Underlined text relates to the Ecopolis strategy and 1,2,3,4,5 relate to girure 2.4

Although the conceptual framework was set up to relate the six different systems, defined by Bossel (1998), to each other within a paradigm of sustainable development, this does not mean that synergetic urban landscape planning solely depends on this. As a matter of fact synergetic planning can be done with other objects of study. In this case the object of study is an urban landscape. Also, other urban concepts or paradigms can be used as an object of study. As such the SULP approach should be flexible and have a modular set up. In **[Figure 2.14]**



1 2 3

FIGURE 2.14 Examples of different urban concepts and paradigms ranging from Swarm Planning, the Rotterdam Climate Adaptation Strategy to the conceptual framework. All can be the object of study within synergetic urban landscape planning.

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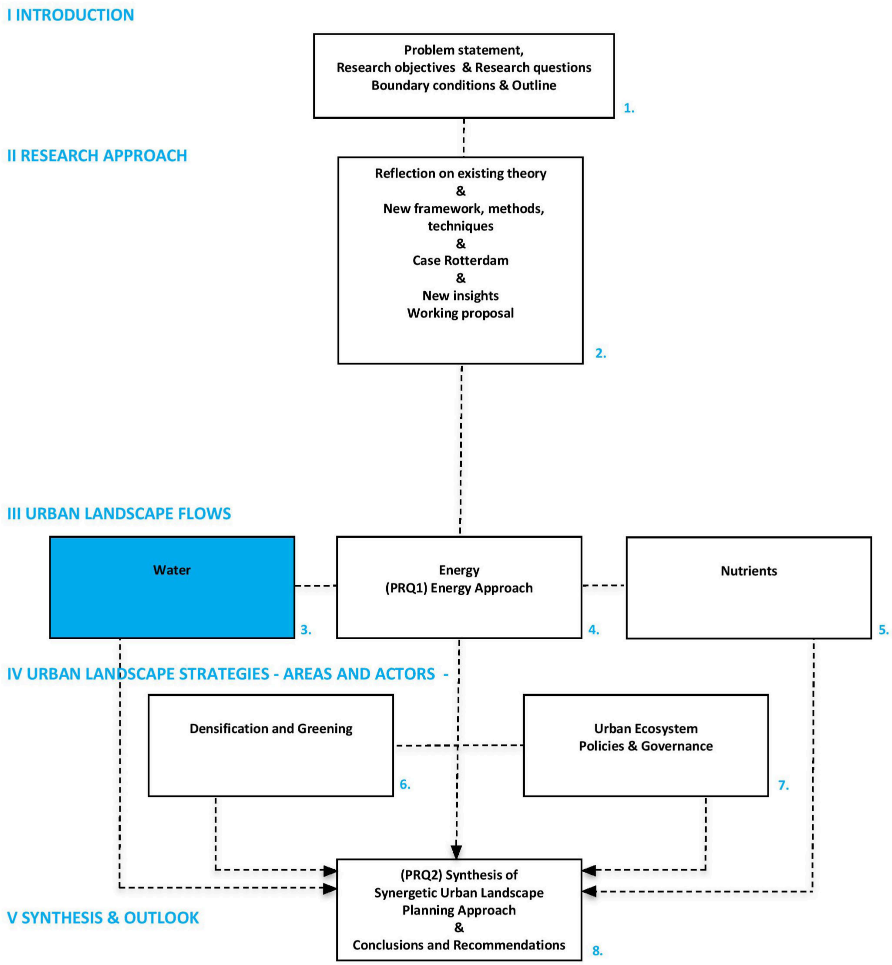


FIGURE 2.15 Bridging two - three

Bridging two-three

Urban landscape systems and a preliminary approach for identifying synergies have been introduced at the end of chapter two. This should be part of a new framework for synergetic urban landscape planning. As shown in the integrated framework of coupled urban ecosystems, important aspects for urban landscape systems include urbanlandscape **flows** (process) and the urban landscape **areas**(patterns/forms). Both either feed urban landscape **functions** or are a result of it, or both. To understand these urban landscape systems and plan for synergies, three research lenses are defined which are used in this thesis. Water, energy and nutrients.

Chapter three is linked to **flows**. Climate change and precipitation is introduced as well as how Rotterdam tries to turn the challenge of dealing with more water in the city into an opportunity.
For the 'Rotterdam Water City 2035', plans are placed within a range of existing planning frameworks such as the 'Framework model' and the 'Layer approach'.

Several aspects are reviewed including the way the water project was organised, governance, actors and follow ups. Also, the quantity of extra rainwater storage and effects on quality of life aspects over the course of the last years have been evaluated. The pre-studies in the 'Master Case Approach' presented turned out to be very valuable for the process and are used again later on.
In this flow, many synergies with urban landscape qualities and publicspace, are discovered. The link to low carbon issues is mainly indirect but nonetheless important. The most important part of this chapter, in line with the research objective, is the fact that the water challenges are combined with other urban challenges such as poor housing, poor public space and low-income neighbourhoods. It can serve as an excellent example of synergetic urban landscape planning and as such is directly connected in a large part to the main research objective.

PART 3 Urban Landscape Flows

3 Water

Redesigning urban water systems and exploring synergies Rotterdam Water City 2035 and follow ups

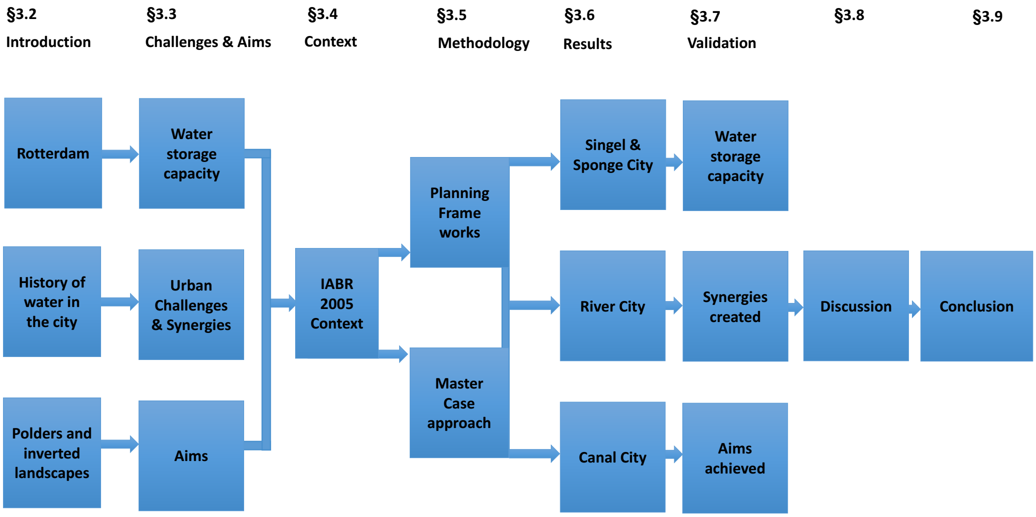


FIGURE 3.1 Outline chapter 3

Note in advance

A shorter version of this chapter was published in the Journal of Sustainable design: *Tillie N., (2017). Redesigning urban water systems and exploring synergies; lessons from an urban planning perspective on the 'Rotterdam Water City 2035' vision and follow ups 2005-2016; Journal for sustainable design EcoWebTown http://www.ecowebtown.it/n_16/*

A part of this chapter was published as paper in the conference proceedings of the 2007 Metrex Climate conference in Hamburg:
Tillie, N., Greef, P., de 2007, conference proceedings, Hamburger Metrex-Konferenz zum Klimawandel 2007, Metrex Hamburg

§ 3.1 Context

Cities are complex ecological systems dominated by humans (Alberti, 2009). With a changing climate (IPPC, 2007) we are already experiencing more peaks in precipitation (higher as well as lower) in many parts of the world. The majority of the existing urban water systems are not built with climate change in mind and can be considered vulnerable. Problems such as flooding and droughts occur more frequently. Also, older infrastructures mix waste water with cleaner run off and ground water, nutrients are not recovered, and it is expensive (De Graaf et al., 2007). As a result, urban water systems are being redesigned or newly built in new urban areas. Apart from addressing hydrological issues, the redesign in some cities of outdated urban water system is an opportunity to address other prevailing issues such as social, ecological, recreational and economic aspects.
One of the first cities worldwide to have picked up this opportunity is the city of Rotterdam. In 2005 a novel planning approach led to the Rotterdam Water City 2035 vision. Now more than ten years later and with several achievements in hand, it is possible to look back and evaluate this approach to draw some lessons.
Although this plan takes river flooding and sea level rise into account, the key issues addressed revolve around storm water problems and how these challenges can be used as opportunities to improve safety and the quality of life in the city.
Main drivers to grasp these opportunities can be found in synergetic goals; therefore, unexpected resources and a joint focus of many organisations has proven possible. This joint focus was also a result of the envisioning and process of the Rotterdam Water City 2035 project. It was presented at the International Architecture Biennale Rotterdam 2005 (IABR2005) as a vision in a magazine, in maps and models. It was opened by politicians, visited by the public and, public debates were organised.
With the vision in place, activity programs were rolled out, international networks were tapped or created and most importantly, community engagement programs were set up.

This chapter addresses two main topics. The first is the description of the Rotterdam Water City 2035 approach, a systematic water approach for Rotterdam dealing with storm water, and at the same time ,exploring synergies to improve quality of life. The second topic deals with the question of if the approach was successful as well as what lessons can be learned.

§ 3.2 Introduction

The use of mounds to protect houses and settlements from floodings has been recorded for this area as early as 100 A.D. but may well have been used much earlier. The first dikes were built to protect land and settlements from the water around 1100 [Figure 3.2]. The area east of the coastal dunes, that today is below sea level, used to be 10 to 20 meters above sea level (with the exception of Flevoland). Huge, often forested, peat beds fed with rainwater dominated this area and acted as a natural sponge storing the rainwater and releasing it slowly. Early pioneers used the rivers such as the Schie and Rotte, cutting through or originating in these peat beds, as access. In many areas peat beds were drained for agriculture. Also, peat was dug away and dried, to be burned in homes for cooking and heating (Sijmons, 2014).
At the mouth of many of these peat rivers, such as the river Rotte, the tidal influences from the North Sea occasionally pushed up water levels into the narrow rivers, making these areas unfit for habitation.
In the 13th century, a dam was constructed at the confluence of the small Rotte river and the Meuse river to prevent tidal water coming upstream of the river Rotte. Hence the name Rotterdam (as well as Schiedam, Amsterdam etc.). Merchants settled along the dam and trade was soon flourishing. Trades-people, fishermen and sailors created the settlement, the city grew and more ports were built. After the opening of the New Waterway (Nieuwe Waterweg) in 1872 – canalisation of the main river and a direct connection to the North Sea – the (port) economy of Rotterdam grew rapidly (Tillie, 2016).

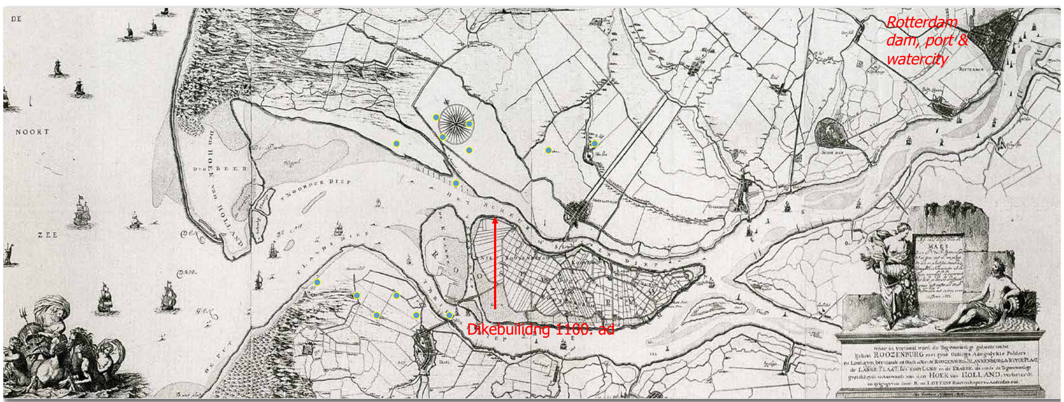


FIGURE 3.2 History and water of the Rotterdam water system (image courtesy of Stadsarchief Rotterdam).

§ 3.2.1 Polders and the inverted urban landscape

The city of Rotterdam is built on the riverbanks of the Meuse and Rotte rivers, just above sea level. With some exceptions, the northern and eastern part of the city is built into many different kinds of areas below sea level (Steenbergen, 2009). Over the course of some 800, years the drained peat beds subsided to lower levels. At a certain moment, the subsidence continued below sea level, meaning that water from the land could no longer naturally drain to the main rivers and sea. In order to keep the land dry, the water had to be pumped out, using windmills and networks of constructed ditches and canals at different elevations to guide the water out. A unit of land below sea level, that formed an artificial drainage unit as a result of pumping water to another level, is a polder system. In some cases, the peat was not only drained but dug away completely until they hit layers of sea clay at -4 or -6 to almost -7 meters, leaving behind lakes. In many cases these lakes where later pumped dry turning them into so-called lakebed polders.

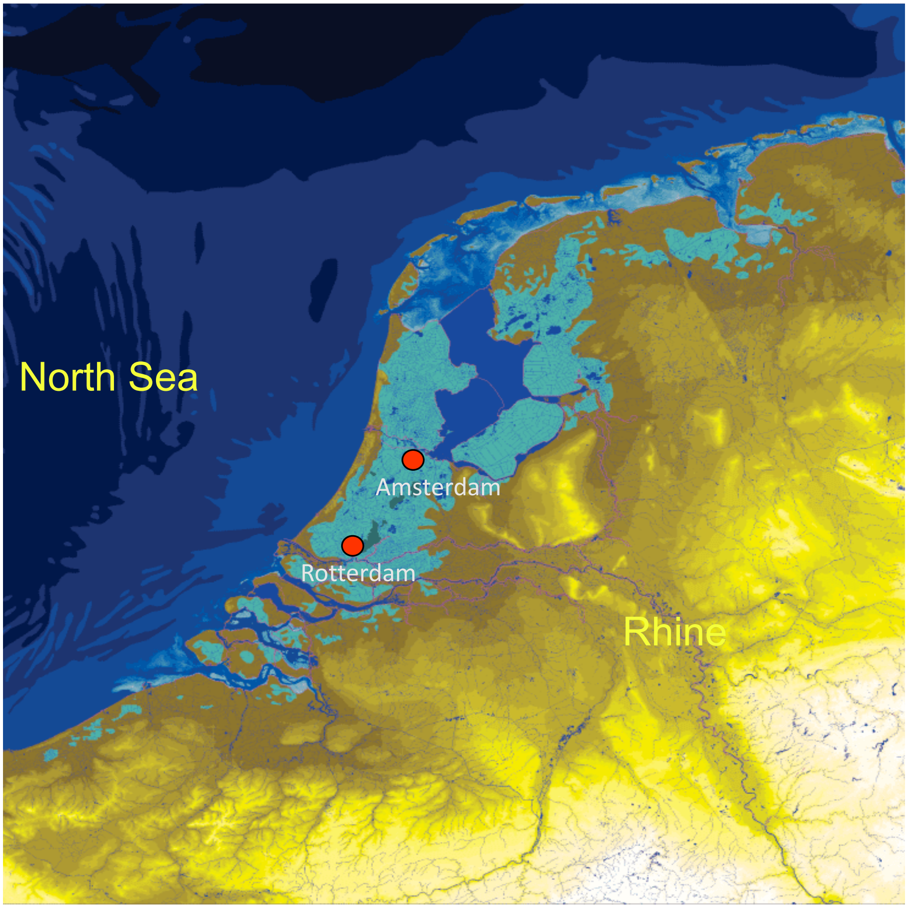


FIGURE 3.3 North-Western Europe today with areas below sea level -shown in light blue-, mainly in the Netherlands, parts of Belgium and Germany (Image courtesey of Minisrty of VROM, 5e Nota Ruimtelijke ordening 2001).

Nowadays the western part of the Netherlands consists of a patchwork of either different kinds of polders below sea level, -(originating from different eras, with either peat or sea clay)-, or (former) riverbeds above the surrounding landscape **[Figure 3.3]**. The sandy riverbeds did not subside. This is refered to as the inverted landscape.
In the southern part of Rotterdam, the polders are less deep and have a different origin. Here the polders are former pieces of land near, in, or next to the river Meuse, which were surrounded by dikes; the soils mainly consist of (sandy) river clay. The central area of the city near the banks of the river Meuse and the port are the highest grounds in the city.

In past centuries, these typical conditions with most of the land below sea level, have led to the development of a technical water system existing of canals and pumping stations as precipitation runoff does not flow to the sea naturally. The technical water system has reached its growth limit and cannot cope with too heavy a rainfall event. Other solutions have to be found.

§ 3.3 Challenges for the existing urban water system

With a changing climate, natural water cycles are also influenced. As a delta city, Rotterdam already had to deal with water issues coming from all sides yet due to climate change, the extremes of discharge and precipitation are becoming greater [Figure 3.4]. More river discharge is expected as well as sea level rise. These are issues that are addressed at national and local levels, such as by the national 'Room for the River' program and others. This is not part of the scope of this study. In the area studied, there will be more peaks in precipitation, which means more rain showers will release more water than average. This will alternate with periods of no or little rain (KNMI, 1999). Over the years more capacity to store rain water was, and is, needed in the city. Van der Brugge et al. (2010) mention that for the Rotterdam region, 600.000 m^3 of extra water retention is needed before 2015 and 900.000 m^3 before 2050. This storage capacity cannot be realised in the existing infrastructure.
The developments described above show that it is necessary to examine the consequences of the water issues for the existing city in the medium- and longer term. What are adaptation strategies for storm water in the densely built environments of Rotterdam?
The existing Urban Waterplan 1, from 1999 (Rotterdam Waterplan 2000-2005), was a sectoral plan, focusing on an inventory of waterways, sewer overflow, fish mortality and so on. Van der Brugge et al., (2010) mention that in Waterplan 1, future ambitions for the water system in terms of water quality and ecological quality were formulated for the first time. Water also played a central role in the RPR2010 (Spatial Plan Rotterdam 2010) as well as the Regional Plan Rotterdam (RR 2020). None of these plans however, which were written between 1999 and 2004, provided for extra water storage on a large scale in the city itself. At first, a few solutions, -such as adding small ponds and extending the existing water system-, were suggested by the planning department, but there was no integrated systems approach for the whole city. As Tjallingii (1998) mentions; the 'micro-logics' of all these systems make sense. In land use planning and urban planning,the actions of participating parties have their own logic, but water flows through all kinds of monofunctional systems. Water management needs 'macro-logics' in which overarching connections in the whole system can benefit.

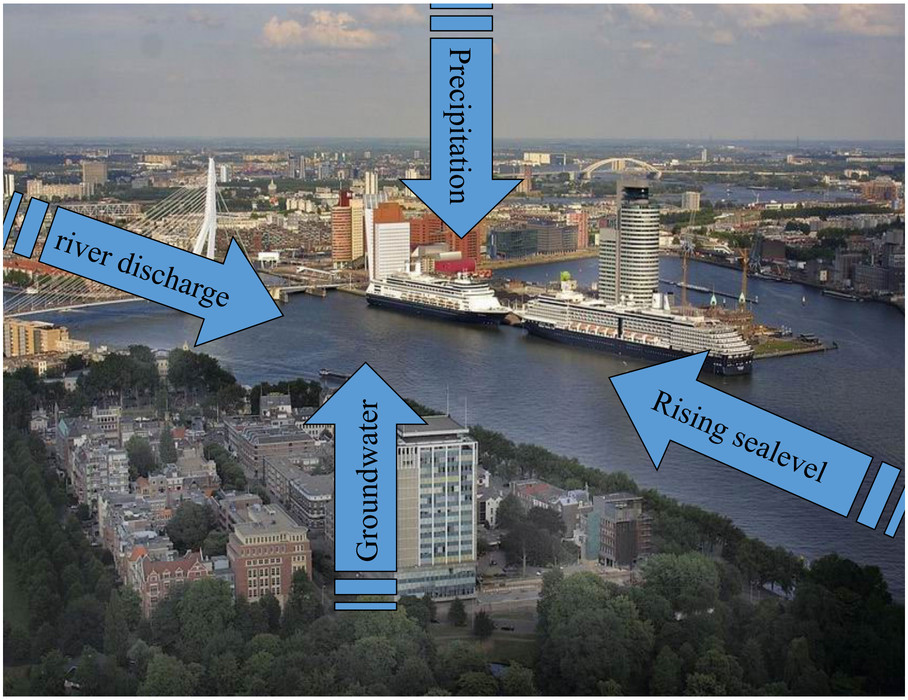


FIGURE 3.4 The situation in 2004. As a city in the Rhine-Meuse delta, Rotterdam always had to deal with river discharge, tidal influences, groundwater levels and precipitation. Due to climate change, the extremes are becoming greater bigger and to deal with this the city needs to adapt with climate change in mind. (Image courtesy of city of Rotterdam).

§ 3.3.1 Other urban challenges

Apart from the water issues at hand, the city had to deal with social and housing problems and Rotterdam was in need of high-quality housing and public space. When smaller cities bordering Rotterdam built high-quality neighbourhoods in the vicinity of Rotterdam at the end of the 1990s, many people who had made an educational and professional career now had the opportunity to find high-quality houses and left the city. In 2004, more employed people left the city than entered it, whereas unemployed people depending on social welfare stayed and came in. Over the years this social imbalance became noticeable and many neighbourhoods in the city were struggling [Figure 3.5]. Policies to turn these developments around were based on a few criteria: providing good-quality housing within the city of Rotterdam, high-quality public space, easy access and links to the surrounding landscapes for recreation and to aid the creation of an attractive international city centre.

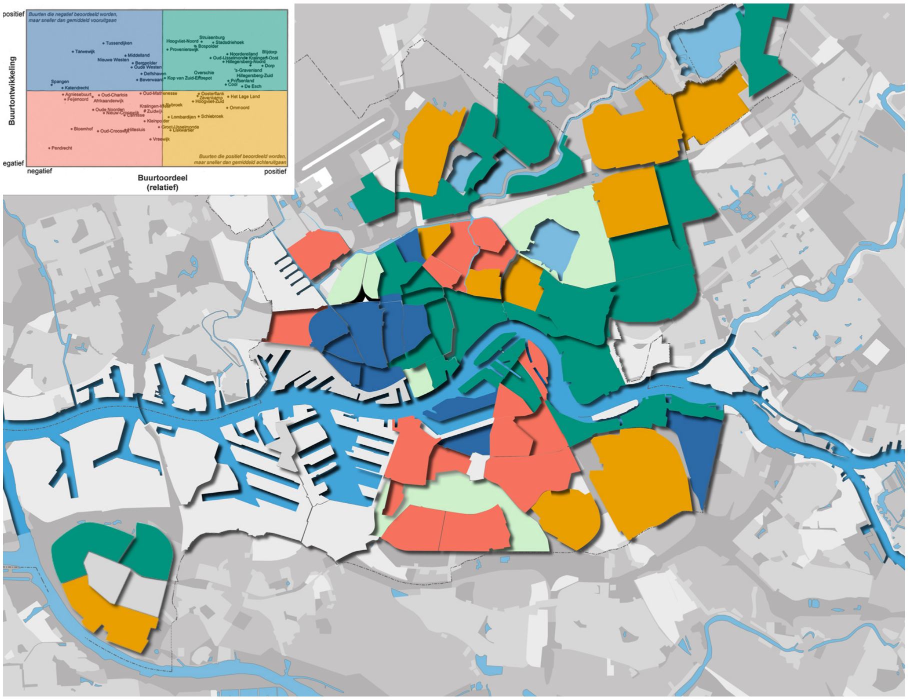


FIGURE 3.5 Scoring according to neighbourhood indicators to determine neighbourhood quality as well as neighbourhood development. Red = low score and negative developments, Blue = low score and positive developments, Orange = high score and negative developments, Green = high score and positive developments. (figure courtesy City of Rotterdam).

The water challenges and the need to address this at the city level via an integral systems approach gave the city the opportunity to rethink its vision for the future: water again used as a guiding principle in the spatial planning of the city. How can the necessary ongoing and new interventions in the water system be done in such a way that these interventions make a positive contribution to the quality of the city?

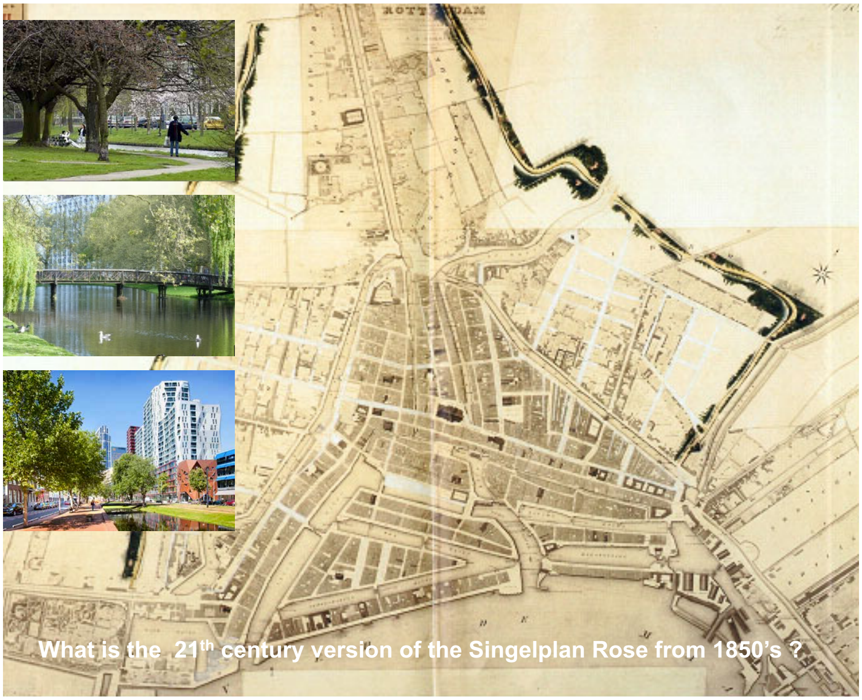


FIGURE 3.6 The challenge was how to solve the water issue and link the solution to other synergetic effects such as those in the socio-economic domain.

For landscape architects in the city, the parallel with the 'Waterplan Rose' from 1854 or commonly known as 'Singelplan Rose' immediately arose [Figure 3.6]. The Singelplan Rose emerged from the acute necessity to resist cholera epidemics in the city, by solving water hygiene problems. The solution was not just a new water structure to flush the canals, but constituted a new use for water in the urban structure of Rotterdam, where the canals were set in English landscape style parks surrounded with new high-quality housing. The question at hand was: what is a 21st century equivalent of the 'Singelplan Rose' for the whole city region of Rotterdam?

§ 3.3.2 Aims

The IABR2005 gave the opportunity to explore and develop new possibilities and the aims of the City of Rotterdam for the IABR2005 were multiple. The exchange of information and knowledge between colleagues as well as the development of knowledge with others at the IABR2005 also played an essential role, one argued that this project could be an accelerator for business, by showcasing local challenges and opportunities to be used in other cities for example. Finally, the IABR2005 was an excellent opportunity to place the water issue on the political and professional agendas (Greef et al., 2005).

Aims of the city of Rotterdam deployment in the IABR2005:

- Profiling Rotterdam through a joint approach of dS+V, GW and OBR (the planning, economic and engineering department of the city administration at that time), in close cooperation with its partners (water boards, design firms etc.);
- Convincing the administration and citizens of the need to use the water issue as an opportunity for Rotterdam;
- Contributing to the dissemination of Rotterdam as a city of architecture and urban design at a high level on an (international) stage;
- More professionalism in the organization (through research, design and debate);
- A podium for Rotterdam's craftsmanship and plans (profiling with good integrated, comprehensive and concrete plans);
- The motor and accelerator for these topics.

How can the necessary ongoing and new interventions in the water system be done in such a way that these interventions contribute positively to the quality of life in the city? That was the main question of the IABR2005 (Greef et al., 2005). Topics to deal with were:

- Water as a guiding element for the urban structure;
- Opportunities & synergies present or to be created;
- Water for the cultural identity of the city;
- Most promising locations for water in the city;
- Right amounts/volume of water in the city [Table 3.1].

	Required in 2100	Already present	To be built
North side	344.000m³	184.000 m³	160.000 m³
South side	733.000m³	443.000 m³	290.000 m³
	112,1 ha water	68,1 ha water	44 ha water

TABLE 3.1 Calculated amounts of cubic meters of water required, already present and to be stored (after Greef et al., 2005)

§ 3.4 Context of the International Architecture Biennale Rotterdam 2005

The water issues in the city were addressed in a wider urban context. This was the result of the link to the International Architecture Biennale Rotterdam 2005 (IABR2005), which was organised in the city. The Biennale offered an opportunity for the city administration, water boards and other stakeholders, to demonstrate in a concrete manner a future-oriented approach with opportunities for the city, free from political constraints. The Biennale topic of 2005 was "The Flood" with sea level rise, precipitation increase and flooding as a result of climate change. One of curator Adriaan Geuze's goals was to show the past, present and future of the Dutch water city. With this at hand the city of Rotterdam had found itself a perfect stage to showcase its plans along with other international projects.

§ 3.5 Exploring a research Method for Water City 2035

§ 3.5.1 Existing Planning Frameworks

In paragraph 2.2. different frame-works are discussed ranging from the layer approach and, the framework model to SWARM planning. When combining sustainable water management and urban planning, the Ecopolis strategy turned out to be very valuable. This strategy was developed by Tjallingii (1992) and Berends (1995) in close cooperation with the Ministry of VROM. The strategy results from practical experiences with urban ecological projects (Koning & Tjallingii, 1991). Ecopolis means 'the ecological city'. It represents an ecological approach for the entire urban system, with respect to economic and sociological approaches, which might highlight other aspects. In this ecological approach, the interactions between society and the physical environment are central (Tjallingii, 1998). Decisions about these interactions are taken in the context of three decision areas: flows, areas and/or actors. In planning, there is usually only one perspective to start from. With water and nature development, the 'quality of space' is the perspective to start from. Tjallingii (1998) notes that 'In the case of rainwater and waste water discharge, the 'flow' is the entrance, and in the organisation of maintenance and management and the financing thereof, the actors is where it all starts'. It is important to note that whatever the perspective at the start

will be, the whole system should be overlooked. Environmental issues can be linked to underlying processes from these perspectives. The Ecopolis strategy aims to make living areas where residents feel at home, places that fit local nature and culture and that can adapt to management in new circumstances (Tjallingii, 1998).
Crucial parts of the Ecopolis strategy, the layer approach and the framework model were used by individuals, the planning department or incorporated into the work of water experts. In many cases, professionals did not know about them. However, as this case was not merely a spatial planning or water management task but involved different actors and disciplines, the existing frameworks were not used as such or were framed differently. Sectoral issues were in some cases hard to overcome and a different approach was needed in order to build a city vision with a long-term planning approach. A new approach, tailored to Rotterdam situation, was set up.

§ 3.5.2 'Master Case Approach'

The focus of the Rotterdam commitment to the IABR2005 is what was called the Master Case Rotterdam. Although the timeframe set for the IABR2005 was 2070, the Rotterdam project focused on 2035 as the 2070 timeframe was too abstract to link direct outcomes to local policies. With a 2035 horizon this was easier to achieve. Water retention is a topical issue and should be a priority on the political agenda right now. Using the 2070 horizon would run the risk of turning the subject into a speculative subject (Greef, 2004).

To link the perspective of technical engineering to planning and creative design, the 'Master Case Approach' was led by two 'masters'. Lodewijk Nieuwenhuijze from H+N+S Landscape Architects and Govert Geldof from TAUW engineers, bringing together the technical and design craftsmanship. With a limited number of professionals from the participating city departments (planning, economy and engineering), in cooperation with representatives of the water boards and a few external parties, the total number of participants in this project did not exceed 20. All this was led in cooperation with the core steering group with representatives from the three municipal departments, as well as representatives from the water boards [Figure 3.7].

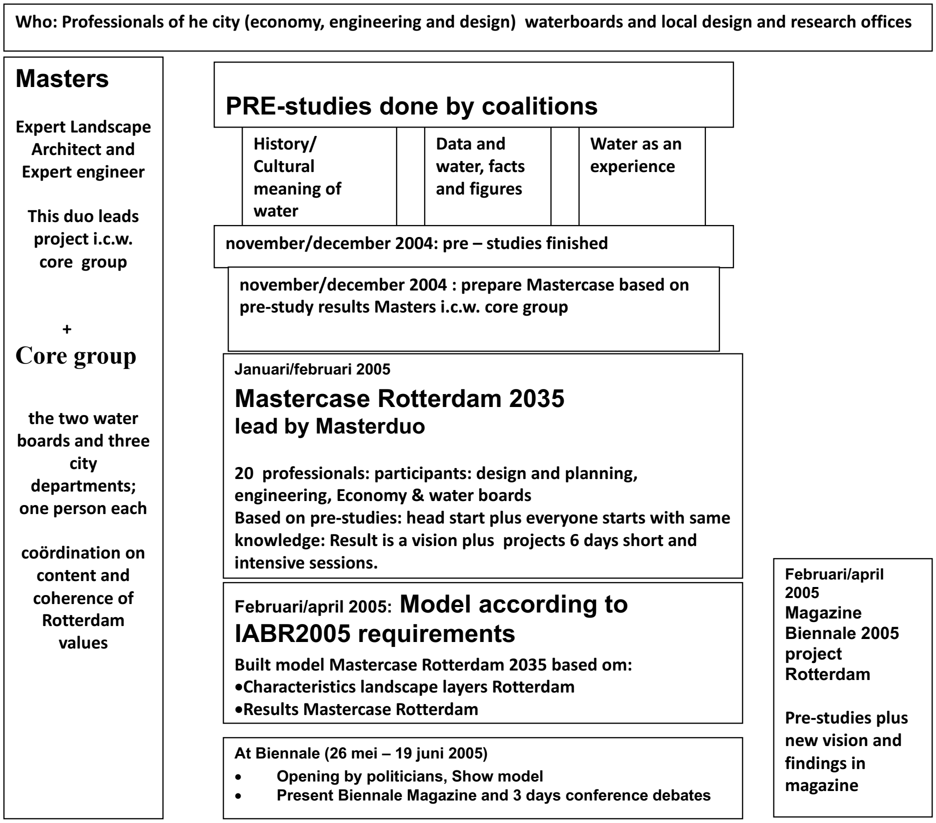


FIGURE 3.7 'Master Case Approach'; schematic overview of the process of the International Architecture Biennale Rotterdam 2005 entry with Water City 2035 after (Greef, 2004).

Pre-studies

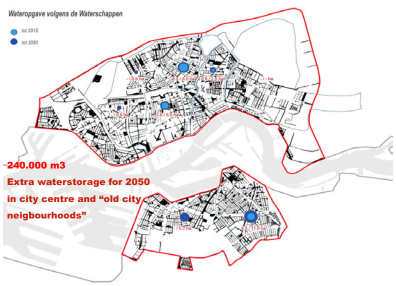
Before the Master Case itself took place, a very crucial step was made. This was the phase of the pre-studies before the actual work could begin. In order to answer the main question and sub-questions, a lot of information and new insights were required. In order to get this information and insights three pre-studies were assigned to three different coalitions (an engineering company and a design firm were present in each coalition). The three pre-studies were: 1. Water, history and culture, 2 Water quantity in numbers, 3. Experience and enjoy, about how to use and experience water in the city. The 20 people in the Master Case team were a mix of water engineers, designers, landscape architects, urban planners, economists and traffic planners. All people had access to the outcomes of the pre-studies before the actual workshops. The result was a more level playing field concerning knowledge; bridging the gap between hard-core engineers and designers was easier since a new kind of language and understanding was slowly developing, -and because there were many maps available now-, available time could be better used to focus on building the Water City 2035 vision.

The actual Master Case took place in January and February of 2005 (prior to the IABR2005). Participants were selected based on capabilities and availability. The time commitment was 120 hours per participant over two months. The way of working was short powerful sessions ant the result should be a plan for the city of Rotterdam (1:25.000) with a number of crucial details at the scale of 1:1.000 (Greef, 2004). Other planned outcomes were:

- Model (March-May)
- Magazine (April-May)
- (International) Debate in the city with experts, citizens and politicians (June)

§ 3.6 Results of the Rotterdam Water City 2035 Vision

As described previously, before, the water challenge was used as an opportunity to look for synergies that address water related issues and at the same time improve the quality of life in the city. The results of the pre-studies, such as maps, were an important part of the project. In [Figure 3.8] the extra water storage needed for each neighbourhood is calculated. These maps are combined with maps and data at city and neighbourhood level in order to come up with the right solutions. Before moving to the neighbourhood level, an overall guideline and city vision had to be developed.



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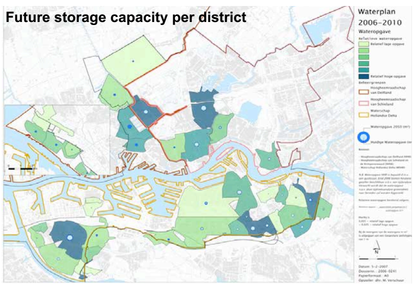

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FIGURE 3.8 Outcomes of the pre-studies were basic data and maps such as the future storage capacity required per neighbourhood.(maps courtesy of Florian Boer and City of Rotterdam)

§ 3.6.1 Overall vision of Rotterdam Water city 2035

The result of the Master Case is the Rotterdam Water City 2035 vision as described by Greef (2005). It consists of three images [Figure 3.9]: River City (Rivierstad) in the centre, which is one of the most elevated area in the city, Canal City (Vaartenstad) in the south, and Singel City (Singelstad) in the north of Rotterdam. Various strategies were used for each image to combine urban development with the (specific) water management assignments (Tillie et al., 2007). The 2035 vision was a starting point to do back casting. In other words look back in a stepwise way from 2035 to the current day This way measures and actions to be taken today and in the short term could be defined.

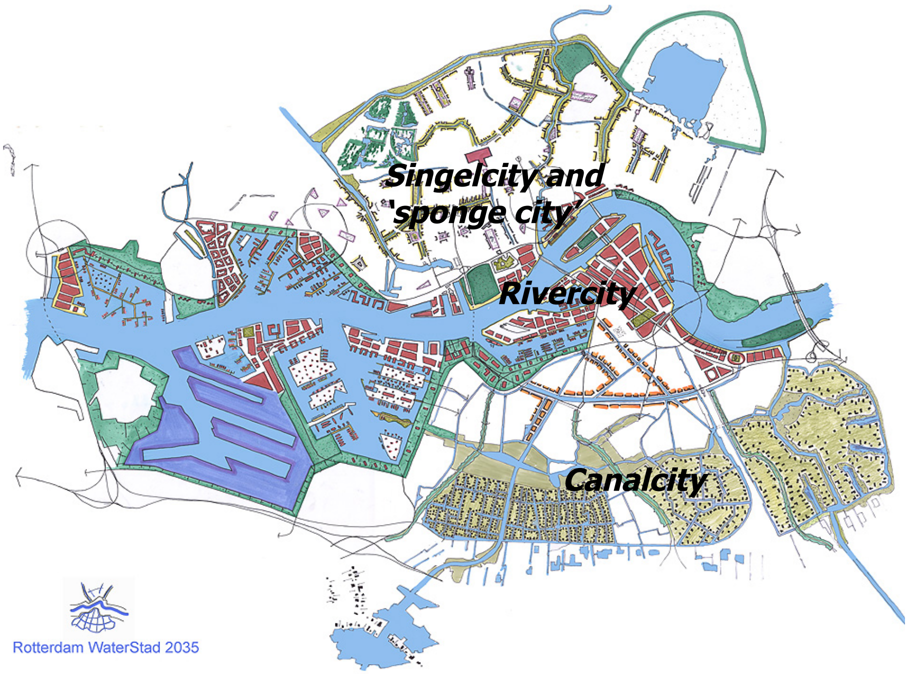

FIGURE 3.9 Rotterdam Water City 2035 vision. Water solutions + good housing + public space = good connections (map courtesy of the City of Rotterdam, Pieter de Greef)

§ 3.6.2 Singel City Image

In the north of Rotterdam is an area close to the centre with green surroundings. Water will become tangible in the streets: it will be seen and heard. Rainwater will no longer be hidden in drainage gutters. It will flow into the canals via roof gutters and gutters in the street. Wide gutters covered by a grid will become a permanent aspect of the street scene.
An extensive network of singels, better housing quality and a new kind of square will characterise Singel City or Sponge City in the north of Rotterdam. A Singel is a kind of canal with green parks and housing along. The emphasis in Singel City is on combining the extended singel structure and realising the so-called dry solutions for peak water storage. By increasing the number of singels, a network is created to drain water and to control ground water:

- More canals with green parks and housing along (singels) where possible;
- Innovations such as the water squares;
- Green blue roofs and buildings acting like a sponge.

A Super Singel

Because more water also means more seasonal storage, dry solutions were suggested. A number of existing canals will be linked together and extended towards the Oude Noorden. Excess water can be pumped into the Boezem (drainage canal) by pumping stations on both ends of this super canal. A link will be made with the Vroesepark near Blijdorp Zoo creating extra space for peak storage during excess rainfall. A number of new canals are connected at right angles to the central canal, of which the present Bergsingel is an example. Water from various districts can be drained via these canals to the central canal. Through a network of so-called hidden gutters that lead to the singels, water from various neighbourhoods can be drained to the canals.

Green roofs and water squares, a new kind of square

Part of the need for peak storage is met by this canal structure, because the water level in these canals is allowed to rise for a short period of time. However, a substantial part of peak storage will need to be found.

The solutions that have been found for this are green roofs and the so-called dry-wet squares. Green roofs (roofs with grass and small plants) absorb rainwater. In addition, a green roof also functions as insulation against cold and heat. Dry-wet squares are linked to hidden gutters, when there is too much water for these gutters to handle, the squares will flood. After heavy rain showers, you can hear and see the water flowing in the gutters. The appearance of some squares and parks will change because water has taken possession of them.

§ 3.6.3 River City Image

River City is dynamic in every way. With a wide range of dynamic living and working environments, the river offers Rotterdam an opportunity for inner-city development. Apart from urban environments, dynamic living environments are created with very low population density, consisting of mount dwellings, houseboats, jetty houses and fortress houses. By using public transport on the river these new areas for living and working will be ten minutes away from the city centre. The dike will be transformed into a dynamic development zone. The dike will be an uninterrupted structure allowing it to respond to different scenarios for the rise in sea level. In 2035, Rotterdam will truly be a city on the river. The threat of water is taken seriously but also looked at in terms of the opportunities it creates:

- The river is the main artery and, centre for further urbanisation;
- High urban density; more houses and companies in and on the water adjacent to the city centre;
- Public transport on water;
- Morphology of the main dikes can change.

Fascinating Landscapes

In open areas, there is enough room on the land side of the dikes to reinforce them and new dike designs can be used in those areas to create fascinating landscapes. If there is enough space for development outside the dikes, the dikes can be reinforced on the waterside. If there is not enough room on either side of the dike, other constructions than the ones we know now will have to be invented.

For each situation in the city where there is not enough room on either side of the dike, a different solution is suggested for the areas outside the dike. Valuable urban areas will be protected by a new sea defence. The port will have moved towards the sea and the city will have moved closer to the river. Towards the west the building density as seen from the city centre will be gradually lower. There is high building density near public transport stations. West of the Waalhaven the port continues to exist.

Preparing for the future

The influence of sea level rise, and therefore the water level in the river, determines how the water system is managed in River City. In order to protect River City against flooding it is necessary to raise the main sea defence by ten centimetres if the sea level rises by ten centimetres. "No-regret" measures are suggested to deal with this bandwidth of the expected sea level rise. These measures ensure that areas outside the dikes and adjustments to the height of the dikes are carried out in such a way that they can be adjusted again in the future. It will leave options open to respond to future climate scenarios that are as yet unknown.

§ 3.6.4 Canal City Image

The south of Rotterdam will be completely transformed to Canal City. A new and attractive (sub)urban living environment will be created with a more integrated urban structure and an extensive network of waterways. Every house will have its own back garden on a waterway.
These waterways will also connect the city to the delta via the area of small lakes between Rhoon and Carnisselande.

Attractive living environments

The south of Rotterdam currently has a one-sided population make-up. It is a city behind the port which is closed in by infrastructure. The neighbourhoods offer insufficient living quality and the water structure is inadequate. These shortcomings are addressed by Rotterdam Water City 2035. The new structure of Canal City consists of three east-west oriented waterways and green zones, a system of north-south oriented waterways and an underlying intricate system of waterways. The main north-south waterway will run underneath the A15 motorway and is linked to the large recreational area with small lakes between Rhoon and Carnisselande. Fascinating housing and recreational areas can be created here. The missing rural, fashionable housing environments which are in great demand in Rotterdam can be realized here. By creating waterways particularly in green zones and by building houses with their fronts on the water's edge, parking space can be created in the streets. In this way, a car-free system of waterways will be created which gives access to the front doors of houses combined with public gardens, private gardens, roof gardens and allotments. In short:

- Connected network of waterbodies and canals for little boats;
- Attractive floatablehousing;
- Good recreational routes to surrounding landscape;
- New high quality spatial structure for a 'difficult' part of town.

An uninterrupted system of waterways

The intricate waterway system consists of the existing canals that will be linked together with new waterways. This can be done because the water system in the south of Rotterdam as a whole already has one identical water level or it can be kept at one level. This allows for one uninterrupted system of waterways. The waterways will be designed so that every waterway can be sailed on.

Waterway City will be characterised by many bridges and few culverts. The surface water will play a big role in storing and draining rainfall from the area as rain water can be released directly to the surface water. Partly because the uninterrupted water network will be regarded as a quality of the south, it will be possible to create even more capacity than strictly necessary. Flooding will be prevented because there is ample storage space in the waterway system (Greef et al, 2005).

§ 3.6.5 The water challenge solved?

In order to solve the quantitative water challenge, the right amounts of water need to be stored and planned for in the city [Table 3.2].

In the Water City 2035 the following numbers were used.

	Required in 2100	Already present	To be built	Planned in the vision
North side	344.000m³	184.000 m³	160.000 m³	25-40% green roofs (goal 160.000m²) 8.8 ha dry/wet squares 10 ha in green canals and parks
South side	733.000m³	443.000 m³	290.000 m³	
	112,1 ha water	68,1 ha water	44 ha water	182 ha water

TABLE 3.2 Calculated volume of water required in cubic meters already present, to be built and planned for in the vision (after Greef et al., 2005)

§ 3.7 Validation

For validation, the Rotterdam Water City 2035 can be compared to prevailing plans at the time in 2005. These, such as the Waterplan 1, the RPR2010 (Spatial Plan Rotterdam 2010) as well as the Regional Plan Rotterdam (RR 2020), played a central role in the city's policies on water and spatial planning. As mentioned before, none of these plans provided for extra water storage on a large scale in the city itself. Solutions for local water problems were in line with the water system itself but were solved incident by incident. There was no integrated city-wide approach for water storage, nor for linking solutions for this to additional synergies to improve the quality of the city. With the Rotterdam Water City 2035 this had changed. In 2017, more than ten years after Rotterdam Water City 2035 was developed, the question was asked if the approach has been successful and what can be learned from it. The review process consisted of analysing monitoring documents and performance data published by the city, as well as other policy documents and two scientific publications on this matter. Furthermore, built projects were visited and studied, follow-up developments and projects explored, and key figures who have been involved in the project for the past ten years interviewed. While working for the city administration in Rotterdam as a landscape architect from 2001 to 2015 I was directly and indirectly involved in many projects in this field. This experience itself formed a valuable source of information over the years.

In order to determine if the approach had been successful, three criteria were selected to be reviewed and discussed. These criteria are gradually introduced in this chapter as:

1. Is the water challenge (partly) solved? In other words, is the required storage capacity for the city on schedule?
2. Exploring synergies and values for the city by guiding ongoing and new interventions in the water system in such a way that these interventions make a positive contribution to the quality of the city. The quality of the city is narrowed down to providing good-quality housing, high-quality public space, easy access and linkage to the surrounding landscapes, and an (internationally) attractive city centre.
3. Have the aims of the city of Rotterdam for entering the IABR2005 been achieved?

§ 3.7.1 Storage Capacity

The Sustainability Monitor Rotterdam, mentions that in 2013 more than 8,800 m³ of additional water storage was built. The total water storage capacity had grown from over 36,000 m³ to 45,000 m³. About 11 percent of the total storage required in 2025 had been built. This means that in order to be successful, more needs to be done and a scaling up is required. The step from pilot to mainstream projects is an important part of this.

[Table 3.1] shows 450,000 m³ to be built in 2100, which was the original number in Rotterdam Water City 2035 but in 2013 this target was moved to 2025.

By 2013, the number of square meters of green roof for which subsidy was requested increased by 20,000. At the end of 2013, 135,000 m² of green roof had been constructed. In addition, another 5,500 m² of green facades had been realised (Gemeente Rotterdam, 2013a). In order to increase the water storage capacity, it was proposed to install water depots on roofs. In 2016 there was about 220,000 m² of green roof in Rotterdam (the target was 160,000 m²). The ambition is to scale this up to 600,000 m² in 2025 (Gemeente Rotterdam, 2016). The future landscape of Rotterdam's roofs consists of so-called green (plants), blue (water), yellow (solar) and red roofs (social functions). Roofs are increasingly used as meeting places, a welcome expansion of public space in cities that are becoming too crowded (Rotterdam, 2016). Recent studies show interesting opportunities for development of the 5th façade and a new kind of city (Haaksma, 2017).

§ 3.7.2 Synergies

Providing good-quality housing

Water is an important resource to make Rotterdam an attractive city to live in. Over the years the number of houses increased considerably, and the supply of living environments has increased on both ends of the spectrum. Apartment buildings have been built near the river, suburbs like Laag Zestienhoven and Nesselande were built within the city borders using water as a structural element. In the Nassauhaven in the Feijenoord neighbourhood, 18 floating houses will be realised. It will be the first floating residential project in the port of Rotterdam (excluding houseboats). As the houses move along with the tidal water levels, the shallow water must be dredged out. The dredge will be used to create a tidal park adjacent with a natural shore line. This brings nature and more biodiversity to the city (Gemeente Rotterdam, 2016). These developments helped in stopping people with medium to high incomes from moving out of Rotterdam and actually new people within this income range have come to live in the city. In this way, Rotterdam will achieve a varied and balanced population make-up, as desired.

Providing high-quality public spaces

Water square Benthumplein is the first large-scale water square in the world [Figure 3.10]. It catches rainfall in large amounts and brings it back to the natural environment. In addition, the high-quality water square improves the neighbourhood. Students from surrounding schools spend many hours on the square with basketball, skating or just talking to each other and sitting on the steps of the square. Bellemyplein is another small-scale water square. Urban floodplains are introduced where possible, such as the Westersingel, so that extra water can be stored [Figure 3.10].
Apart from open water squares, there are also innovative underground solutions, such as the 10,000 m³ sewage overflow cistern adjacent to the underground parking garage at Museumpark or the peak rainfall storage in front of central station.
There are more examples of linking water solutions to high-quality public space. A new Olympic rowing track was built near one of the seasonal water storage areas outside the city which allows for more water to be stored when necessary. Another solution for instance, is using the empty space underneath motorway intersections for water storage. Multifunctional dikes are another way of improving the public space. The roof park in the western part of the city is a fine example of this. Van Veelen (2016) finished his research on designing multifunctional dikes and how to develop an instrument to link different factors to area development and create innovative solutions. For example, creating a growth model that yields its benefits in the long run. This was done for Feijenoord and Noorder Eiland.

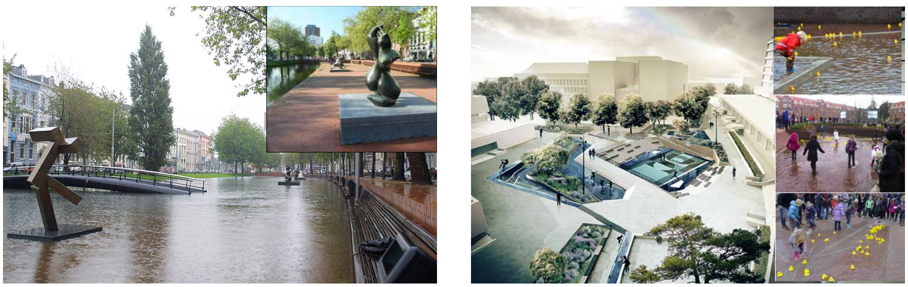

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FIGURE 3.10 Urban floodplain at Westersingel and Benthumplein water square, designed by De Urbanisten and Bellemyplein on the far right (Image courtesy of city of Rotterdam and De Urbanisten).

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Providing easy access and linkage to the surrounding landscapes

In the last decade, water has gradually been rediscovered as a means of transport and both the water bus and the water taxi were successfully introduced. The river is optimally used for transport on waterand new interchanges were created to connect public transport on water to transport systems on land. In the city centre new city bridges, next to the existing Erasmusbrug and Willemsbrug, will connect River City, Singel City and Canal City with each other. The bridge in the Rijnhaven is a good example. The city is better connected with the surrounding landscapes with high-quality recreational links, such as the newly built north-south link, the 'Blauwe Verbinding' (blue connection). This is a thirteen kilometres long waterway that links Zuiderpark water system to a regional water retention buffer. It discharges water, increases biodiversity and provides for recreational activities. Other links are around the river Rotte and river Schie.

An (international) attractive city centre

Over the years, the presence of water has become more tangible in the city. Rotterdam Water City 2035 has contributed to an attractive (inter)national city centre. A higher building density is created near the river: more housing, more facilities, new public space such as the Boompjes, more employment and improved accessibility. The river has become the central area for urban development in the heart of the city.

§ 3.7.3 Aims of the city of Rotterdam achieved

The city of Rotterdam's aims for entering the IABR2005, as described in paragraph 3.3.2, have all been met. Van der Brugge et al. (2010) refers to this as such, 'the discourse has changed as the result of a collective understanding that creating additional water retention capacity in existing urban areas will only be realised if water management links up with the dynamic of urban renewal. The new discourse suggests that water retention can contribute to an attractive city for residents and companies and thereby contribute to solving other urban problems.' The follow-up examples described and illustrated below are linked to the previously mentioned aims and confirm this conclusion.

Profiling Rotterdam through a joint approach, as well as showing more professionalism in the organisation (through research, design and debate) can be linked to all other aims below. Since the IABR2005, many developments have taken place. A number of new developments will be described as a spin-off of IABR2005 [Figure 3.11].

FIGURE 3.11 Timeline of Rotterdam's transition process towards a resilient city shows that over the years, water climate adaptation work was merged with the climate mitigation work as well as other resilience topics addressed from a wide sustainability spectrum (adapted version of image courtesy of the city of Rotterdam)

Convince the administration and citizens of the need to use the water issue as an opportunity for Rotterdam

Next to the Waterplan 2 (Gemeente Rotterdam, 2007), the Herijking Waterplan 2 (Gemeente Rotterdam, 2013b) and other policies, the Rotterdam Adaptation Strategy (Gemeente Rotterdam, 2013c) was introduced. Based on the Rotterdam Water City 2035, it sets out a strategy in which the city wishes to prepare for climate change. This strategy has been fully implemented and has become increasingly dynamic over the years. Since Rotterdam is vulnerable to risks related to water safety, severe precipitation, drought and heat, the target is that the city will be climate-proof in 2025. This requires systematic use of adaptation measures in all spatial developments in the city (City of Rotterdam, 2016).

Contribute to the dissemination of Rotterdam as a city of architecture and urban design at a high level on an international stage

As a result of its international role related to the Rotterdam Water City 2035 and follow-ups, the city is part of international networks. Next to the Connecting Delta Cities network and Rockefeller Foundation, the list ranges from the World Council on City Data, Covenant of Mayors, C40, Transatlantic Cities Network of GMF, to ICLEI. The launch of the Connecting Delta Cities (CDC) for delta or coastal cities took place in 2008 in Tokyo during the first adaptation conference of the C40 Cities Climate Leadership Group. Rotterdam took up the challenge of ??creating a network of delta members (Rotterdam, 2016).

At the celebration of its 100th anniversary, the Rockefeller Foundation announced a commitment of $100 million to improve urban areas in preparation for climate change. Cities were called to participate in the '100 Resilient Cities Centennial Challenge' and submit their plans for adaptation. Together with the Rockefeller Foundation and other partners, the 100 cities can prepare themselves better for climate change or other 21st century shocks and stresses as well as invest in a sustainable world. Rotterdam was among the first 33 selected cities. Arnoud Molenaar, already involved in the Rotterdam Water City2035, was appointed Chief Resilience Officer, (CRO) of Rotterdam. Over the years, Rotterdam has hosted several CDC and Rockefeller conferences on water. For over 15 years, Rotterdam has hosted the International Architecture of Biennale Rotterdam (IABR).

Motor and accelerator by scaling up

As more storage capacity needs to be planned and constructed for each neighbourhood, typologies were developed for implementation. A good example of this is the Zomerhofkwartier (ZoHo), which for a long time, was a forgotten area on the edge of the Rotterdam city centre with many empty offices. The crisis had had its impact and also safety in the neighbourhood had dropped. A number of parties, including the Havensteder housing association, De Urbanisten (designers of the Benthum water square in this neighbourhood), the water board of Schieland and Krimpenerwaard, STIPO (Urban Development Office), and the Municipality of Rotterdam, decided not to demolish in this area but to choose a gradual urban development, "slow urbanism". By linking this development to solving water pollution after heavy rain, the Zomerhofkwartier could become a lab for spatial adaptation where new applications and concepts are tested and demonstrated.

Riverbank program, River as a tidal Park, and future vision Rotte.

Other scaling up projects involved looking at the river as the biggest regional park within the city borders, adjacent to the city centre. Along the banks of the Nieuwe Maas, cooperating parties are realising beautiful new park areas. Outside the city, these tidal parks consist of landscapes of reeds, willows, swallows and bushes. Within the city, they will have a more urban appearance where people can enjoy the river. The transformation of bare stone quays into a park with trees, reeds and willows along a river with tidal influence is unique in the Netherlands and is a new habitat for birds, fish, amphibians and insects. When making tidal parks, conditions are created for natural processes to go ahead, ‘Building with Nature'.

Accelerator for business and political agenda setting

Many cities in the world face major challenges in terms of water pollution and water safety. An opportunity exists for Rotterdam's companies and institutions, by utilizing joint know-how and experience. The city's approach is a model for other cities. By 2015, the Rotterdam Centre for Resilient Delta Cities (RDC) had been established (Rotterdam, 2016). The RDC is a regional partnership consisting of educational institutions, knowledge institutes, government agencies, design agencies, engineers and architectural firms, focusing on water technology, water management and urban development. In the past years, knowledge and business played an important role in the recovery after floods in New Orleans, New York, Ho Chi Min City and Djakarta.

Knowledge development and platform for craftsmanship and plans

Research institutes such as the Rotterdam University of Applied Sciences, Delft University of Technology and Erasmus University have an international focus and publish frequently on these topics (Meyer, 2009; Nijhuis, 2014; etc.). Rotterdam's design agencies are very active in this field and are involved in many water projects around the world from New York, New Jersey to Copenhagen. Henk Ovink, water ambassador of the Dutch national government, mentions that ‘Rotterdam is like a testing ground and acts like a showcase for many other cities that are dealing with these issues; the city is not just inspiration and example, it is also initiator and organiser of knowledge exchange’ (City of Rotterdam, 2016). In the past years many European projects and research projects have been built around this emerging theme in the Rotterdam region.

At http://www.gis.rotterdam.nl/wpr/ the city of Rotterdam provides a map with the built and ongoing projects. The Delta City App also provides an overview of locations and structures that prepare Rotterdam for ever-increasing weather conditions with severe rainfall and protection against water.

§ 3.7.4 What went wrong and lessons

One can argue that there have not been many projects in the southern part of the city (excluding port-city area). There was an attempt to build a water square in one of the neighbourhoods on the south side of the city. However, miscommunication and a lack of involvement by the right stakeholders, led to protests from the residents. People were afraid that mosquitos would breed and their children would be at risk from drowning. Other water square initiatives learned from this and were successful after all. More attention to the southern part of the city is still required.

Another issue is that building water squares is an expensive undertaking. The Benthumplein water square could only be realised because it was linked to a European project. The question arises as to how to make these squares cheaper or redesign them so that they can become more mainstream. Part of the Rotterdam Water City 2035 vision was that in older inner-city neighbourhoods housing should be demolished to create room for new canals, waterways and squares. This has not happened since other solutions were formulated, and it has not been a priority till now.

Lessons:

- When building the 'Master Case Approach', one can argue that there were already a few frameworks and strategies around, which could have been incorporated. It is valuable to have these strategies readily available when starting a project like this. One of the pre-studies could have focused on this aspect.
- The pre-studies of the 'Master Case Approach' turned out to be a crucial part of its success. In future approaches, it would be wise to incorporate the gathering of best practice and failures.
- Scaling up of solutions is required.
- Keep a connection between what happens in public space and water goals.
- No direct involvement of citizens was a problem when building the first water square and this is a requirement to find more synergies.
- Analysis in the approach needs to link more with the neighbourhood level in order to link better to synergies, especially in the southern part of the city.
- City Data and detailed (GIS) maps on water (or the topic addressed) as well as on other topics need to be in place. If possible, link these to neighbourhood dashboards, apps and so on as a link to smart cities program (Tillie et al., 2015).

§ 3.8 Discussion

The Rotterdam water approach has gained a lot of attention over the years and has been used as an example in science and practice all over the world. Van der Brugge (2009) uses IABR2005 - Rotterdam Water City 2035 as a case study in transition management and how water policy is linked to urban renewal. The reason why this chapter focuses on Rotterdam Water City 2035 is that it is has never been described in a research paper before, whereas it is at the base of so many follow-up developments in Rotterdam itself and in other cities. Also, it is a good example of synergetic urban landscape planning. This approach served as an example for the energy and food approach in chapter three and four, as well as for the densification and greening approach in chapter six. One can argue that the success of this project lies in its subject. Would the results have been the same if the topic was not flooding and climate change?
Frantzeskaki et al. (2014) describe that in some cases there is a disconnection between a long-term vision, and short- to medium-term actions in projects. Planning officers expressed that there was a 'fatigue' of too many unconnected visions created in the past. The opposite was actually the case with the Water City 2035.

At the moment, more planning frameworks that deal with climate change have become available, such as Swarm Planning, a planning methodology to deal with climate adaptation (Roggema, 2012). This methodology has been applied successfully in the province of Groningen, in the Fukushima area of Japan and in Australia, dealing with sea level rise, flooding, bushfires and restoration after tsunami and earthquakes. Another new development is the so-called adaptive framework built for the Rotterdam region by Meyer & Nijhuis (2016), which allows for short-term societal changes as well as for long-term adaptation to possible changes.
Rodin (2017) mentions that cities integrate solutions inclusively, in order to deal with the impacts and challenges of climate change. In other cities, or when dealing with different topics, a vision document might not be enough to trigger actions and more is needed. In the past decade, there has been a lot of awareness and new developments. Design frameworks without the involvement of the community and practitioners in cities will risk being merely academic exercises.

The methodological framework used for this research is based on the experiences in this project and overlap in many steps. In the methodological framework the urban landscape, its systems, functions and patterns (spatial characters) have been studied as follows:

1 Existing Urban Landscape (baseline): analysis of current system to identify shortcomings, challenges and opportunities which can be dealt with from a spatial perspective.
2 Framing the challenges
3 Involve stakeholders and explore potential synergies, setting of goals and indicators
4 Vision making and where needed, develop new approaches.
5 Application or simulation study
6 Planned urban landscape: assess new developments or planning ideas and improve where needed

§ 3.9 Conclusions and link to main research objective

Link to research objectives

The approach worked well for establishing urban synergies [Figure 3.12]. Water has become tangible in the city and adds to safety as well as quality of life. Rotterdam Water City 2035 has helped to create an attractive (inter)national city centre near the river: more housing, more facilities, more employment and better access. The river is unfolding as the central area for urban development in the heart of the city with good (river) public transport. New people (with higher incomes) stay or come to live in the city much more tourists also visit the city. This will result in a more varied population make-up and in the differentiated economy the city desired.

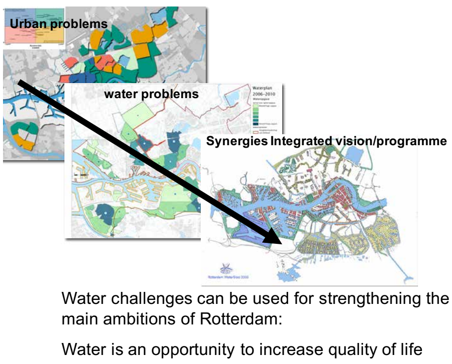

FIGURE 3.12 Planning for synergies (Tillie, 2015b) (maps in image courtesy City of Rotterdam)

To identify potential synergies, from challenge to opportunity, the pre-studies proved to be a crucial part.
Furthermore, several strategies were developed to improve water quality as related to sewage overflows?
Outcomes and related synergies are listed below.

Synergies and water related issues

The following points were achieved (Tillie, 2007):

- An attractive city centre, more housing and employment adjacent to the river;
- New public transport nodes, where water and land transport lines meet;
- Recreational connections;
- A new recreational landscape with an authentic identity;
- A new network for small boats;
- Reduction of heat island effect;
- Improved water quality, little to no overflows;
- Enough storage capacity for heavy rainfall and enough seasonal storage capacity;
- Little fluctuation in ground level water;
- Water solutions all year round;
- More housing within the city;
- Better quality houses;
- New typology of housing areas;
- Housing areas the city needed realised.

Rotterdam Water City 2035 created a new perspective for Rotterdam and gave direction as to how politicians, policy makers and planners should act (Greef, 2005).

Main conclusion for SULP

Pre-studies are important to inform stakeholders and create a more level playing field when planning for synergies. Apart from placing challenges in a cultural and historical context, they also help to make clear what there is to integrate.

Acknowledgements

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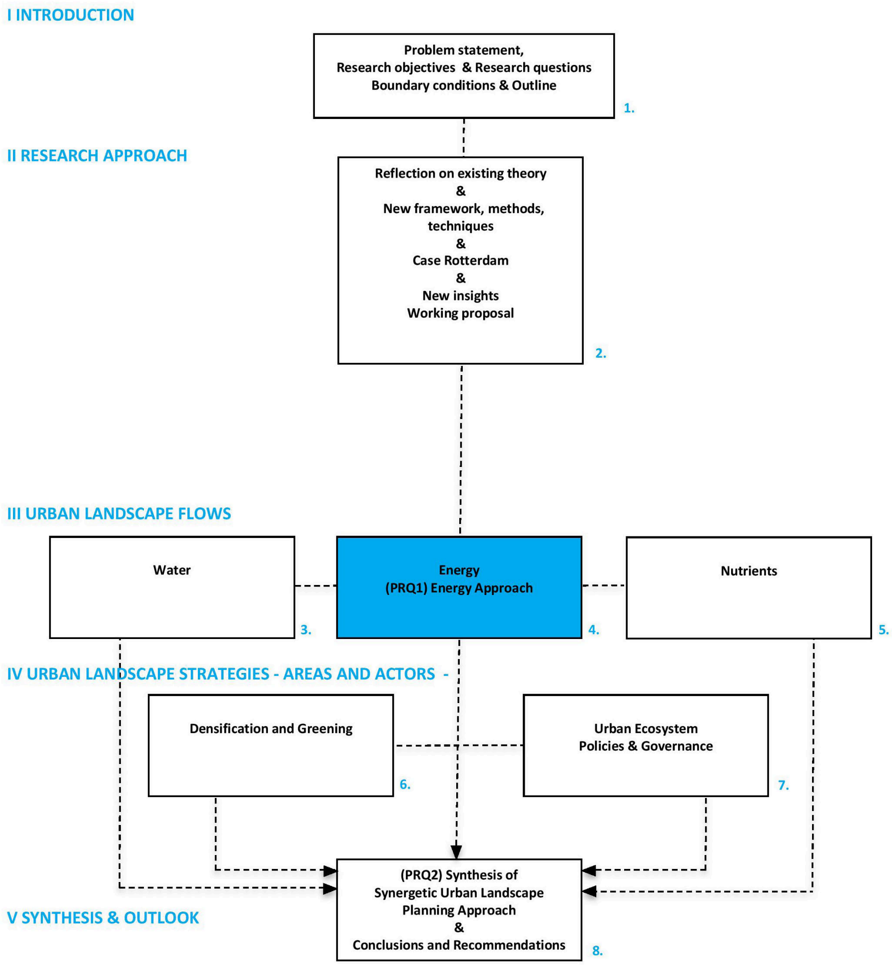

FIGURE 3.13 Bridging three-four

Bridging three - four

Chapter three was linked to **flows** and focussed on exploring synergies, turning water challenges into opportunities for the city. Governance aspects, landscape architectural and spatial issuesdominated. Whereas chapter three presented synergies with mainly indirect low carbon outcomes.

Chapter four is also linked to **flows** but is focusses on direct low carbon outcomes as well as on exploring synergies. Chapter four presents a big part of the energy provision of the built environment of the city itself, namely heating. The energy flow itself is the starting point. The four steps of 1. Reduction of demand, 2. Exchange of energy waste flows, 3. Production of renewables and 4. Scenario planning structure this chapter.

The use of CO_2 and energy use maps per household typologies guided policies for energy demand reduction. Combining existing approaches such as the trias energetica and the new stepped strategy in a multidisciplinary team resulted into a novel approach for the exchange of energy waste flows. This is the Rotterdam Energy Approach and Planning (REAP) on how to link (thermal) energy and urban planning. It deals with the scale of the building to neighbourhoods, district, cities and regions; with the exchange of waste heat between different functions at its core. Energy principles are tested in several design cases. In REAP 2 the new principles were tested and explored with energy specialists, a legal specialist, architects and urban planners to come up with practical cases. Heat mapping and energy potential mapping were used to plan for renewable energy in the city. The scenario planning tool GRIP was used to develop several stakeholders based transition pathways with 60-80% CO_2 reduction in 2050 compared to 1990 levels. For this, all relevant sectors were involved, the residential, services, transport, industry and energy

industry sectors. GRIP requires the use of specific data of primary energy used at city level. There are, other simpler but, less precise examples of energy scenario methods which can be done with children in school. Many outcomes of this study have been used in the city throughout the process. The energy scenario paths were input for the cities' energy masterplan of heat networks. Also, aspects of REAP are now being used in some areas of the city also in the 'Rotterdam building' exchange of waste flows of heat energy are exchanged between different functions.

4 Energy

Planning for the transition to a low-carbon city

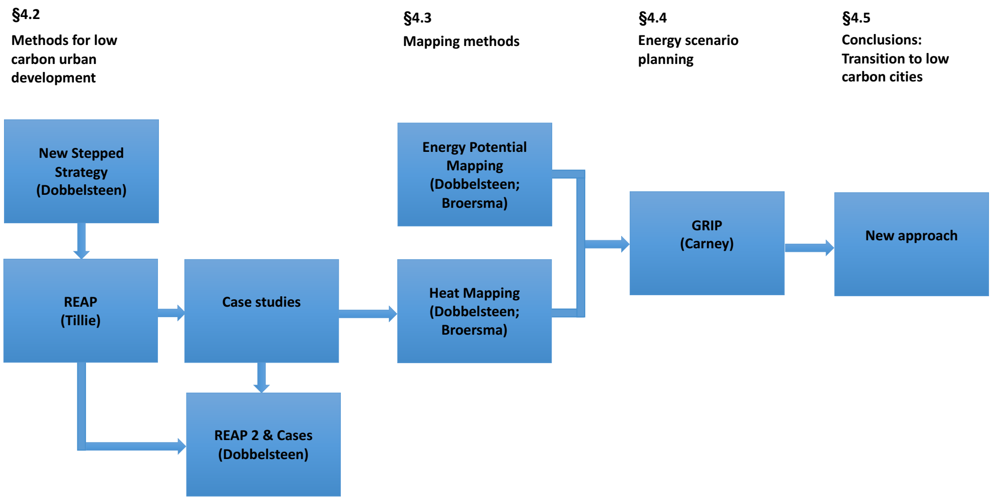

FIGURE 4.1 Outline chapter 4

Note in advance

This chapter is slightly adapted form of a paper published as a book chapter and was peer-reviewed by the author Prof. Steffen Lehmann:

Tillie N., Dobbelsteen A. van den, Carney S. (2014); A Planning Approach for the Transformation into Low-Carbon Cities, in: S. Lehmann (ed.), Low Carbon Cities; Earthscan

This was for a large part based on an earlier double peer-reviewed paper

Tillie N., Dobbelsteen A. van den, Doepel D., Jager W. de, Joubert M. & Mayenburg D. (2009b); 'Towards CO_2 Neutral Urban Planning – Introducing the Rotterdam Energy Approach and Planning (REAP)'; Journal of Green Building, Vol. 4, No. 3 (103-112)

§ 4.1 Introduction

§ 4.1.1 Energy in the existing urban landscape

This chapter explores the 'research lens' energy and presents the results of a practical approach for assessing and managing the transition to a low-carbon city. It utilises a combination of the New Stepped Strategy (NSS) (Dobbelsteen et al., 2008b), the Rotterdam Energy Approach & Planning (REAP) (Tillie et al., 2009b), Energy Potential Mapping (EPM) (Dobbelsteen et al., 2011; Broersma et al., 2013), and a stakeholder-based energy scenario planning process called GRIP (Greenhouse gas Regional Inventory Protocol) (Carney et al., 2009) [Figure 4.1]. The results and analysis provided are taken from a case study of the City of Rotterdam.

Cities are responsible for approximately 75% of global CO_2eq[1] emissions. The majority of these emissions are linked to energy. Currently, limited approaches are available to urban practitioners to reduce carbon emissions in a systemic way, making it difficult to build long-term strategies, take effective steps and produce focused initiatives. This leaves us with a question: 'How can CO_2 and energy become an integral part of urban planning?'

The value of connecting urban planning, energy and CO_2 is apparent from the results of the studies undertaken. The REAP study showed the energy saving opportunities of exchanging waste heat within and between buildings, neighbourhoods and at the city scale, through a smart district heating grid. We used EPM to present the capacity generation of Rotterdam in a user-friendly format for a wide range of stakeholders. In preparing a stakeholder-based heat-cold vision for Rotterdam, energy potential maps were used with Geographical Information Systems (GIS) and fed into the GRIP scenario process. This process gave urban planners, policy makers and other stakeholders direct insight into the potential future energy mix, carbon emission reduction, and a hint of the spatial consequences of such a future.

1 CO_2 equivalents: all Greenhouse gases converted to carbon dioxide, according to the relative effect on climate change.

This chapter is divided into five sections. In the first section, we discuss the heating energy requirements of the city. In the second section, we examine the NSS and REAP. In the third section, we present EPM in the context of Rotterdam. In section four we present GRIP and its results in the city. Finally, in section five we present our conclusions.

§ 4.1.2 The significance of heat exchange in cities

An opportunity often overlooked for urban energy efficiency is the potential to reuse waste heat. Buildings in the Netherlands use approximately 30-40% of national energy. However, in a westernised city where heavy industries are often absent, this contribution can be 50-75%. Of this energy, the component used for space and water heating is approximately 70-80% [SenterNovem 2008; Broersma et al. 2011a]. In the Netherlands, the predominant part of this heat is met by natural gas (producing hot water of 60-90ºC), often by means of onsite boilers that are energy-efficient but have an exergetic efficiency of around only 10%. In other cases, district heating (urban heat grids) provide this heat through transported hot water (at 90-130ºC), powered by residual heat from a power plant or industrial site fired by fossil fuels; this heat is seldom transported over distances exceeding 25 km.

So, the reuse of waste heat that otherwise would have been wasted may essentially be good, the current system however is not very efficient.

Studies indicate that 40-50% of the heat consumption in cities can be reduced through more efficient use of the residual heat within it [Tillie et al. 2009a; Kürschner et al. 2011].

§ 4.1.3 Exergetic inefficiency

Buildings in cities currently consume energy with a higher thermal content than required. As stated, temperatures of around 90ºC are used to create an indoor temperature of around 20ºC. Whilst this may remain necessary for old, unretrofitted buildings with traditional radiators (which cannot be energetically renovated); in modern well-insulated houses with a water based floor heating system temperatures of 30-40ºC would suffice. In passive houses the source heating requirement would even be 25-30ºC. This means that while thermal comfort can remain the same, the energy used to provide it (based on natural gas) can be reduced by up to 70%.

A city relying on gas or heat from power plants/industrial sites may have a serious problem with meeting its energy supply requirements in the near future. Under a low-carbon future this heat will need to be met by such sources as geothermal, inter-seasonally stored solar heat and biomass-fired power plants, which are not abundant enough to meet the world's urban areas.

If a lower input-temperature requirement could be met, whilst maintaining thermal comfort, and in-turn this requirement is served by waste heat from other buildings, then the overall input energy requirements can be further reduced. This is the 'essence' of exchanging or cascading heat within neighbourhoods or between buildings. Depending on the number of connections or cascading steps and the efficiency of the exchange the input energy requirements could be further reduced, by a factor two at least.

§ 4.2 Methods to support low carbon urban developments

In this section, we mainly focus on heating and cooling of the built environment.

§ 4.2.1 The New Stepped Strategy

The New Stepped Strategy (NSS) was developed by Dobbelsteen (2008b), based on the Trias Energetica (Lysen, 1996), to improve the efficiency of buildings. The NSS adds a step between consumption reduction and the deployment of sustainable sources, a strategy to incorporate waste flows.

1. Reduce the energy consumption (using smart and bioclimatic design)
2. **Reuse waste energy**
3. **Produce** renewable energy
4. ~~Supply the remaining demand cleanly and efficiently~~

The second step of the NSS optimises the use of waste heat and water both within and between buildings, possibly onto a city-wide scale. For example, waste water can be purified and the silt fermented to form biogas which can be reused in the energy chain. Step 4 will eventually no longer be possible or desired but it continues to be necessary for the coming decades, albeit to an ever-decreasing extent.

§ 4.2.2 The REAP Method

Within a city the energy consumption of buildings can, and must, be reduced to meet efficiency and carbon targets. Thereafter it is useful to determine whether waste flows from the building can be usefully reused. This is already being done by recycling heat from ventilated air and waste water from showers, for example. It is much more difficult to purify waste-water on an individual building basis than a collective to reclaim biogas. After applying step 2 – reuse waste energy – of the NSS to individual buildings there remains a requirement for energy that must be solved using renewable energy sources. If we consider the city as a system then we must establish how to scale up from the building level to the level of the neighbourhood, district or city/region **[Figure 4.2]** (Tillie et al., 2009a).

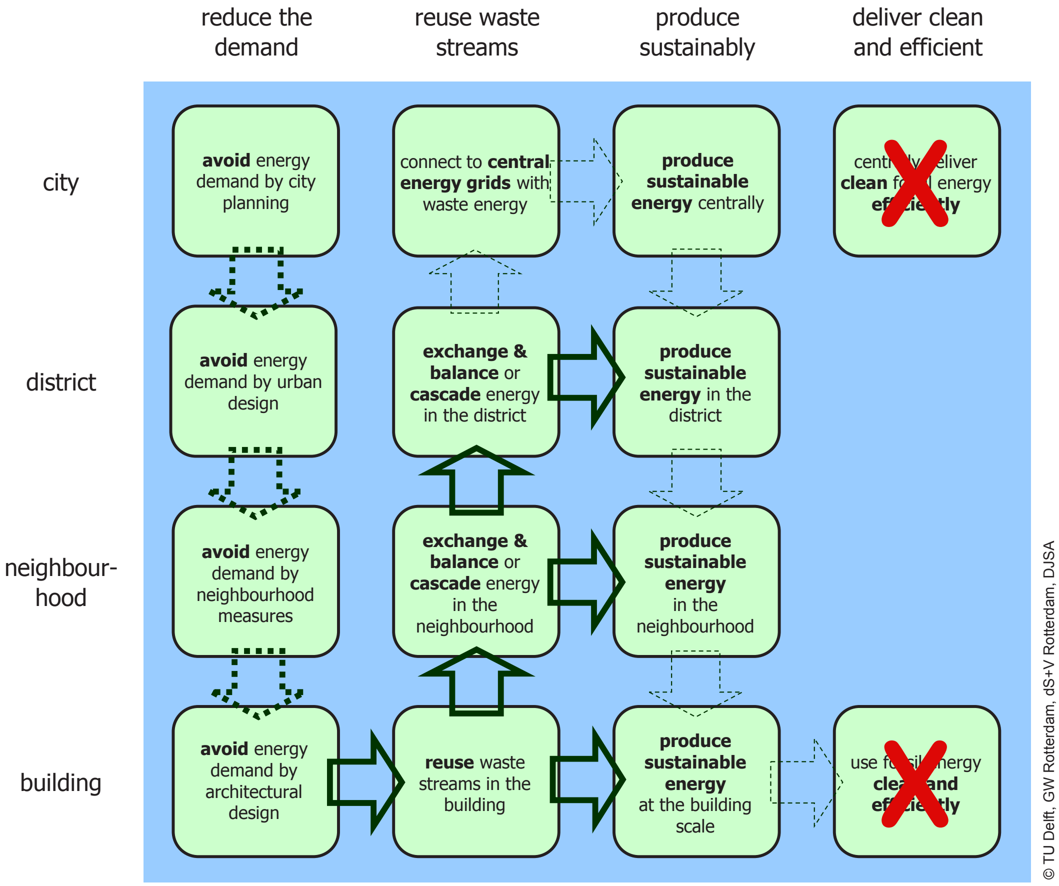

FIGURE 4.2 The REAP methodology (Tillie et al., 2009; image courtesy of Andy van den Dobbelsteen)

From building to neighbourhood

- In Western Europe, modern offices often start cooling as soon as outdoor temperatures exceed 12ºC. Meanwhile, at these temperatures residences still require to be warmed. This provides opportunities for heat exchange between buildings, particularly during spring and autumn. Within this, a particular opportunity exists for the combination of supermarkets (which always require cooling[2]) with residences (which predominantly demand heating). This applies to temperate and cold climates.
- Heating/Cooling is only in excess when there is an overall lower demand (i.e. a particular point in time) for them. There is potential for optimising these energy flows to be stored and exchanged between seasons.
- A greenhouse captures a considerable amount of passive solar energy, which is usually released into the air through operable glass roof panes. An air-to-water heat exchanger could enable capture of this waste heat (30-40ºC under sunny conditions) to be used (or intermediately stored) to heat homes, provided these are well insulated and make use of a low-temperature heating system. This is an example of heat cascading.

If all waste flows at cluster or neighbourhood level are being used optimally the remaining energy requirements need to be generated through renewable technologies. Some technologies are feasible at the individual scale – e.g. PV panels and solar collectors – other forms of generation are potentially more feasible at the neighbourhood level – e.g. ground source heat pumps and wind.

From neighbourhood to district

If energy planning can be tackled at the level of the urban district the remaining discrepancies in the energy balance at the neighbourhood level (for example excess demand for waste heat or cold) may be solved. At the district level, it is likely that there will be a larger mix of functions available with different patterns of energy demand, and therefore supply. It is also possible to exchange, store and cascade energy at the district level. Larger amenities, such as shopping centres, swimming pools and concert halls, have a very specific energy pattern. Combining a number of these different amenities might achieve a higher level of energy efficiency and waste reduction.

In addition to exchange, storage and cascading, another option is possible. Useful functions might be added to complete missing links in the energy balance of an area.

2 Refrigeration, but also the air temperature inside supermarkets, in order to avoid condensation.

Once the existing amenities in the area have been optimised we consider any residual demand for heat or cold. In this case it is necessary to look for an amenity that requires extra heat on a yearly basis (for example a swimming pool) or one that requires coolth (for example an ice skating rink). The provision of renewable energy can then be tackled at the district level. As mentioned, some sustainable measures can be implemented at building or neighbourhood level, but other more capital-intensive projects are more appropriate at the district level. An example of this is a biogas fermentation plant that recycles biogas from waste water and uses cogeneration for heat and electricity. Geothermal energy plants are usually only feasible on a grand-scale.

From district to entire city and beyond

Amenities in many Northern European Cities are regulated centrally, many have a heat grid (fed with waste heat from conventional power plants, cogeneration plants, waste incineration plants, or industries). These heat grids provide temperatures between 90 and 130°C. This temperature level is necessary for buildings which are poorly insulated and which contain central heating systems based on these temperatures. However, new housing projects are more effectively served with lower temperatures – providing the same levels of thermal comfort.

Once connected to the high-caloric heat grid the whole exercise of exchange, storage and cascading at neighbourhood and district level is no longer logical. In this situation the heat grid takes care of the heating and potentially also the cooling (e.g. via absorption cooling). The problem with this is that the local waste heat can no longer be functionally used and disappears into the environment – the urban surroundings. The lower-caloric heat from buildings as offices, supermarkets, swimming pools and dwellings is abundant and seldom utilised. This has two negative effects: the demand for energy is higher than necessary, and energy is lost and the city heated up, which in summer can aggravate the urban heat island effect, which statistically leads to higher mortality rates (Huynen et al. 2001).

The REAP methodology aims to solve the problems of matching energy demand and supply starting at a low scale from the building, clusters, neighbourhood level upwards. After which 'help' can be called in from higher levels which – depending on the starting-point – can be clusters, neighbourhoods, districts, cities and regions. In addition to the heat grid fulfils a useful role as backup system, or as a loading and unloading system for too much or too little heat in a district or neighbourhood. REAP can help make an existing neighbourhood more energy efficient. The following cases will show how this can lead to low-carbon neighbourhoods and discuss how this can be done.

§ 4.2.3 Case studies of the Hart van Zuid shopping mall and IKAZIA Hospital area

REAP can be used to identify the key decisions to be made at economic, political, public, urban development and architectural level to meet the desired reductions in CO_2 emissions. Subsequently, the consequences for the buildings in a city and the open spaces in-between can begin to be identified. In addition, combinations of measures for CO_2 reduction can mix with sustainable development by means of a combination of functions, social integration and integration of food production in the urban landscape (urban and peri-urban agriculture).

In the Rotterdam Hart van Zuid district, in particular the IKAZIA hospital and the Zuidplein shopping mall, a mix of 1960s' urban development and 1980s' architecture, functioned as test cases for the REAP methodology.

Hart van Zuid shopping mall:

Step 0 Make an inventory of the current energy consumption.
Step 1 Reduce energy consumption through insulation and bring heat and cold demand in balance as much as possible.

The new cluster's total energy demand is: heat 8,654 GJ, cold 7,231 GJ, electricity 14,629 GJ. w

New functions will be added: 20,000 m² shops, 6,000 m² supermarket and apartments buildings. The Zuidplein Theatre will be renewed. Better insulation of the existing shopping centre significantly improves the situation.

Step 2 Reuse of waste flows; waste heat generated by the supermarket, 1 m² supermarket can heat on average 7 m² of housing! If 45.550 m² (650) apartments are added, the heat-cold ratio improves and becomes 1:1.08 assuming that heat and cold storage will be used. Thermal storage covering heating demand 7,231 GJ. The resulting heating demand is 1,423 GJ

Step 3 Renewable energy generation. The remaining demand for heat can be solved by the addition of greenhouses on the first floor 1 m² greenhouse on top of the roof can heat 4 m² of housing (extra electricity demand 142 GJ) these could be public areas (or greenhouses for growing tomatoes) or by the addition of PVT-panels. PV panels could also be installed on the roof to supply electricity for the shopping centre (2,547 GJ). The remaining energy demand (12,224 GJ) could be required sustainably generated at a higher scale level [Table 4.1].

STEP 1		STEP 2		STEP 3		ENERGY	
Reduce energy demand and through isolation + heat cold demaning program in balance		H : C balance total cluster		Resulting heating demand sus-tainably generated by greenhouse and renewable energy generation		Contribution PV panels	2547 GJ
		Heat-Cold ratio H:C	1:0,8			Resulting en-ery demand	12224 GJ
Total demand cluster		**Thermal storage covered**		H : C (dis) balance		**Demand**	
H	8654 GJ	Heating demand	7231 GJ	Contribution green-house	1423 GJ	H	0 GJ
C	7231 GJ	Resulting heating demand	1423 GJ	extra electricity demand due to usage greenhouse	142 GJ	C	0 GJ
E	14629 GJ					E	12224 GJ

TABLE 4.1 Heat, cold and electricity data shopping mall Hart van Zuid

The IKAZIA hospital cluster is to be extended. The Hospital consumes a lot of energy at a relatively constant level, seven days a week. Possibilities for creating an improved heat-cold balance by the addition of other functions is limited.

Step 0 Make an inventory of the current energy consumption.
Step 1 Reduce energy consumption. The hospital can be optimally insulated by adding a climate facade. A new entrance will provide an improved link to the public areas. 'Pyjama gardens' on the green roofs with orchards and vegetable gardens will form a healing environment which will contribute to the patients' more rapid recovery.
The cluster's total energy demand is: heat 32362 GJ, cold 7918 GJ, electricity 5676 GJ.

Step 2 Reuse of waste flows. Recycling heat from waste air and water can be applied using heat and cold storage. Heat-cold ratio is 1: 0.24
Step 3 Renewable energy generation. The demand for heat can be sustainably satisfied using the climate facade and asphalt heat collectors at the new Zuidplein. Any remaining energy requirements will be satisfied by renewable energy generation at a higher scale level [Table 4.2].

STEP 1		STEP 2		STEP 3		ENERGY	
Reduce energy demand and through isolation + heat cold demaning program in balance		H : C balance total cluster		Resulting heating demand facade sustainably generated by climate and asphalt collectors		Contribution PV panels	0 GJ
		Heat-Cold ratio H:C	1:02,4	H : C (dis)balance		Resulting en-ery demand	6675 GJ
Total demand cluster		**Thermal storage covered**		**Contribution climate**		**Demand**	
H	32362 GJ	Heating demand	7918 GJ	Facade contribution	9090 GJ	H	0 GJ
				Asphalt collector	8113		
C	7918 GJ	Resulting heating demand	24443 GJ	Contribution city heating	-6340 GJ	C	0 GJ
E	5676 GJ				24443 GJ	E	6675 GJ
				Extra electricity demand due to usage climate facade:	909 GJ		

TABLE 4.2 Heat, cold and electricity data IKAZIA Hospital Rotterda

§ 4.2.4 Case study REAP2: smart grid for heating and cooling of the Merwe-Vierhavens

In this case study, the REAP approach was extended and tested, which led to new technical concepts for energy exchange. As in most other urban areas, the Rotterdam Merwe-Vierhavens inner-city port area is confronted with a gradual transition toward energy-neutral buildings. At present the area contains warehouses, industrial buildings, offices and a small power plant, many of which will continue operation for several decades, whereas others will be demolished, creating space for new, sustainable premises. This means that the energy demand and supply, heat in particular, will be very diverse and that the technology and infrastructure in place and to be developed need to be multifunctional, serve variable demands now as well as all kinds of demands in the future (Dobbelsteen et al., 2012).

The core focus of the project was on the elaboration of technical concepts for tuning the demand and supply of heat and cold (exchange of waste flows, step 2 of the NSS). There are four principles of balancing heat and cold:

- matching supply and demand directly
- (inter-)exchanging and storing residual heat and cold
- cascading waste heat
- storing temporal differences in supply and demand

These principles were applied at the scale of separate buildings, neighbourhoods (quays), the total area of the Merwe-Vierhavens and the city scale of Rotterdam. Five strategies emerged [Figure 4.3].

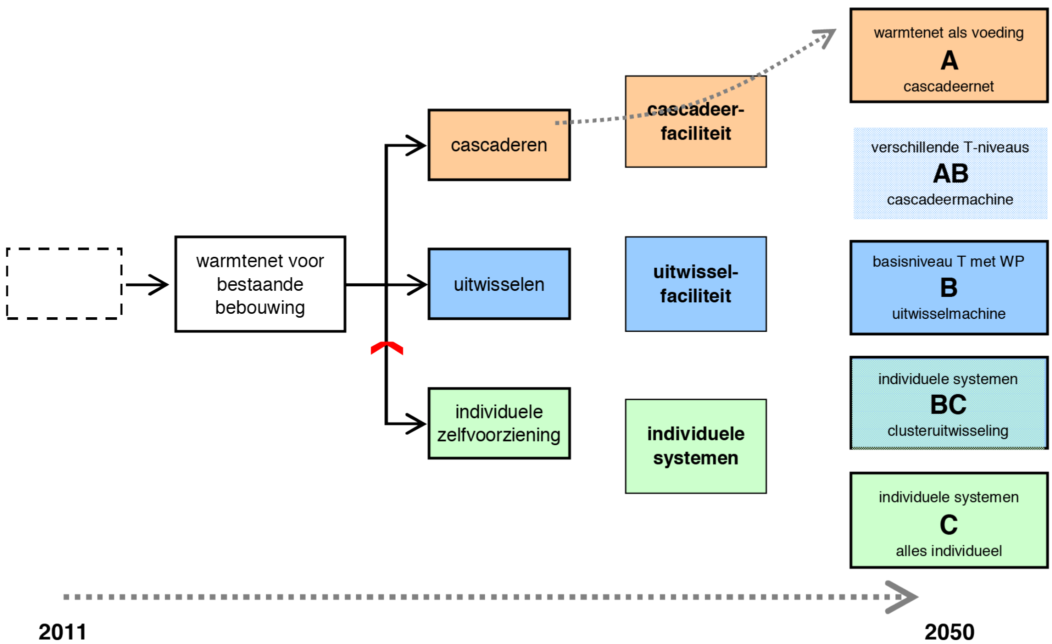

FIGURE 4.3 The five strategies from REAP2: two based on connection to the central high-temperature heat grid: A. heat cascading grid and AB. cascading machine; one introducing a neighbourhood facility: B. exchanging machine; and two disconnected from centralised energy infrastructure: BC. inter-exchange within a cluster and C. individual self-provision (Dobbelsteen et al. 2012; image courtesy of Andy van den Dobbelsteen).

The five strategies can be translated into technical solutions using available utilities but combining and connecting these in a novel way. The principle of a heat-cascading grid, using the return flow of one neighbourhood as main supply for the other [Figure 4.4].

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FIGURE 4.4 Heat-cascading grid, connecting an old neighbourhood with a newer one (left) and connecting a newer neighbourhood with a very well-insulated one (right); the latter grid can be an extension of the first (Dobbelsteen et al. 2011a; image courtesy of Kees Wisse DWA, energy advisors)

Cascading can also be established by a 'cascading machine' connected to the central provision of high-caloric heat. This concept could provide water at different temperatures for buildings with different demands – depending on their heat system and thermal insulation – based on the temperature difference between the feed water and the return water. An inter- seasonal heat and cold storage (e.g. underground aquifer storage systems, boiler systems and ATES) can shave off peaks in supplies and demands [Figure 4.5].

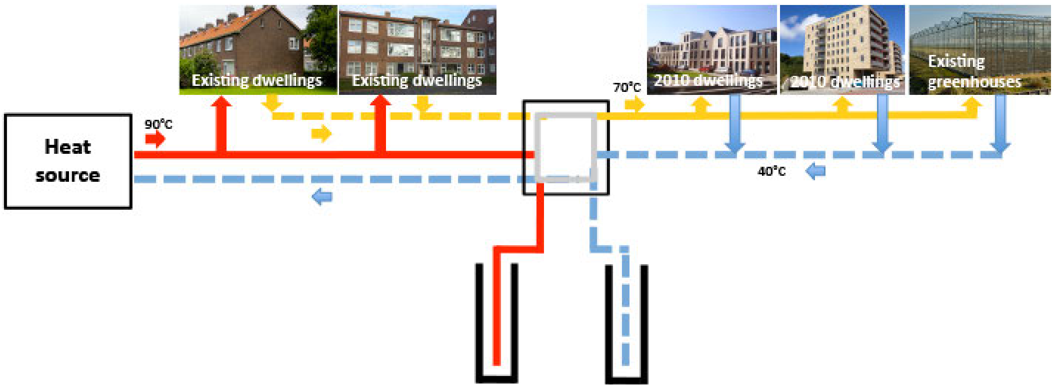

FIGURE 4.5 Heat cascading via heat and cold storage facility: excess heat in summer can be stored in the underground for use in winter, when excessive cold can be stored for use in summer (Dobbelsteen et al. 2012; image courtesy of Kees Wisse DWA, energy advisors).

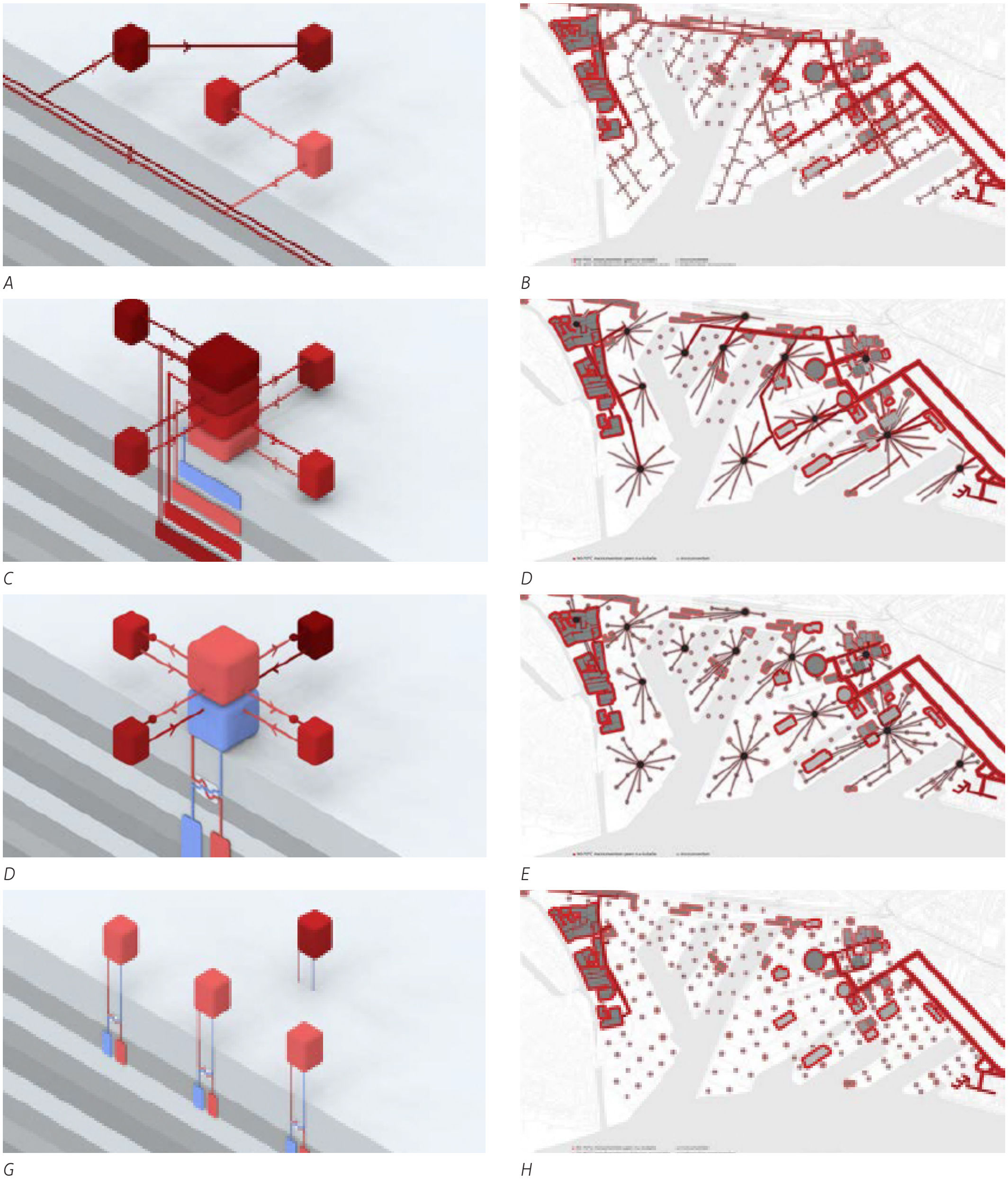

FIGURE 4.6 Technical concepts and spatial implications to the Merwe-Vierhavens of the heat exchange strategies of A (heat-cascading grid), AB (cascading machine), B (heat exchanging machine) and C (individual self-provision). BC is a smaller combination of C and B (Dobbelsteen et al. 2012; image courtesy of Doepel Strijkers Architects).

The five strategies have specific spatial, social, legal and institutional implications. Some of these implications became apparent when they were clarified by sketches of the technical principle and their respective spatial influence **[Figure 4.6]**.

The heat exchanging machine is still a theoretical concept but could be ground-breaking for the exchange of heat and cold in cities. The exchanging machine provides water at a low- caloric level (e.g. 40ºC), which can be upgraded or downgraded – depending on the demand of a building – by an individual heat pump. The return temperature depends on the heat demand of the building. If the building requires higher temperatures, then the return temperature is lower than 40ºC. If the building requires lower temperatures, then it can send back water of higher temperatures. The heat excess can be stored, for instance in hot wells of underground aquifers, and cold in cold wells. Finally, and not least, the question of exchanging heat and cold in cities will bring science on a higher level, integrating thermodynamics into urban planning and taking patterns of energy demand and supply in cities as the basis for novel utilities and infrastructure.

The heat and cold storage proves to be a valuable asset to a sustainable energy system as the availability of renewable energy in the future will fluctuate partly due to demand changes through the seasons. In the case of a cascading machine a multi-temperature storage system may be welcomed, delivering the possibility to store heat at different temperatures, which may avoid exergy losses. Although technically possible, this multi-temperature system does not exist yet.

The REAP2 case lacked one important aspect that should have been studied: the economic consequences of different energy solutions. The introduction of new vast infrastructures for this heat exchange in cities may be uneconomical when compared to traditional systems. This is, however, dependent on the way things are solved and exactly the reason why low-temperature systems should be tackled at neighbourhood level (typically with a radius of not more than 300 m).

These approaches focus on the development of heat and cold grids additional to the traditional industry-fed high-caloric heating grids. The local exchange of (low-caloric) heat within buildings and between buildings within an urban neighbourhood or district is not very common. Nevertheless, considering the energy futures of cities, it has great potential.

§ 4.3 Mapping energy

Planning for a low-carbon sustainable energy future requires an overview of the various possibilities to propose changes about energy efficiency, changing energy systems and the use of renewables. Accessible energy data relating to consumption, supply, and renewable energy potentials are crucial in the transition to a low-carbon city. This data needs to be presented in an accessible format to stakeholders of varying levels of expertise. This may take the form of visualised data in the form of maps, helping policy makers and other stakeholders to use the information in planning sustainable urban developments and energy systems.

§ 4.3.1 Energy potential mapping (EPM)

The key component of Energy Potential Mapping (EPM) is to provide visualisations of energy potential and demand. This includes information relating to quantity, quality and the spatial implications of demand and supply accessible. EPM gives an overview of the characteristics of energy sources, sinks and infrastructures within an area. Theoretically, all energy sources can be subject to an EPM study but generally renewable and anthropogenic (e.g. residual heat) sources are studied (Dobbelsteen et al., 2011; Broersma et al., 2013)

A special kind of EPM is Heat Mapping (HM) where the focus is on heat (and cold). The visualisation of exergy, or the quality of energy, was an additional parameter utilised in the case of Dutch Heat Maps. These maps can help to identify the practicalities of matching energy demand consumption to the potential of renewables (or in the case of HM exchanging or cascading heat or cold). Therefore, EPM and HM enable the application of exergy principles in the built environment. Moreover, EPM and HM can be seen as a local energy catalogue and can be useful in spatial planning for energy-based urban and rural plans. The outputs of the study generally consist of one or more energy sources, energy demands, transport and storage possibilities of an area, displayed both in a map and in figures (Broersma et al., 2013). GJ/ha or GJ are commonly used units for all sources and sinks but this depends on the scale of the area.

Sinks: Input for energy consumption can come from different sources including.

1 Simulation models which can estimate energy consumption per building type;
2 Real consumption data from energy companies per household or clusters of households;
3 National or international database such as the International Energy Agency and Eurostat.

In the Netherlands data is available for some 30 different housing typologies for which average energy consumption and measures to improve energy efficiency are known. Capacity has been built in to enable this data can be crossed referenced with local data sets and altered if necessary.

Consumption can be divided into sectors depending on the data available and how they are organised. The sectors generally used are residential, services, transport, industry and energy industry (i.e. refineries), in such a way that all data can be mapped and connected to geographical information systems (GIS). Data of consumers with a geographical location, such as factories, residential areas and networks, are all included. This is especially useful in a decision support system.

Sources: as Broersma (2013) describes, renewable energy originates from the sun, wind, water, soil and biomass, and in the case of waste flows from the built environment. After the selection of the different sources to be involved in the EPM, their theoretical potentials need to be calculated. Basic information on climate, topography, geography, land use, underground and built environment is required. For instance, at a basic level, in order to calculate the solar potential, solar radiation per square meter that reaches the area's surface is considered. For wind, the average annual wind speed is a common parameter. Water energy is considered in different ways; for hydro-electric energy, heights and annual quantities of water flow rates, or average river speed can serve as the required data inputs. In order to define the amount of heat available in geothermal sources, temperatures and volumes of existing underground aquifers are data inputs. For biomass, quantities of waste flows such as from inhabitants, livestock and data of land use must be determined. Anthropogenic sources, e.g. residual heat from industries, are measurable (Broersma et al., 2013).

When the theoretical potentials have been calculated, they need to be corrected for what can realistically be harvested taking at least technical efficiencies into account. For some sources detailed modules (in GIS) are available. For solar energy, for instance, shading, roof angles, weather patterns, cloud coverage etc. make it possible to get realistic harvestable data. Other restrictions such as politics, costs, public opinions etc. can be debated or added during the process of which EPM is a big part.

Storage: Broersma (2013) mentions that some renewable resources may have a fluctuating delivery potential, energy storage systems are needed to make their energy available at times other than it was harvested or produced. As with the energy sources themselves, storage systems deal with geographical and quantitative (as well as qualitative and temporal) input that can be mapped (Dobbelsteen et al., 2007). Heat and cold storage systems have a specific theoretical capacity to store either heat and/or cold water. Water basins or salt caverns act as storage systems for potential energy to be converted into electricity, input data being volume, height and pressure. Energy infrastructures: infrastructures have geographical and quantitative and qualitative characteristics, e.g. heat or electricity networks (Broersma et al., 2013).

§ 4.3.2 Heat Mapping (HM)

As Broersma 2012 points out: "In HM the heat demand is depicted as a series of elevated contours; the heat supply potential present subsequently fills the resulting sink.[3] When all these individual 3-D maps are stacked, the resulting 3-D landscape quickly indicates where demand may potentially outstrip supply, and vice versa. Large energy users, such as supermarkets, swimming pools, industries and power plants, are depicted by cylinders, where the colour denotes heating or cooling load and hollow cylinders represent the net demand for an installation. Larger roads can be equipped with integrated pipes to become giant solar collectors and are depicted as yellow bands. When present, a district heating grid providing heat transport opportunities is hatched in red" [Figure 4.7].

3 Note that, although this can be compared to filling a bucket, height rather than volume indicates the amount of energy as this makes it possible to asses a collection of areas of different sizes.

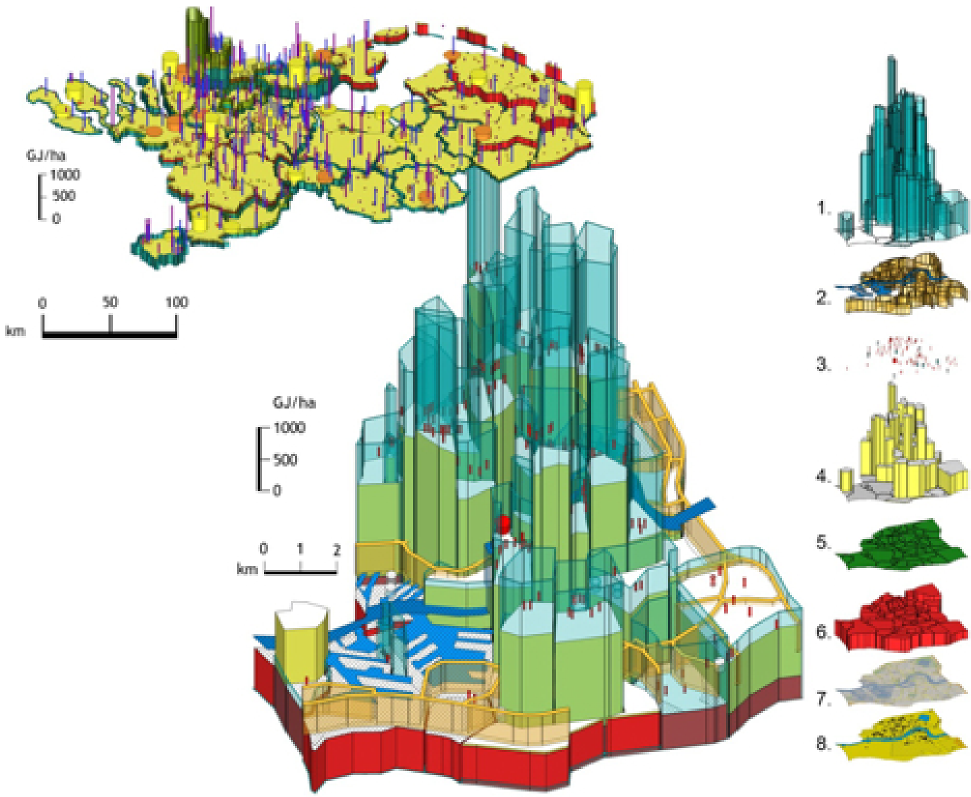

FIGURE 4.7 Heat map of The Netherlands (upper left) and for the city of Rotterdam (middle; sketch-up 3D modelling software was used for the graphs). The right-hand graph shows the stacked annual supply potentials (and demand) of the middle graph, from 1 to 8 representing: 1) heat demand of dwellings, 2) heat potential from road collectors, 3) point sources and sinks of heat and cold (supermarkets, hospitals, power plants etc.), 4) heat potential from roof collectors, 5) heat potential from biomass, 6) geothermal heat potential, 7) map of the area, 8) soil suitability for underground vertical heat exchangers (Broersma et al., 2013).

In the heat map of Rotterdam there is a big discrepancy between the heat consumption in the densely populated city centre and the heat consumption of the much sparser populated periphery. Excess geothermal flux from the periphery could be transferred to the city using district heating. The potentials that can be harvested in the city from the sun and geothermal sources cannot cover the demand for heat as in general the demand is twice as high. Also in this approach energy savings remain an important means to establish a low-carbon future. (Dobbelsteen et al.,2012).

§ 4.4 Energy scenario planning with GRIP

The previous sections have presented a step-by-step energy approach to integrating energy (mainly heating and cooling) into spatial planning and making energy data about consumption, storage and supply easy accessible by energy potential mapping. In this section, all these aspects were utilised to plan for a low carbon future. The scenario process can be run using bottom-up or top-down data. However, the internal consistency of the scenario pathways developed and their value for stakeholders will be much higher using local and data and potentials as explained before.

§ 4.4.1 Introduction to GRIP

The Greenhouse Gas Regional Inventory Protocol (GRIP) is a three-stage process toward forming energy action plans at the local and regional level. The first stage is the formation of a greenhouse gas emissions (CO_2eq inventory and energy baseline, the second stage is the production of consensus driven low-carbon energy scenarios aided by a scenario tool, and the third stage is using the results and experiences to inform energy plans.

The GRIP Scenario Process, aided by a user-friendly tool, brings together stakeholders representing different sectors into an iterative exercise. The process is based on the principle of 'to hear is to forget, to see is to remember and to do is to understand' with the design of the exercise based on the learning methods postulated by Brunner (1960, 1961, 1962). The process, coordinated by an energy expert, combines qualitative and quantitative viewpoints to deliver a whole system energy scenario that represents the consensus views of the stakeholders partaking. The results include a breakdown of changes to energy consumption, the fuel mix and energy generation; together with the learning that takes place during the exercise. As the outcomes are consensus driven they reflect the vision of the stakeholders present rather than the interpretations of a researcher or a consultant (Carney et al., 2009).

GRIP has been applied in cities and regions in 15 countries. The results of the scenario process regularly fall short of the targets set, for example a reduction in emissions of 80%. This is an important finding as it shows the discrepancy between what stakeholders envisage being delivered and the CO_2 targets being sought. The stakeholders that have partaken in the process all work on energy and climate change, however feedback from them suggests that just 3% have previously tried to quantify the CO_2 implications of an energy future. This suggests an important gap in experience that needs to be filled. It should also serve as a concern to national, European and international policy makers that there is insufficient support and experience in place on-the-ground where energy policy is to be delivered to meet the emissions reduction targets and associated climate goals.

GRIP was applied in Rotterdam, with four scenario sessions being conducted. These have been used to shape policy. The results of the inventory for Rotterdam, show the fairly unique situation of the city in the western world where emissions from industry (traditional and energy) account for three quarters of the emissions [Table 4.3 & Figure 4.8].

	CO_2	CO_2eq
Residential	1259	1287
Services	1586	1591
Industry	5640	5646
Energy Industry	10553	10576
Fugitive	275	275
Total Energy	20562	20637
Industrial Processes	44	148
Waste	0	280
Agricultural	0	132
Total	20606	21197

TABLE 4.3 Results of the inventory for Rotterdam TABLE Caption + Table > Merge Cells

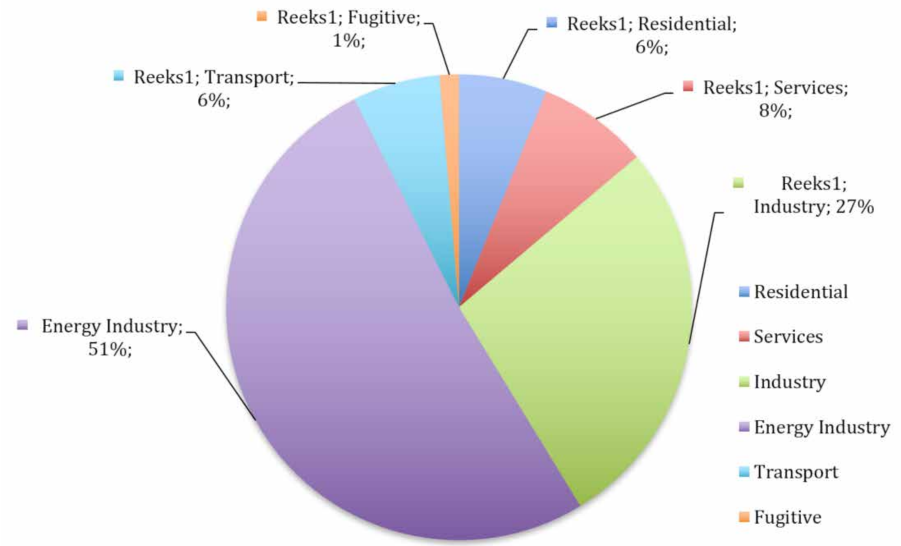

FIGURE 4.8 Results of the inventory for Rotterdam

The emission reductions in the scenarios were: 74%, 50%, 83% and 82%. These figures do not include international aviation or marine. The figures partly show a failure to meet the targets. This was largely caused by the complexities of reducing emissions from industry and in two of the sessions a belief that Rotterdam will continue as a focus for petroleum refining.

The stakeholders involved in the process included planners, policy makers, academics and local business makers. As a consequence of this work a memorandum of understanding was formed between the city and local businesses for extending the heat cold grid in the city. This supportive network is now being used as a conduit to form and implement policy locally. Follow-up work is being conducted with the Province of South Holland, South wing of the Randstad metropolis, City regions of The Hague and Rotterdam, in combination with the Rotterdam Climate Initiative and the Dutch Ministries for the Environment & Infrastructure and Economic affairs.

GRIP is being made available through the International Coalition for Local Environmental Initiatives (ICLEI) to aid and inform low-carbon energy plans in up to 84 countries.

In some cases, it is also possible to use a quicker simpler method albeit less accurate and less interactive. For instance, using little rectangular pieces of paper which make up for a certain amount of energy production (plus CO_2 emission from one source. Children in school have made different scenarios putting together different mixes as long as they are provided with the right information on energy demand they need to meet. Among many other new insights, McKay, (2008) shows some examples of this.

§ 4.5 Discussion, Conclusions and link to main research objective

Although the New Stepped Strategy (NSS) and Energy Potential Mapping (EPM) method, as well as the REAP study, started off as a theoretical exercise, over the years it has developed into a practical approach to link energy and urban planning. The fairly abstract fields of energy and CO_2 have become part of urban planning. The approach of using waste flows of energy at different scales has led to the necessity of designing smart grids for heating and cooling in many scenarios. This is now picked up in several follow-up studies including the European Celsius Cities project.

EPM has proven to be a structured methodology, which is currently evolving into a generic model that integrates energy databases in order to calculate energy potentials for a specific location or area by means of a web tool. Also gathering the knowledge of stakeholders in the building process via smart phones can accelerate data collecting and thus decision making early in the process. When linking EPM to GIS even more datasets can be used and all energy data can be matched with present socio-economic and urban data. At the moment, a GIS based Transilience Approach for cities and neighbourhoods is to facilitate stakeholders for accelerating the transition into more resilient cities (Tillie, 2013). A scalable GIS Resilience profile with socio-economic and ecological indicators is built to feed this approach. Energy and CO_2 are part of this.

The Energy Scenario Planning Tool GRIP has been combined with REAP, EPM and GIS. Apart from speeding up the process of data collection it has also made developed scenario paths more valuable as direct links could be made to local situations, potentials and policy-making. Scenario paths can easily be altered making it an easy tool for making changes in existing policies. While planning a heat network for the city of Rotterdam a new energy vision was built based using a combination of GRIP, REAP, NSS, EPM and GIS. The bandwidth of the scenarios was established with stakeholder input.

Outcomes of CO_2 scenarios can be spatially concretised. The scenarios are a way to link Energy, Spatial Planning and Sustainability.
So, the overall approach presented can be applied to all scales but is mainly applied to city-regions. As explained it serves as a good tool to have an overview for making scenarios and a long-term vision. In order to connect a long-term vision with areas and actual projects, it is valuable to calculate CO_2 emissions or expected effects for different projects or scales such as neighbourhoods or smaller areas. One can also think of the expected results of introducing a bike network or densifying the city.

Main conclusion for SULP

New futures have to be imagined, designed and drawn for many stakeholders to understand what is possible and desirable or not.

It is important to understand the expected future make up of a city so one plans for todays as well as possible future challenges. Vision making, scenario planning and back casting is covered in paragraphs 3.6.1 for water and in 4.4.1 for energy.

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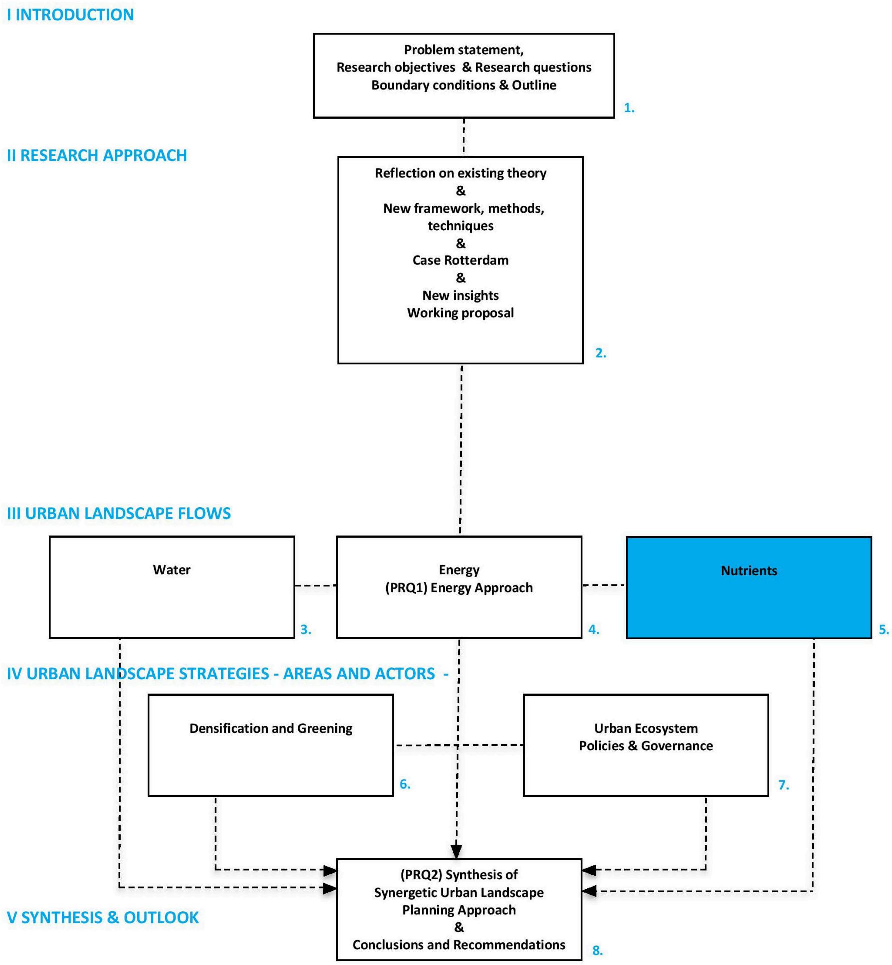

FIGURE 4.9 Bridging four-five

Bridging four-five

Chapter four is linked to **flows**. Chapter four addressed energy in the built environment. Solutions provided can have a direct effect on CO_2 reduction and provide for synergies.

Chapter five is also linked to **flows** and is an important addition to water and energy concerning the water energy food nexus. This chapter gives a short background and discusses current flows of food and nutrients, mainly phosphorus. Dealing with food and nutrients in a different way has a huge potential from a synergy perspective as well as reducing the carbon footprint. There are two main parts in this chapter. One part focuses on a wide range of synergetic effects on quality of life by implementing urban agriculture. Synergetic effects are planned for and are presented in the fields of health, economy, spatial quality, social coherence and to a lesser extent food production

The second part deals with the recovery of nutrients and in this case, that is Phosphorus. In a material flow analysis, the sources and amounts of Phosphorus that enter and leave the urban system are described. Also, a comparison is made how much agricultural land and hectares of urban agriculture could be provided with this waste(d) flow of Phosphorus.

Retrieving Phosphorus and reuse it locally is again an example of improving the environmental performance of the flow itself. In this chapter ideas on new garden cities are mentioned but is not elaborated on much further. Potentially a new design studio could pick this up. Many parts are still left open but fall outside the scope of this research.

5 Nutrients

Urban Agriculture: potentials for a liveable, low-carbon city and sustainable phosphorus flows

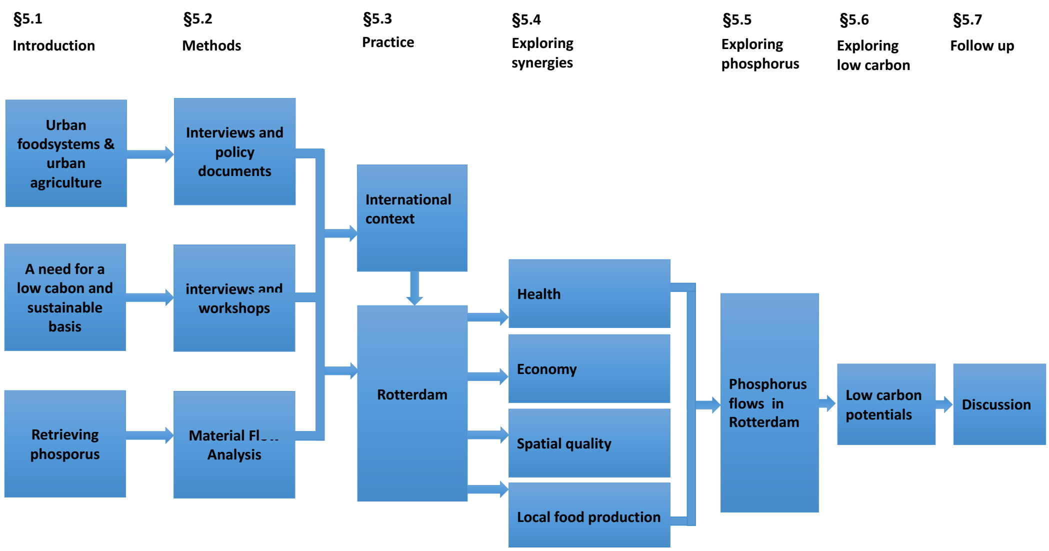

FIGURE 5.1 Outline Chapter 5

Note in advance

This chapter is slightly adapted form a paper published as a book chapter, which was peer reviewed by both editors of the book, Prof. Rob Roggema and Prof. Greg Keeffe:

Tillie, NMJD , Kersimaa, K , Dobbelsteen, AAJF van den, Sijmons, DF (2014). Urban agriculture in Rotterdam: Potentials for a liveable, low-carbon city and sustainable phosphorus flows. Why we need small cows, (eds) R. Roggema and G. Keeffe: Ways to design for urban agriculture (pp. 137-163), Leeuwarden: VHL University of Applied Sciences.

§ 5.1 Introduction

Food production in cities has gained a lot of attention lately with increasing urban agriculture initiatives in many cities across the world. It has long been discussed that developing urban agriculture in cities can have many benefits for the urban environment, not only in terms of growing its own food, but also issues such as developing ecosystems, job creation, improving access to a healthy lifestyle, as well as local solutions to address municipal waste problems (Mougeot, 2006). In the Netherlands, urban agriculture has increased in popularity (Van der Schans, 2010). However, unlike in many developing countries, growing your own food is not the main concern for the urban poor in the Netherlands (Van der Schans, 2010). Although in western countries urban agriculture for food production is marginal, these local initiatives offer an interesting perspective because of their integration in the city, their potential role in the urban metabolism and their effect on social structure of the city. Due to the multifunctionality of urban agriculture it is claimed to be more sustainable (Wiskerke & Viljoen, 2012).

The research presented in this chapter is twofold and concentrates on: 1. the improvement of liveability aspects in cities by means of urban agriculture policies; and 2. exploration of sustainable Phosphorus (P) in relation to urban agriculture **[Figure 5.1]**. Phosphorus (P) is an essential element in our environment, an important nutrient for plants, animals, and humans, or - put simply – without P life would not exist. As large quantities of our P resources are not recovered, urban agriculture creates a perfect opportunity for practicing the reuse of urban organic waste, which naturally includes P. For this research, the policy of the Dutch city of Rotterdam was studied by literature and interviews. It turned out that improvements were especially made on several aspects of liveability, ranging from social inclusion to reduction of food miles. For the study on phosphorus flows from household waste in Rotterdam, the base year 2011 was selected. Flow diagrams were drawn using the material flow analysis method.

§ 5.1.1 Urban food systems and urban agriculture

For centuries, cities and their countryside had an intimate relationship for food and other resources. For a long time, most food was produced and used locally. With the start of urbanisation, food and goods are transported over longer distances. It is well known that food and goods from North Africa were shipped to Rome more than 2000 years ago already. Leisink (2016) describes the situation of the Phoenician coastal city

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of Byblos in 3200 BC which thrived, partly as a result of the cedar forest nearby which was mostly used in ship building by Egyptian pharaohs.

Apart from these examples, in many cases nutrient flows such as nitrogen and phosphorus were for a large part in balance with agricultural production. Barles (2007) describes for Paris how this system changed in a 100-year period with growing urbanisation and industrialisation. But also, how food was transported to the city.

It was visible from where food, traded in the city, originated. Steel (2011) describes special routes for cattle, which had to travel for weeks from Scotland, on their way to cattle markets in major cities. In London for instance the cattle arrived in the north where the meat markets were established. As corn and fish came in via the river, those markets were established near the river Thames. In many old cities street names refer to their old functions with an important role for the food supply. Many jobs and social networks such as markets in cities were related to food production and distribution.

With the development of railways, it was suddenly possible to get food into urban areas much faster. The relationship between city and countryside became less visible. For example, vast agricultural areas in the United States could be accessed by rail and as a result, grain became quickly a global commodity. When it also became possible to keep food fresh for longer periods of time by preserving or freezing it, food could be stored on the outskirts of cities from where it was distributed.

A good effective food system forms the basis of a well-functioning society and thus for many aspects of liveability. Nowadays a lot of food is being processed at different locations travelling across continents, thus adding food miles, i.e. the distance food has travelled before it reaches the consumers. Steel (2011) mentions that it often comes down to a few big players who control the food chain. Research by PBL (2012) shows that in the Netherlands 65,000 producers deliver their products to their consumers via five purchasing offices **[Figure 5.2]**. It is clear that the modern food chain has replaced direct relations between producers, shopkeepers, restaurants and consumers. So, what is the value of urban agriculture, in terms of liveability, of bringing some of these direct relations back, and are there other synergies?

Urban agriculture (UA) is different from rural agriculture in a way that urban agriculture is integrated into local urban economic and ecological systems. The concept of urban agriculture was defined by Mougeot (2006, p.11): "an industry located within (intra-urban) or on the fringe (peri-urban) of a town, a city or a metropolis, which grows or raises, processes and distributes a diversity of food and non-food products, (re-)using largely human and material resources, products and services found in and around that urban area and in turn supplying human and material resources, products and services largely to that urban area." Moreover, Richter et al. (1995, in Mouget, 2006, p. 9) made the distinction that "it is not its urban location which distinguishes UA from rural agriculture, but the fact that it is embedded in and interacting with the urban ecosystem". In this respect, it is interesting to study how a sustainable form of industrial horticulture can be mixed with urban areas.

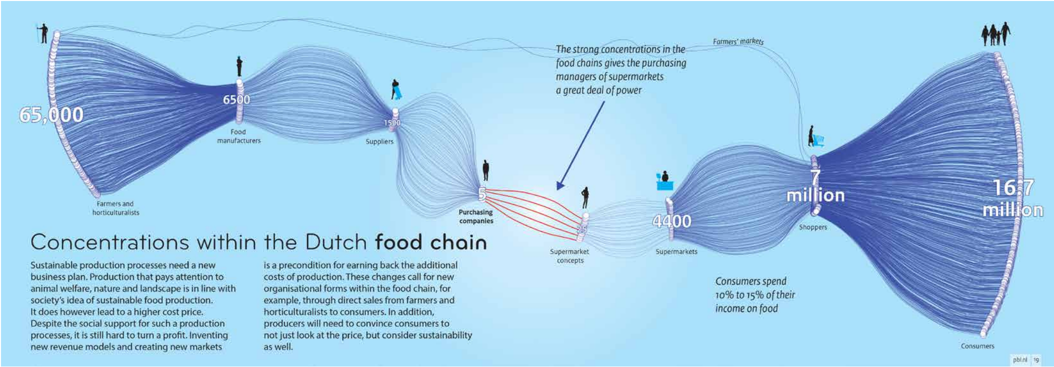


FIGURE 5.2 65,000 producers (left) are linked to 16.7 million consumers (right) via 5 purchasing offices of supermarkets (middle). Alternative routes via farmers markets are marginal.

§ 5.1.2 Shifting to a sustainable low-carbon basis for food production

Inventions and developments as artificial fertilisers, railroads, mechanisation in agriculture and techniques to improve crop yields helped to make it possible to produce enough food to feed a global population. The way our cities are provided with food is in itself an achievement (Steel, 2011). However, to what extent is this system without failure? A growing world population and the fact that hundreds of millions see their standards of living rise and eat more meat (a resource and energy-intensive form of food) puts extra pressure on the achievements of our food system as the demand rises. With less arable land available due to phenomena such as growing cities, climate change and soil erosion, more natural areas are cultivated in a monofunctional way, with huge losses of biodiversity.

The modern food industry is depending on finite sources such as fossil energy (e.g. fertiliser) and rock phosphates. With less fossil energy, less rock phosphates, less arable land and less biodiversity it is clear that, in order to function properly in the decades and centuries to come, the modern food 'industry' needs to shift to a sustainable basis. Retrieving phosphorus is an important step.

§ 5.1.3 Phosphorus and household waste management

Phosphorus is an essential element of our food production (as fertiliser and necessary ingredient in soils) and therefore for our lives in general. Without this element in the soil, agricultural production would decrease significantly (Rosemarin et al., 2011). Can urban farming have a role in the local phosphorus metabolism? In the past, there has been a lack of nutrients available for agriculture. Since the Green Revolution, mineral fertilisers were used to solve this issue (Shiva, 2011). This in turn resulted in the oversupply of nutrients, leading to eutrophication of waterways and the environment. Some years ago, this issue turned from an excess problem into an issue of sustainability: i.e. the non-renewability at the human time scale of primary phosphorus (mined from phosphorus rock) and the inefficient and non-cyclic use of secondary phosphorus in present society (Cordell et al., 2011). Being a non-renewable resource, the increasing usage of phosphorus worries many countries (Rosemarin, et al, 2011). Instead of recovering it from waste flows, the phosphorus is extracted from phosphate rock, a non-reproducible resource that cannot last forever. Phosphorus is geologically also unevenly distributed: 85% of the global reserves are located in five countries: China, Morocco, USA, South Africa and Jordan. Given the fact that Europe has almost no own reserves, this imbalance makes EU countries vulnerable to geopolitical tensions and prices (Rosemarin et al., 2009). Current global reserves may be depleted in 50–100 years. While phosphorus demand is projected to increase, the expected global peak in phosphorus production is predicted to occur around 2030. The exact timing of peak phosphorus production might be disputed; however, it is widely acknowledged within the fertiliser industry that the quality of remaining phosphate rock is decreasing and production costs are increasing (Cordell et al., 2009). Therefore, more efficient P recovery options should be developed and introduced, especially in terms of waste management. Also, economic gains can be made if phosphorus prices rise in the near future. In our society, the current practice is inefficient, with high losses of P to waterways and infrastructure, and accumulation in soils and society. Environmentally this presents huge problems as it destroys existing ecosystems.

Unlike many other countries, the Netherlands has a huge surplus of phosphorus coming from agricultural production. One can therefore argue that phosphorus produced in Dutch cities is not significant. However, looking at the future and at a global scale, lack of phosphorus is a growing concern. Moreover, the urban phosphorus study presented here could be used by other cities where a phosphorus deficit already occurs. Furthermore, many cities have growing financial problems that influence their waste treatment, as it is assumed that waste management can consume up to 50% of cities' operating budget (RUAF, 2013). In the meantime, urban and peri-urban farmers are in need of organic matter to enhance or keep the quality of the soil. This is

commonly done by the addition of fertilisers and conditioners. Clean and nutrient-rich organic waste flows therefore are a valuable resource for (urban) agriculture. Mougeot (2006) mentions that by linking waste management to urban farming, a 'triple-win' situation or synergetic effects can occur – the urban environment is cleaned up, health hazards are reduced, and agricultural production is increased.
Additionally, there also is a number of limitations that obstruct the reuse of urban waste and make its management therefore more challenging. For example, when organic waste is mixed with other types of waste, there is a high probability that this organic waste becomes contaminated with heavy metals, plastic particles, organic pollutants, etc. (EU Commission, 2011). The same applies for waste water: it is important to consider its chemical constituents before using it for irrigation. The potential uptake of chemicals by crops, as discussed by Chang et al. (1995) as well as Birley and Lock (1997) is most likely to lead to chronic and long-term toxic effects in human beings. Therefore, serious technical measures should be taken before applying waste to land, i.e. appropriate waste water treatment for phosphorus recovery.

Is it possible to connect urban agriculture with more sustainable household waste management?

§ 5.2 Method and Approach

§ 5.2.1 Urban Agriculture and social aspects

Rotterdam was a case study for the research presented. Policy documents and other background data were studied. An important document to frame this study was Food & the City (Gemeente Rotterdam, 2012). Next to site visits, 11 interviews at 11 urban farms in Rotterdam were conducted between June-August 2013. The interview procedures were based on semi-structured interviews, which means that the same list of questions was asked from each of the interviewee, but a new question was sometimes free to be raised as a result of the answer of the interviewee (Drever, 1995). Also, five policy makers in the City of Rotterdam were interviewed. In the questionnaire, different liveability aspects were mentioned, such as number of volunteers, employment, use of renewable energy and other purposes than just the production of food, i.e. cultural services, tourism, health, spiritual experience and art inspiration.

§ 5.2.2 Urban Agriculture and a low-carbon city

To define the carbon intensity of the urban agriculture food chain is beyond the scope of this study. However, as there are links especially to potential developments this is an important aspect to consider for future initiatives. For better insight, the questionnaire encompassed specific questions in relation with products and distribution, use of bio-waste, and use of renewable energy. A transition to a low-carbon city is a complex issue; however, there are three basics, which can be used to lower carbon emissions (Carney et al., 2009):

1. Decrease the energy consumed (this can be consumption or demand);
2. Change the energy consumed (at home, office, factory), for example, from gas to bio-energy or gas to electric for home heating;
3. Change the way energy is generated (e.g. electricity) for example gas to solar.

These three basics are in line with the New Stepped Strategy (Dobbelsteen, 2008), as used in the Rotterdam Energy Approach & Planning (REAP) (Tillie et al., 2009) and other urban energy approaches.

§ 5.2.3 Phosphorus and household waste management

For the phosphorus flows in the consumption and waste system of the Rotterdam of city a Material Flow Analysis (MFA) was conducted. The major focus was on the phosphorus losses in household and municipal waste flows.
MFA allows a systematic performance of the flows and stocks of materials within a system defined in space and time (Cencic & Rechberger, 2008). This method therefore was considered as the most suitable for this research, as it provides a systematic performance of the flows and stocks of phosphorus by the application of the 'conservation of mass principle' (Cencic & Rechberger, 2008). This universal principle requires that the mass of a closed system will remain constant over time, for instance by a balance equation: the sum of inputs = the sum of outputs + change in stock (Brunner and Rechberger, 2004). Software tool STAN 2.5 (Beta) was used for this. MFA can be done at the level of goods or chemical elements. In this study phosphorus was used as an indicator of nutrient cycles in the city of Rotterdam, specifically for household waste sector. In general phosphorus flows as such are not provided by data and have to be calculated by multiplying a mass flow with certain phosphorus content of the products involved. Data availability is mostly limiting, so assumptions and simplifications had to be made. This study focuses on the flows of phosphorus to

and from the households within the Rotterdam city limits. However, it was difficult to find data of the influx of different materials specific to households only. Furthermore, the domestic supply of products as food and paper are consumed both within these households and outside, such as in public places, at work, in schools, restaurants etc. Therefore shops, supermarkets, and distribution centres, as well as consumption outside the domestic boundaries of households were included in the calculations. The data are based on the year 2011.

§ 5.3 Urban agriculture in an international context

Bottom-up initiatives of urban agriculture are often translated into policy. Cities as London, Toronto, Vancouver, New York and Chicago have set up ambitious food strategies. Although there are many similarities, there are different points of view. Toronto positions food at the centre of its policy to improve or enhance social cohesion and strengthen the economy and the health of its citizens. Vancouver supports agriculture to maintain the landscapes around the city. In many US cities, the food strategy is seen as a means to provide for a healthy diet. In many urban areas people, solely can reach supermarkets by car, which cuts out a certain percentage of the population. Areas without nearby shops are known as food deserts. Urban Agriculture offers an alternative for these. As Will Allen (Allen, 2010) from Milwaukee puts it, "Everybody, regardless of their economic means, should have access to the same healthy safe, affordable food that is grown naturally. Just as important, farm projects grow communities and nourish hope." The London food strategy emphasises the importance of good and affordable food for health, limiting the environmental impact of food and creating opportunities for the local food economy. In many foreign cities, the long distances that both food and waste must travel are a reason to look for opportunities to bring production closer to the consumers. Amsterdam focuses strongly on improving the urban-rural relations. Other municipalities in the Netherlands, such as Rotterdam, The Hague and Utrecht, reflect on their role in the production and marketing of food. The Dutch Ministry of Economic Affairs, Agriculture and Innovation (EL&I) has set up a nationwide network of cities for urban agriculture. An interesting example is the approach of Rotterdam, where in the past four years more than 100 initiatives have started. The Rotterdam approach will be described to put local strategies in perspective of other policies and phosphorus flows in the city.

§ 5.3.1 Rotterdam Urban Agriculture case study

Based on the results of the interviews one can say that the main reason for urban farming in Rotterdam is about creating a closer community. The existing urban agriculture classification by RUAF is for a large part based on food production and set up from an international perspective. It proved to be difficult to distinguish typologies with this classification in Rotterdam since urban farming in each city depends largely on the network of people who are involved, as well as their situation and perspectives (Veenhuizen, 2006).
Therefore, a new categorisation was done for the 11 studied urban farms, informed by their socio-economic role in the urban environment. As there are overlapping cases the focus was on the main activities.

- *Institutional garden* – De Enk and BuurtLab are both meant for children's education. Every kid has its own plot in the garden where they can learn to grow their own vegetables and take them home (or learn to cook collectively directly in the garden). They are considered institutional since these kinds of gardens are normally connected with kindergartens or schools in order to attract children in particular.
- *Commercial* - Social peri-urban farm – De Buytenhof, located just outside of the city limits in a peri-urban location, was the only real farm within this research. It was the only urban farm breeding cows and pigs. It is 'social' as it provides working places for disabled, socially isolated and people who have suffered from mental health or other related problems such as burn-outs and job-losses. This farm is a care community that people join to get a sense of belonging. The farm's objective is to bring benefit for both people and the planet. Besides, organically grown local food is delivered to several catering businesses within and around Rotterdam and as such contributes to the farmers' income.
- *Social community garden* – These urban farms contribute to the social well-being of people who work in the garden and at the same time grow food for Rotterdam Foodbanks. Foodbanks are voluntary organisations operating in several areas of the city that donate food to low-income people. In many of these farms, mentally disabled or people with other health issues work there and are paid for by the Dutch social services for their contribution (AWBZ Dutch health care law).
- *Community garden* – This type of UA is established on the city's vacant land in order to improve the neighbourhood and argument against the government's plans to build those areas up. The food production for (poor) people in those gardens is generally not the main purpose (although it is a benefit). Rather, it serves as an outdoor area for people in the neighbourhood, a place to create a

close community and organise outdoor events, such as music evenings, outdoor cinemas, or educational workshops (permaculture, mushroom growing).

- *Commercial farm* – Uit je Eigen Stad is the only commercial urban agriculture type in the city of Rotterdam. Organically grown food is sold in several locations within and around the city and extra financial profit is made through the local restaurant. Thus, similarly to De Buytenhof, financial profit is an important aspect in terms of the farms' income.
- *Roof garden* – Dakakker is to some extent commercial: beside growing food for the people who work\volunteer there, it is also sold to nearby restaurants.

The interview results from the practitioners show that the average age of the people who are leading or who started up the urban agriculture initiatives in the city of Rotterdam is between 40-50 years. These are mainly highly educated and active people, who in approximately 50% of the cases are not interested to gain personal financial profit, but use it more as a hobby for their own use or for their fellow neighbourhood people or other volunteers (Moestuinman, Tussentuin, Pluktuin, BuurtLab). However, in gardens such as Voedseltuin, De Enk, Ghandithuin, Carnissetuin or Uit je Eigen Stad, there are people working under contracts. In those cases, up to five persons benefit financially, depending on the type of garden. These are mostly projects with higher financial profits or higher social funding.

In the policy for urban agriculture the city of Rotterdam focuses on three themes: health, sustainable economy and spatial quality. These are synergetic affects to be explored. As such the urban agriculture policies in Rotterdam are part of the sustainability agenda of the city. The municipality of Rotterdam stimulates urban agriculture and trade of regional food products. Stimulating urban agriculture is about both intra-urban and peri-urban food production, both commercial and non-commercial food production as well as trade, processing and distribution of food (Gemeente Rotterdam, 2012).

FIGURE 5.3 Dakakker on Schieblok, centre of Rotterdam (roof agricultural field) (image courtesy of Kees van Oorschot)

FIGURE 5.4 Urban farming initiative by new inhabitants at the Müllerpier, Rotterdam (image courtesy of Kees van Oorschot)

In Rotterdam, the municipality wishes to maintain the current, spontaneous character of urban agriculture. As Loorbach mentions (Tillie, 2012, p.112), "inhabitants create places for themselves that meet their own needs, and in doing so they become shareholders in the development of their city. They feel responsible for the co-creation of their own world and its safety through commitment to their places and each other. In this manner, sustainable cohesion will be established, because of the connection to an activity or the development of a place."

Existing initiatives are mainly bottom-up, both groups of citizens and professionals who are already working in this field. Organisations such as Eetbaar Rotterdam, Rotterdamse Oogst, Transition Towns, Buurtlab and Creatief beheer (Creative Maintenance) play an important role in this and are often combinations of social activation and gardening. Vegetable garden projects have a positive contribution to the greening of the streets and school and allotment gardens for children can develop into neighbourhood vegetable gardens.

So, there are great opportunities, especially when mobilising entrepreneurship and knowledge of the multicultural population of the city. With this approach to urban agriculture Rotterdam distinguishes itself from other Dutch cities. The challenge in the city is mainly to increase the availability of sustainably produced and high-quality food to broad sections of the population.

§ 5.4 Synergetic effects of Urban Agriculture in Rotterdam

§ 5.4.1 Health

In improving the health of the people in the city urban agriculture can play a role. The policy is a combination of consumption of more 'real food' (healthy food) and promoting more physical exercise is meant to contribute to reduce obesity and other health problems. There are also educational programs on healthy food and gardening and informing the public and children at school about healthy food. Furthermore, new community gardens are facilitated in dense urban districts and near schools (Rotterdam, 2012).

The interview results show that the main motivation of the volunteers comes from their wish to spend time outside while enjoying, carrying out physical activities in the garden, gaining better health and meeting other people. The average number of volunteers is between 10 -15 people per day. The volunteers have very different backgrounds – there are people employed full-time or part-time – but also unemployed people; some volunteers may have diagnosed with psychological or other health-related conditions. These initiatives welcome everyone.

FIGURE 5.5 The 'Uit je Eigen Stad' (From your own city) Foundation initiated the city farm Marconi-strip. This former marshalling area in the Merwehaven in the City Ports is a temporary farm before it will be developed into a mixed residential/work area. The foundation aims to bring the food back to people in the city; it also links government, education, business, and science. The project also provides workspace for participants in reintegration programs (image courtesy of Kees van Oorschot)

FIGURE 5.6 A neighbourhood Farmers Market (image courtesy of Kees van Oorschot)

§ 5.4.2 Strengthening sustainable economy

The policy described in Food & the City (Rotterdam, 2012) for strengthening a sustainable economy is composed of four parts: vital landscape, stimulating sales, green employment and reducing food miles.

Agricultural entrepreneurship around the city can get a boost when farmers get better access to the urban market. For this, it is desirable that the number of farmers' markets increases and that the direct sales via shops and restaurants grow. In order to improve the marketing of regional products, a new logistics system is set up to shorten chains in and around the city.

Facilitating farmers' markets and turning an annual harvest festival into a quarterly market are examples of how this is promoted. Next to this, the municipality organises new network meetings of producers and (potential) customers. By setting standards in the procurement of catering to canteens and company restaurants and of other institutions, the marketing of local products can be significantly boosted. The municipality therefore has a direct impact on the marketing of regional products. A new tool is the organisation of 'trade missions' to the farmers, that help to connect producers and potential consumers like retailers, restaurants and traders [Figure 5.7]. In order to link the worlds of urban agriculture and the large-scale horticulture, a new regional food council was installed in Rotterdam. It is a kind of advisory board that connects producers, food industry, traders, health care, education and research. It focuses on awareness of food and business cases for projects and tries to link agro-business in the port to the national top sector agro.

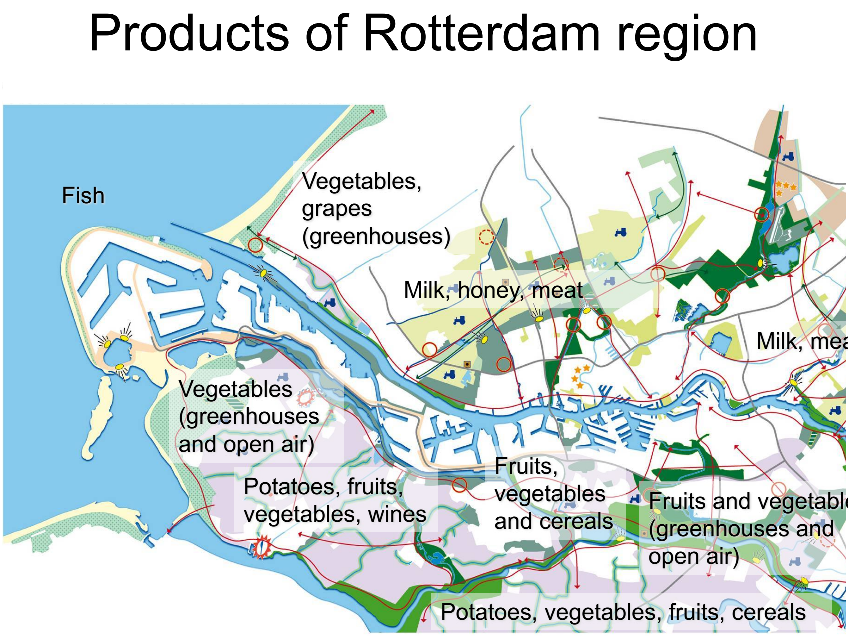


FIGURE 5.7 Overview of regional agricultural products in Rotterdam (image courtesy of Kees van Oorschot)

§ 5.4.3 Spatial Quality

In the policy document Food & the City (Rotterdam, 2012) it is stated that a new form of agriculture in which the farmer is more directly focused on the immediate market for urban consumers and provides additional opportunities for preserving valuable landscapes surrounding the city. Also within the city a greener environment can be realised by adding vegetable and fruit gardens. This is an addition to the existing allotment gardens.

Urban agriculture can contribute to the achievement of other policy objectives **[Figure 5.8]**. Gardens have a positive impact on social cohesion as people cooperate with each other and share experiences (De Graaf, 2011).

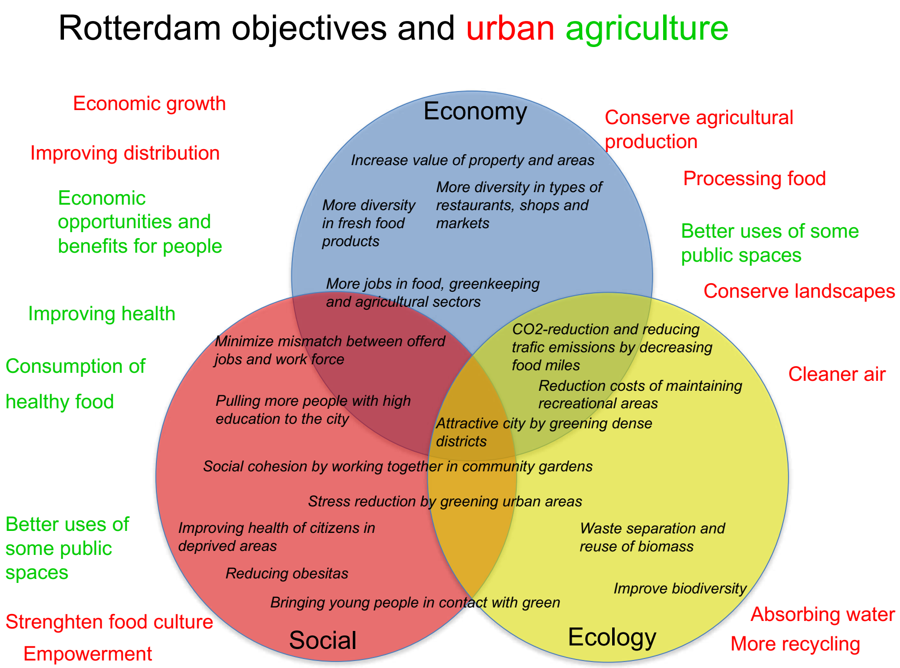


FIGURE 5.8 Overview of how different policy goals are connected and synergies explored (image courtesy City of Rotterdam)

Many benefits were also mentioned in the interviews. The most important ones for Rotterdam can be summarised as:

- Offer a healthy green space for the citizens who are interested in gardening;
- Promote green roofs (in case of Dakakker) with other the benefits such as rainwater storage;
- Offer a healthy green space for all kinds of people to socialise and meet each other;
- Create a care community for mentally disabled or for people with other health issues;
- Offer a healthy green space for cultural services – yoga lessons, music and cooking events, outdoor cinemas, furniture or clay product makings;
- Offer educational services for the citizens, both kids and grown-ups – environmental education for children, courses in permaculture, edible plants, growing mushrooms, conserving vegetables etc.;
- Grow fresh food for people with all kinds of income (food security), localise the food network, decrease food miles;
- Grow fresh food for low-income people and deliver it via food banks;
- Offer a living space for several species to increase the city's biodiversity;
- Help to reduce the urban heat island effect;

So in general, urban agriculture can contribute to more varied green spaces in residential areas and greater involvement of local residents in the public space.

The municipality wants to facilitate initiatives of community groups and civil society organisations to focus on vacant lots around vegetable gardens and poorly used pieces of public green. Priority is given to the ten grittiest or less green areas in the city, as most improvement of environmental quality, social cohesion, health and employment is expected here. There are leaflets in which the opportunities and conditions for the creation of vegetable gardens are described, including soil-related aspects. Also, the municipality has prepared a standard contract to be used when land is available. Mapping empty lots, stimulate roof top gardens and food production in city centre and a yearly competition for best urban agriculture by citizens are ways to stimulate urban agriculture.

§ 5.4.4 Food production in the city region

One of the qualities of a resilient city (region) is that for a basic percentage it can rely on its local and regional potential in terms of food, nutrients, energy and materials. As in this region the main horticultural industry of the Netherlands is situated, it is not a big issue at the moment. Yet it would be interesting to know what the role of urban agriculture could potentially be and if it is compatible with the current habits in food consumption. For instance, with a omnivorous diet one would need ten times the size of Rotterdam to produce its own food [Table 5.1]. This and other information can be useful information for other cities.

	ROTTERDAM DATA	
Surface city of region Rotterdam	80.000 ha	
City Region	1.2 million inhabitants	
Landuse classification		
"Green"	(39%)	31.000 ha
Wood lands		4.000 ha
Recreation areas		5.000 ha
Agricultural lands		22.000 ha
"Built environment"	(35%)	28.000 ha
Semi-built		4.000 ha
Traffic		4.000 ha
Built		20.000 ha
Water	(26%)	21.000 ha
Rivers connected to open sea		12.000 ha
Water bodies in the city		9.000 ha
Demand for food in the region and demand for surface		

TABLE 5.1 Total surface needed for an omnivore's diet of the city of Rotterdam: a region of 294,720 ha. This is about 10 times the available green space in the Rotterdam region and 3.5 times the total space in the region (table courtesy of Sander Klaassen, City of Rotterdam).

§ 5.5 Phosphorus flows and urban agriculture

§ 5.5.1 Phosphorus (P) and household waste management

At the Rotterdam, urban farms there is no reuse of waste water, sludge or source separated excreta on site, except in Moestuinman, were the project leader is imitating the compost toilet principle for people who visit or work in the garden. In general, the cycle of soil-food-human excreta-agriculture is not closed for the sanitation waste flows. This is an important flow that is not reused, but could be one of the solutions for closing the P loop, especially when looking at the city as a whole.
Most of the organic household waste in Rotterdam is not separated from the rest of solid household refuse and ends up incinerated in the ashes, resulting in a loss of phosphorus. It is an essential nutritional component in our soils for food production and plant growth in general, but which unfortunately is a scarce resource. In this study, the aims are (1) to find out how much potential phosphorus is actually lost (in other words, the amount that is not being reused in agriculture) via Rotterdam household waste management, and (2) how could this phosphorus be brought back to the city's current and potential future farmland. Urban farms in the city play an important role in urban nutrient flows and would therefore be perfect places for practicing the reuse of urban organic waste and waste water. Based on the outcome of the calculations of the so-called lost P, calculations were made (based on Dutch nutrient application directives) for the capacity of the current urban agriculture areas in Rotterdam to 'host' the potentially reusable P.

§ 5.5.2 Overview of phosphorus in the Netherlands

According to Smit et al. (2010), who provided all quantitative measures, the Netherlands is a net phosphorus importer by importing 108 kton phosphorus, mainly from agricultural feed and fertiliser [Figure 5.9]. The gross export is 49 kton phosphorus, mainly from food products (estimated in 2005). Overall, this annual balance leads to an accumulation of 60 kton P/year in 2005. Half of this is accumulated in agricultural soils and the other 28 kton phosphorus is accumulated either in the environment (inland water and seas) or sequestered in infrastructure and non-food products via the waste sector. While the Netherlands is a country of phosphorus accumulation, recycling from society (households, industry) back to agriculture is minimal. Households in the Netherlands are a major contributor to main input (66%) to the waste industry. The waste flows from Dutch households back to agriculture are almost negligible since not more than 2.7 kton out of total amount of 30 kton of processed phosphorus is recycled to agriculture or gardens. From this 2.7 kton, about 7% is exported abroad and the rest of the 25 kton of P, ends up either in open water (from wastewater plants), cement or in incinerator ashes. The P that enters the households is almost entirely embedded in food, supplemented with detergents such as automatic dishwasher soap (Smit et al., 2010). It was calculated that almost 60% of this input leaves the household via the sewage system and 30% in household refuse that is almost fully incinerated. Moreover, it was estimated that 6% of the household waste output is organic kitchen and garden waste separated from household refuse and eventually composted. The authors argued that the Netherlands could secure their P demand without the import of phosphorus by using phosphorus from secondary sources more sustainable.

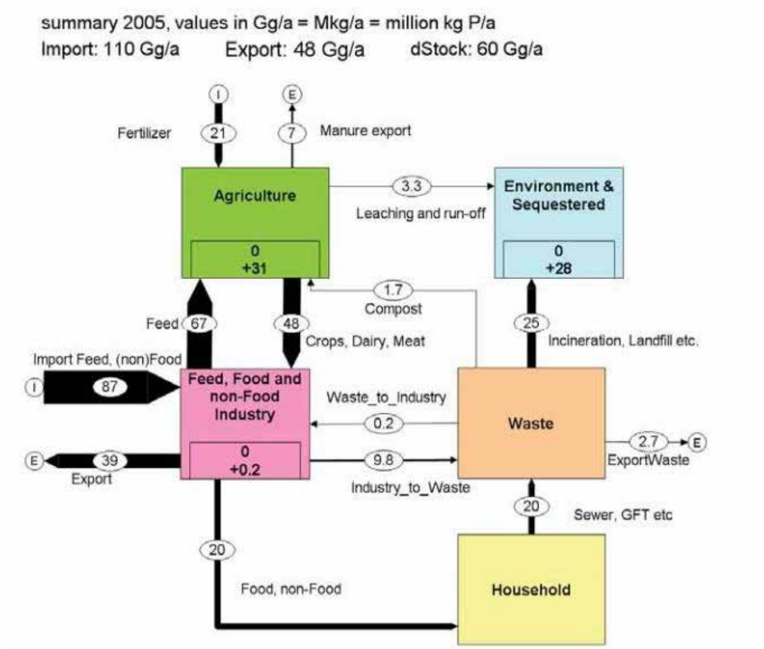


FIGURE 5.9 A summary of the main phosphorus flows in the Netherlands in 2005 for different sectors: agriculture, environment/sequestered, industry, waste management and household sectors. The flows are in kton phosphorus per year. E= Exported, I=imported. Surplus for some sectors are indicated in the boxes (fig.4-2 in Smit et al., 2010).

§ 5.5.3 Phosphorus influx to households in Rotterdam

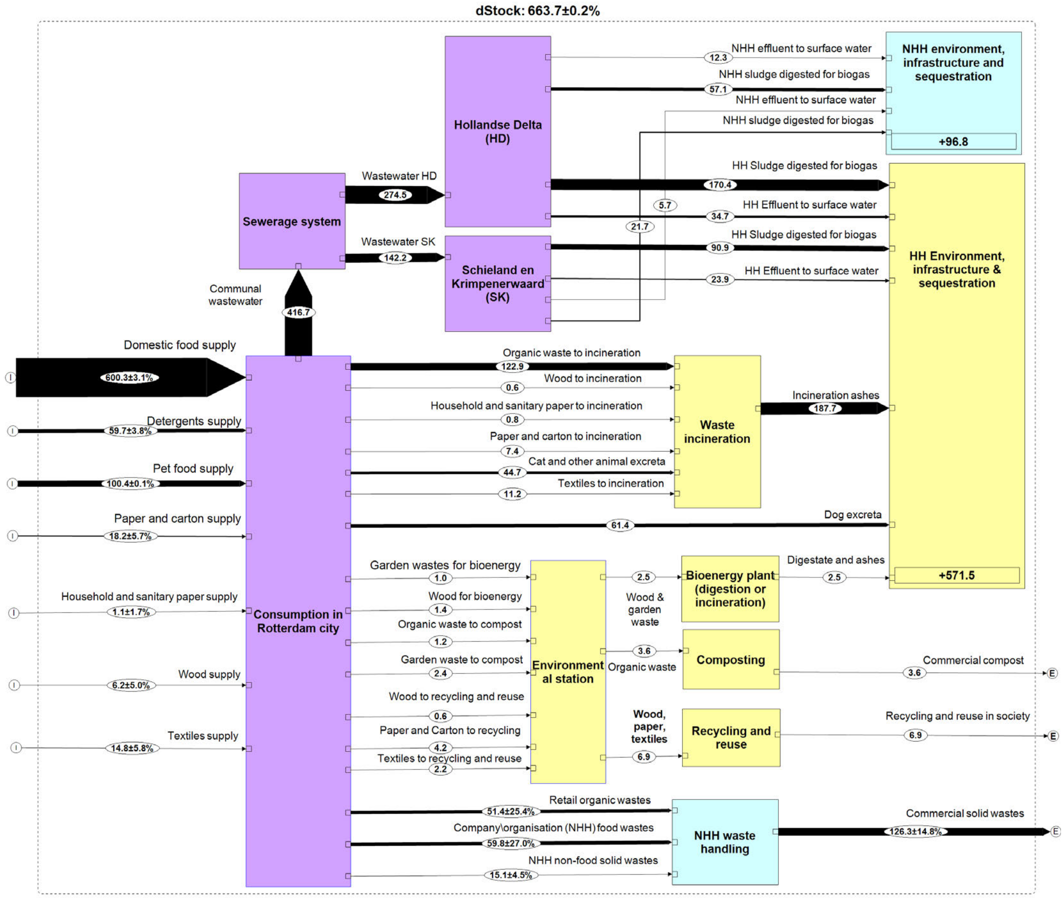
The total domestic P inflows to the city of Rotterdam (612,000 inhabitants) can be divided into seven different sub-flows of the following products: food, detergents, pet food, paper and cardboard, household and sanitary paper, wood products and textiles [Table 5.2]. The domestic supply is defined as the quantity of the product that is available for human consumption. The consumption can take place in households (referred to as HH) and outside households (referred to as non-household, NHH). The NHH supply can be consumed in public spaces, offices, schools or restaurants, for example. For each input and consumption flow the ratio between HH and NHH consumption was based on data or assumptions.

	Grams day/ person	Days/Year	Rotterdam population	Humen excreta in Rotterdam in kg
Urine	0,8	365	610.412	178,2
Feces	0,8	365	610.412	111,4
Total Human excreta in Rotterdam				**289,6**

TABLE 5.2 Phosphorus influx into waste water with human excreta (based on Roeleveld, 2006)

§ 5.5.4 Phosphorus out flux from households in Rotterdam

The out flux from households consists of solid and liquid waste flows [Figure 5.10]. The liquid waste flow is waste water and the solid waste flow is biodegradable solid waste (BSW, in Dutch GFT) that can be part of municipal solid waste (MSW), bio-waste (food/kitchen waste) and green waste (garden waste). In addition, other P-containing outflows linked to the non-food inflows were included. These were textiles, wood, paper and cardboard that can be collected separately to be recycled or be discarded in the MSW going to incineration plants that have ashes as final end products.



Household and non-household phosphorus flows in the city of Rotterdam

FIGURE 5.10 Flows and stocks of phosphorus (P) in the city of Rotterdam describing the imports, exports and internal flows between subsectors and process. Flows are indicated by the flow number and name. Input flows of the city of Rotterdam (left side) are consumed in households (HH) and non-household (NHH), which creates municipal and commercial waste flows (right side).

§ 5.5.5 Reusing phosphorus

As can be seen, the only sector that contributes to the reuse of phosphorus in agriculture is the waste sector that composts bio (kitchen) and garden waste. All the other waste flows containing phosphorus are not recovered. It is important to mention that some of the textiles, wood, paper and cardboard are reused in society and these were not taken into account, neither as lost or reused phosphorus.

The assumption is that within a one-year period, which is the basis for this study, they are still circulating in society before the fibres have become too small to be recycled. Overall the total out flux of phosphorus from households amounts to 582 tons [Table 5.3].

DESTINATION	P OUTFLOW FROM HOUSEHOLDS	TONS	%
Incineration	Organic waste Textiles	122.9 11.2	21,1 1,93
	Paper and cardboard Wood	7.4 0.6	1,3 0,1
	Household and sanitary paper Cat and other animal excreta, including food waste to animals	0.8 44.7	0,1 7,7
	Sludge	261.4	44,9
Environment and sequestration	Effluent wastewater	58.5	10,1
	Dog excreta, including food waste fed to animals	61.4	10,6
Compost	Organic waste Garden waste	1.2 2.4	0,2 0,4
Bioenergy plant	Garden waste	1	0,2
	Wood	1.4	0,2
Recycling and reuse	Wood	0.6	0,1
	Textiles Paper and carboard	2.2 4.2	0,4 0,7
	Total P quantity	**582**	**100%**

TABLE 5.3 Phosphorus (P) out flux [tons P/year] from Rotterdam urban households.

From this total amount, 98.2% of phosphorus is considered as lost. The rest of the 1.2% are the non-food products which during one-year period are being reused or recycled and still used in the society. 0.6% is the amount that is eventually composted. [Table 5.4] shows the potential sources for P recovery.

POTENTIAL SOURCE OF P RECOVERY	POTENTIAL RECOVERABLE P IN TONS
Incineration of solid waste including organic waste	187.8
Incineration of sludge	261.36
Wastewater effluent to open water	58.52
Biomass production for green energy	2.5
Dog excreta incinerated/environment	2.5
Total	**572**

TABLE 5.4 The potential recoverable phosphorus (P) flows per type of the household waste in the city of Rotterdam; current recycling and reuse flows of non-food products are not shown since within one-year period these materials are still used somewhere in cycle in the society.

§ 5.5.6 Phosphorus demand

According to the Dutch Government regulations, farmers are currently allowed to apply 65 kg of phosphate per ha on arable land that has an average soil P status. It was assumed that urban agricultural land and its use is more comparable to arable land than to grassland. Converted into elemental P this gives 28.6 kg of P per ha on arable land. In the near future, this application limit will be reduced to 24.2 kg of P per ha (55 kg of phosphate) (Dutch Government, 2009).

	THIRD AP		FOURTH AP				FIFTH AP	
	2006	2009	2010	2011	2012	2013	2014	2015
Grassland								
Land with high phosphate level	110	110	90	90	85	85	85	80
Phosphate neutral ground	110	100	95	95	95	95	95	90
Land with low phosphate level	110	100	100	100	100	100	100	100
Farmland								
Land with high phosphate level	95 (85)*	85	75	70	65	55	55	50
Phosphate neutral ground	95 (85)	85	80	75	70	65	65	60
Land with low phosphate level	95 (85)*	85	85	85	85	85	80	75

TABLE 5.5 Dutch Government regulations (2009) for the application of phosphorus (P) on arable and grassland for different soil P statuses

Taking the maximum phosphorus use into account, this means that P lost from household waste can potentially be spread on 20 thousand ha of arable land (urban agricultural land). With new reduced requirements set for 2015 [Table 5.5], the amount of arable land needed would be even larger than 23.6 thousand ha. The total surface area of urban agriculture in the city of Rotterdam is estimated to be approximately 31.5 ha.

Consequently, it can be concluded that the potential local supply of phosphorus is high, compared to the potential local P demand. However, P removal of crops must also be taken into account. Ehlert et al. (2009) describe phosphorus removal of main food crops in the Netherlands. The crops with the highest and lowest removal per ha were selected in order to calculate the range of demand. In this way, the phosphorus demand of the crops that could be potentially grown, or that are grown already in the urban agriculture areas, could be considered. Based on that:

1. The highest P removal by harvest is achieved by field beans – 89.3 kg P_2O_5 / ha = 39.292 kg of P/ha (Ehlert et al., 2009, p. 53)
2. The lowest P removal by harvest is achieved by broccoli – 11.8 kg P_2O_5 / ha = 5.192 kg of P/ha (Ehlert et al., 2009, p. 55)

CROP TYPE	P DEMAND CITY	TOTAL POTENTIAL P SUPPLY (P LOST)
Highest P removal **Field Beans**	1.24	572
Lowest P removal **Broccoli**	0.16	
Most common consumed/grown crop **Grain crops**	0.56	

TABLE 5.6 Supply of phosphorus (P) by household waste flows compared to the demand of P based on crop P removal estimated based on the maximum current coverage of UA in the city of Rotterdam multiplied by the P removal of three crops field beans, broccoli and grain crops [tons P/year].

The range of demand assuming total coverage of one of these crops was made for the UA areas of the city of Rotterdam. As it was previously indicated, the total surface area of urban agriculture is currently assumed to be the maximum of 31.5 ha. This means that the calculated range of phosphorus demand for growing food in the city of Rotterdam is currently (assuming 31.5 ha coverage with the crops with lowest/highest phosphorus removal/demand) 0.16 – 1.24 tons of phosphorus.
Another estimation can be made using the grain crops as the most common grown and consumed crop species. Based on the same report (Ehlert et al., 2009, p.56), the phosphorus removal of grain crops is (40.8 kg P_2O_5 /ha/year) 17.9 kg of P/ha/year. Whilst assuming 31.5 ha with these crops, the calculated max phosphorus demand would be as low as 0.56 tons **[Table 5.6]**.
This simple calculation shows that there is a huge regional surplus of nutrients in the household waste supply compared to the local demand of urban farms. It is likely that in the future the area of UA in Rotterdam will be increased, since it is a hot topic and largely within the agenda of the Municipality of Rotterdam. In the hypothetical case that all the green areas within the city of Rotterdam (12.7 thousand ha) would be urban farmland, the calculated maximum demand of phosphorus based on the highest phosphorus removal crop (field beans) would be around 498 tons. This figure would be a considerable portion of the current phosphorus supply (572 tons).

It is important to take into account that since urban agriculture does not necessarily need to take place at land, but can also take place on rooftops, walls and water, there is a potential for more urban agriculture.

In conclusion, for the city of Rotterdam, it was investigated that 99% of the potentially recoverable P (572 tons) is not being reused on agricultural land. This is largely due to the fact that most of the organic waste is not collected separately and therefore incinerated all together with other types of solid waste, but also to the fact that P is not recovered during waste water treatment. Based on that finding the demand for P in terms of urban agriculture was calculated based on the current estimated surface area while taking into account the demand needs of certain crops. The study shows that currently there is lack of urban agricultural land in the city of Rotterdam to close the P cycle. The amount of P trashed by Rotterdam households is 1000 times more than the present demand for urban agriculture. Therefore, taking into account the P flow calculations, which were made for this specific study, it was estimated that closing the P loop within the city would only be possible if the phosphorus input in the city were lowered or if the output could be spread over more agricultural land. The surface of all green areas in the city would need to do this. This raises new questions. More green roofs and green walls plus new views on the 21th century garden city are interesting perspectives for follow research (by design).

§ 5.6 Urban Agriculture and a low-carbon city

Reducing food miles is a way of lowering the energy consumed by a city. Although there has not been a thorough study of food miles, the fact that the food produced is consumed on site or locally within a 10-km radius means that few food miles can be attributed to the food. Since the food production from urban agriculture in Rotterdam is still very marginal, so are the effects on reducing food miles in general.
Production of renewable energy at urban agriculture sites is underdeveloped. Out of the 11 visited gardens, three did not use any energy (Moestuinman, BuurtLab, Tussentuin). Only Pluktuin has its own sustainable energy sources (solar panels). The others have a contract either with a sustainable (Ghandithuin) or non-sustainable (De Enk, De Bytenhof, Voedseltuin, Carnissetuin, Uit je Eigen Stad) energy provider.
Bio-waste flows can be used as a source of energy and/or nutrient. The interview showed that in all the urban agriculture sites visited the organic waste (plants) is composted (in heaps) and reused directly on site, except Uit je Eigen Stad, which also stores its plant waste but transports it to an organic farm in Vlaardingen once a year, where it gets composted and then delivered back to Uit je Eigen Stad. The reason for that is lack of suitable equipment for large-scale compost making. Organic waste is not exported from any of the farms; in some cases, extra organic waste is imported from nearby farms.
This also means that extra organic waste from households is a useful source. In Rotterdam, a lot of this waste gets incinerated for district heating to lower carbon emissions. Although some research has been undertaken to compare different municipal waste management strategies and technologies, more information is needed. Environmental impacts from incineration, decentralised composting and centralised anaerobic digestion of solid organic household waste were compared in a Swedish

case study (Bernstad et al., 2011). Input-data related to site-specific aspects such as source-separation behaviour and transport distances were used. Bernstad et al. (2011) mention: "Results show that biological treatment methods – both anaerobic and aerobic, result in net avoidance of GHG-emissions, but give a larger contribution both to nutrient enrichment and acidification when compared to incineration."
While it is harder to access the nutrients through the incineration of solid waste, the environmental performance of garden waste management in the Municipality of Aarhus, Denmark, showed that both incineration and home composting are good means to improve the environmental profile. From an environmental point of view, incineration and home composting are suitable for diverting waste away from the composting facility in order to increase its capacity (Boldrin et al., 2011).
For home composting, there is the practice of worm composting, where they are allowed to eat organic waste, while humans or animals and birds (e.g. chickens) can eat the worms in turn (Zurbru?gg et al., 2004). This is easy to apply, so the proteins in waste can be recycled back to agriculture via raising of chickens.

§ 5.7 Discussion and follow-up

The different urban farming typologies in the city are useful to map initiatives in the city as well as to study them concerning their social structure and flows. This can be of help to facilitate urban agriculture initiatives better or to scale up certain typologies. This might be necessary as there are also many challenges to get these initiatives started. Many Challenges the interviewees listed had to do with social-economic aspects. For example: how to focus on the energy and time of the volunteers, and how to make them work independently. It seems more difficult to get children actively involved nowadays than it used to be. Some interviewees mentioned that social media consumption is partly overtaking outdoor activities. Also, the schools do not have the resources to transport children to the gardens. Others mentioned the tension and balancing between being a care community and being too much labour oriented. Questions were raised about the economic viability of the farms when there is more competition.
Concerning food production and land use, rough calculations showed that for an omnivorous diet 10 times the surface of the city would be needed. When considering shifts in diets, for instance vegetarian or vegan diets in which amino-acids form the basis for proteins, or using insects as a source for proteins instead of meat, less land surface is needed. Also, Greenhouse gas emissions will drop **[Figure 5.11]**.
These are promising developments and interesting fields for future study.

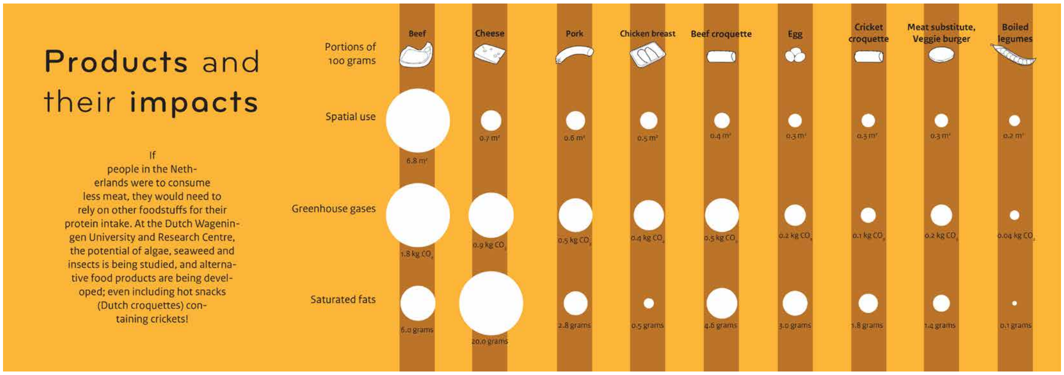
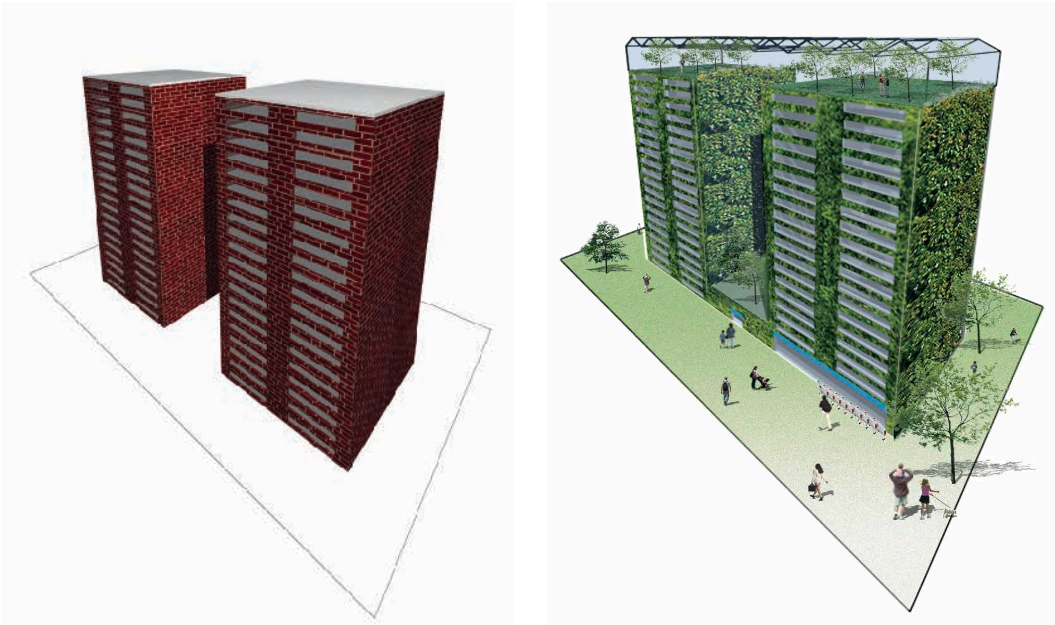


FIGURE 5.11 Relation between 9 different 100 gram portions of food and their space use, greenhouse gas emission, and the amount of saturated fats they hold (image courtesy planbureau voor de leefomgeving)

Although space is available in urban environments on empty lots, roofs and walls, there is also competition with renewable energy production in cities, so smart solutions need to be found that enable both goals.

As discussed earlier, urban agriculture can have a positive impact on a range of issues. Although in this case it is marginal in terms of food production it can play a role in the urban metabolism of the city. As such it can be approached to see cities as organisms (Dobbelsteen et al., 2010) or Urban Ecosystems. Glasshouses and buildings can be combined throughout the city and act as solar collectors and have food production (Tillie et al., 2009) [Figure 5.12]. Different flows, such as compost, water, clean air, biogas, nutrients and phosphorus, can be retrieved using urban farms as central points in neighbourhoods. Timmeren (2006) gives a good overview of built integrated systems and concepts that show how these flows are integrated with synergetic results. Examples of this are Biovaerk, EVA Lanxmeer and Vauban and although some are now about 20 years old they still can be considered a present best practice.

TOC



Existing situation *New situation*

FIGURE 5.12 Ideas for combining thermal insulation, greenhouses as heat collectors and urban agriculture (drawing by DJSA from Tillie et al., 2009) Caption

The new garden city can be a cross between a greenhouse area like the Westland, where food production, phosphorus flows, energy etc. have a synergetic relation with the city, and the way of life of people in the city, where greenhouses do not only produce food but also products for the chemical and pharmaceutical industry. In the Eco-Piramid concept (Derksen et al. 2008) different potential values of biomass are shown beginning with pharmaceutics and cosmetics, food and fodder, bioplastics and natural polymers, bulk chemicals and fuel finally electricity and heat **[Figure 5.13]**.

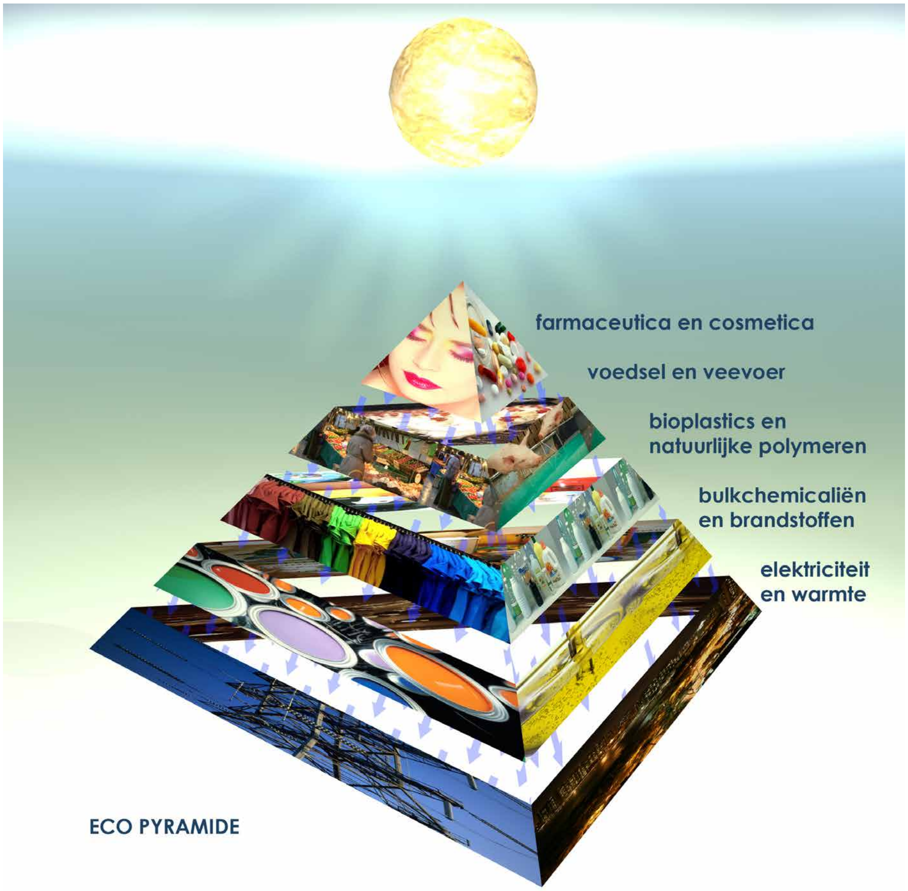


FIGURE 5.13 Eco-piramide showing different stages and potential values of biomass (Derksen et al., 2008)

Most of the lost 572 tons of P lost in 2011 was the result of incineration of waste water sludge (45.7%, 261.4 tons) and the incineration of organic waste (21.5%, 122.9 tons). These flows should be studied in depth in order to make their management more sustainable and to recycle the P. Measures were suggested how to manage those flows also from the perspective of nutrient (e.g. P) recycling. As organic waste in Rotterdam is mostly collected together with other municipal solid waste, new approaches would be needed on how to start collecting it separately. This would already be a considerable step to more sustainable P management, as there is relatively easy access to this potential of recoverable P. A higher amount of compostable garden waste and organic food waste could be reused.

The role of spatial planners in waste management is still relatively limited, despite the fact that urban farming is the hot topic on the urban agenda. Suggestions have been made on how to recover P in the city of Rotterdam in connection to its urban farms. Further research (by design) and specific steps are required to develop and plan the transition towards more sustainable use of nutrients in Rotterdam.

§ 5.8 Conclusions and link to main research objective

Link to main research objective

The values and synergies created by urban agriculture in Rotterdam ranging from health benefits to economic benefits and improved social cohesion in neighbourhoods are described in paragraph 5.4.
Paragraphs 5.3, 5.6 and 5.7 describe how some forms of (urban) farming can act as kind of nutrient collecting point in the neighbourhood and use Phosphorus. However, paragraph 5.5.6 describes that the amount of Phosphorus which is not retrieved is so big that its potential by far exceeds the use in solely urban agriculture.

Main conclusion for SULP

The study on urban agriculture initiatives in Rotterdam and its uptake in policymaking shows the value of small scale projects on one hand and planned experiments on the other hand.

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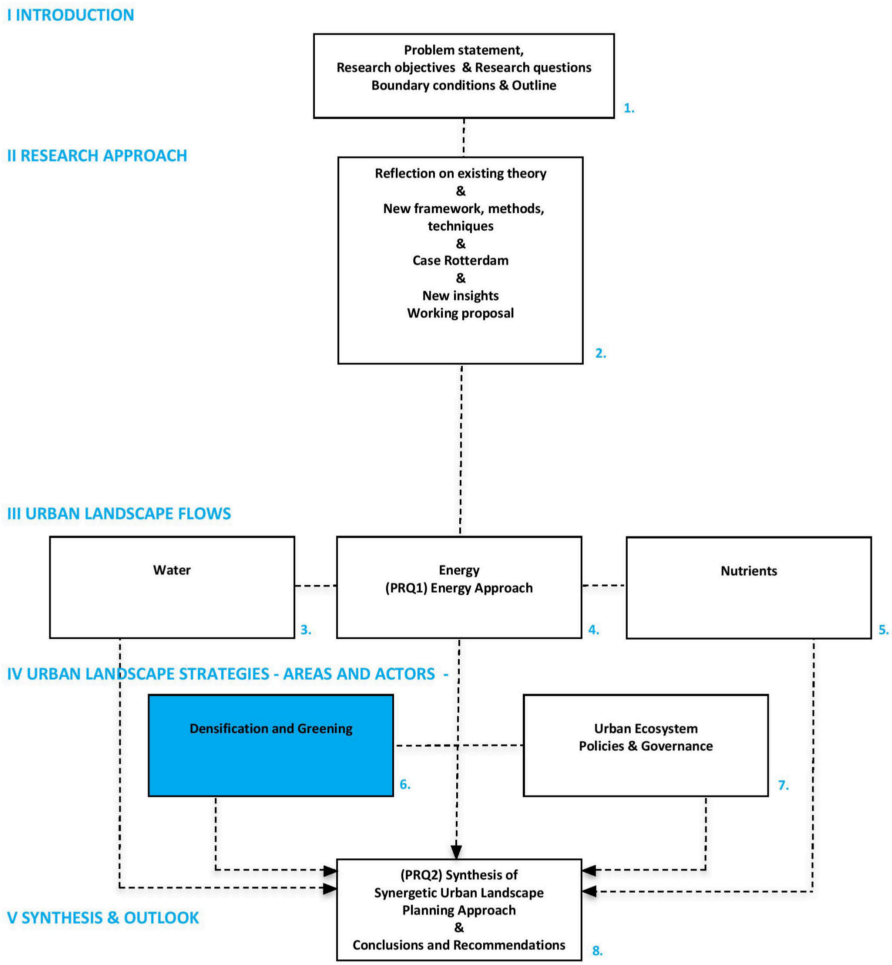

FIGURE 5.14 Bridging five-six

Bridging five-six

In the previous three chapters the research lenses and urban flows of water, energy and nutrients are discussed. All lenses show synergies from a quality of life perspective or from an environmental performance perspective of the urban flow itself. Spatial applications are shown in all three lenses. In chapter five, greening strategies and ideas for using urban agriculture, are presented. What if all of these lenses plus new insights would be combined and applied to one area? For the urban landscape systems providing urban **functions**, the **flow** (process) part has been discussed.
In the following two chapters, urban strategies will be applied to the urban **areas** (patterns/forms).

Chapter six uses the area of the inner city of Rotterdam as a case and explores densification and greening strategies with the goal to set up a stakeholder based urban landscape agenda using transition management.

The history of the inner city of Rotterdam is described. Although changing rapidly there is a lack of synergies in this area. One challenge is the relatively low number of inhabitants per hectare compared to other Dutch inner cities. The hypothetical question was asked does densification and greening lead to a more sustainable city? In 2018 this question is very relevant as for the next two decades, up to 50.000 new homes for the city might be required, and 10.000 around the inner city in coming years.

How can synergetic urban landscape planning be applied.By using insights gained in the different research lenses different topics linked to densification and greening can be addressed in a synergetic way.

But to do this, stakeholder, the actors are needed, that is why transition management is used in this area. To jumpstart this process data and a sustainability profile was used to measure and estimate the performance of the inner city. Computer models were fed with densification and greening data so a prediction of the expected outcome could be made.

PART 4 **Urban Landscape Strategies**

Areas and Actors

6 Exploring a stakeholder based urban densification and greening agenda for Rotterdam inner city

Accelerating the transition to a liveable low carbon city

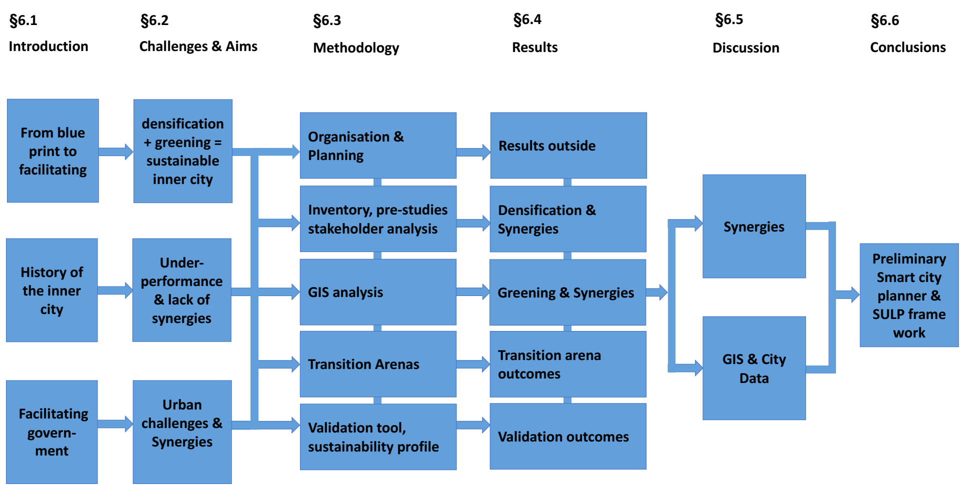

FIGURE 6.1 Outline Chapter 6

Note in advance

This chapter was published as a slightly adapted version in the Journal of Sustainability.

Tillie, N.; Borsboom-van Beurden, J.; Doepel, D.; Aarts, M. (2018) Exploring a Stakeholder Based Urban Densification and Greening Agenda for Rotterdam Inner City—Accelerating the Transition to a Liveable Low Carbon City. Sustainability 2018, 10, 1927 doi:10.3390/su10061927

§ 6.1 Introduction

§ 6.1.1 Densification and greening in an urban quality of life, liveable low carbon context

Uncertainty and impacts of demographic changes, multiculturalism, globalisation of trade, environmental degradation as well as climate change are pressing forces, which urban planning has to consider when drafting a liveability and low-carbon agenda for the short-term and long-term action of a city.
At the start of the low carbon city agenda presented by the city of Rotterdam in 2007, many projects on a low-carbon city were approached in a technocratic way resulting in the first years, in available technical solutions, not finding its way quickly into urban practices or projects. At the same time, there was a lot of knowledge developed and still developing on how to work on a transition towards a low carbon city addressing social economic as well as environmental issues (Davies, 2002; Newman & Jennings, 2008; Loorbach, 2010). Bringing together these issues was an obvious step to be taken and lead to this study. This paper explores a stakeholder-based urban agenda for a more sustainable low-carbon city which improves the quality of life / liveability of the area as well as its sustainability performance. How can this be measured and enhanced using urban data?

The low-carbon focus is on the built environment, for which simulation models are used, based on design strategies. The outcomes presented in this paper will be mainly descriptive (based on data of the existing models) rather than quantitative.
Rotterdam presents a unique European case with a post-World War II modernistic inner city. Like many North American cities, for a long time the inner city mainly served as a business or shopping district with few inhabitants and few synergetic links between processes, urban functions and spatial patterns. In line with many other cities, Rotterdam's long-term vision consists of issues such as reduction of carbon emissions, become more sustainable and provide a high quality of life. To address these goals as well as to create synergetic links between them, they need to be applied in projects. One of the bigger project ideas at hand is the densification and greening of the inner city.
The International Architecture Biennale Rotterdam 2012 (IABR2012) named 'Making City' and the European INTERREG IVB project Music (Mitigation in Urban Areas Solutions for Innovative Cities) served as a platform for this project idea as well as its actual application (Music, 2010). Right now, the topic of densification and greening in

a sustainable way is very accurate since a new urgency has emerged and many cities in the world have to densify to accommodate new inhabitants. Centraal planbureau (CPB) & Planbureau voor de leefomgeving (PBL) 2015, presented two scenarios, a high and low one, both expect population growth as well as growth of housing need. This varies from 250,000 to more than 1 million houses for the Randstad area till 2030. This means that cities like Rotterdam need to add tens of thousands of new houses in the coming decade. The outcomes of this study can help in all these tasks.
To bridge the gap with the technocratic approach applied in the city until then, a governance approach namely transition management (Loorbach, 2010) was used and enriched using urban data, modelling and design throughout the process.
A set of sustainability indicators, is used in a baseline study, GIS mapping and urban simulation models, to predict expected outcomes of the presented plans.

§ 6.1.2 Government as a stakeholder: from 'blueprint' planning to facilitating

The urge to create a more sustainable city that offers a high quality of life, a city where actively engaged inhabitants are required, showed that 'blue print' or top down planning alone, could not be used as a model as it was too strict and left little space for experiments and bottom up initiatives. As such, the role of the governments planning approach is under study. Which strategy should be followed? How to act? In order to build a stakeholder-based urban agenda for the Rotterdam inner city, challenges and opportunities need to be defined, also taking the historical context into account.

§ 6.1.3 Concise history of the Rotterdam inner city

As I already described in an earlier publication (Tillie et al., 2016) 'The centre was a bustling city until 1940. However, after 1945 it was characterised by functionality. The bombing of 1940 unwillingly led to the fulfilment of another cherished desire, which was to become a new modern city. A complete new centre with modern architecture was introduced. However, this was accompanied by an almost anti-urban experiment with the separation of functions, based on a typical model of society at that time: the city as a sum of separate functional clusters, which had nothing to do with each other. As a result, new housing was not part of the inner city and was planned outside the city in one of the new - green - neighbourhoods. Essential for the city was also the vibrant, cultural (night) life that was gone. It turned out that the new 'functionalism'

approach did not offer a good breeding ground for this. In the 1970s and 1980s, the gloss of modernity, so typical of the period of reconstruction after the war, was gone. The ever so modern Lijnbaan shopping mall in the centre of the city had become outdated. There were large bare spots in the city centre and in the evening the streets were deserted. Since 1985 more housing has been planned in the inner city area. The famous cube houses of Piet Blom were built in those days (Fig. 6.2).
Apartment buildings were built and in the following years high rises were permitted as well. In a few years' time the Rotterdam skyline changed. A high-rise policy was implemented. Slowly, the city regained some allure. In fact, in the Netherlands it was nicknamed 'Manhattan on the Maas'. However, this didn't change much at street level at first. It was only after the city implemented a public space strategy with a lot of attention at street level, that public life in the streets started to emerge faster. Instead of skyscraper this strategy was refered to as 'groundscraper'

The idea that the inner city was mainly for business and shopping and not so much for living was left in the late seventies, but only banned in the past twenty years. At the moment, there is a very clear idea that to become a successful sustainable city, the city also needs an attractive heart, and that includes inner city living. The modernistic separation of urban functions from the reconstruction period after World War II is still present in the inner city. Due to the efforts of the last twenty years, the glass is half full, but there is still a backlog in critical mass, amenities, child friendliness, good public space and green. That is why it is vital for Rotterdam to continue to densify the inner city. It might take another two decades to reach the population density of an average Dutch city, but those parts of the city that are already densely densified, such as the Scheepvaartkwartier and the Laurenskwartier, show a buzz of urban life. For example, the Veerhaven and surroundings and De Meent are an attractive entertainment area.

FIGURE 6.2 Piet Blom's 'cubic houses' in Rotterdam built in the 1980s (photo Ossip van Duivenbode, www.rotterdambrandingtoolkit.nl)

§ 6.1.4 A facilitating government

The Rotterdam inner city has the scale of a district or neighbourhood. These scales are crucial as they are the best scales for realising sustainability ambitions in a city: small enough to take quick action and large enough to make an impact.

There has, however, been a shift in approach for urban-area development: a shift from a strong focus on top-down planning and master plans towards bottom-up approaches accompanied by room for initiatives. "The question is how to combine the step towards a sustainable world with the exploitation of forces in an energetic city. This is not about top-heavy committees that launch proposals of the likes of the Delta Works, but about an administration that attempts to channel social energy in the right direction" (Hajer, 2012).
Rotterdam left behind its long-cherished, post-war reconstruction mentality. The municipality has been moving towards a facilitating role. With that a new way of working is introduced in which frameworks play an important role. Defining frameworks is a first step. Another crucial aspect is the competence required for their application such as regulations. Regulation is an extremely complicated exercise

of equilibrium. “Too much regulation will put a check on things. Too little may lead to derailment. Moreover, regulation can be interpreted wrongly or inadequately supervised, and thus miss its goal. The conclusion is that cooperation or this way of working requires socially intelligent civil servants” (Verhofstadt, 2012). This change within the municipality could provide opportunities for a multitude of initiatives from inhabitants and businesses.

§ 6.2 Challenges and Aims

§ 6.2.1 Underperformance and lack of synergies

Urban regions are the engine of our economy with inner cities playing a leading role in this. In the history of the Rotterdam inner city, the background of the main challenge was described: increase urban living in a modernistic inner city where for a long time the focus was on businesses, offices and shopping, where housing was not a priority. In this context, the Municipality of Rotterdam is expected to set priorities and the inner city is at the top of the list. As yet, the potential of Rotterdam’s inner city has not been fully exploited. This is in large part a consequence of the relatively small number of inhabitants the inner city currently accommodates. A confident inner city is vital for the quality of life of the city as a whole. Synergy is an important aspect in this: synergy between the enterprising inhabitants of inner cities and employment, and culture and, for example, culinary meeting points (Marlet, 2009). This is why the Municipality of Rotterdam values inner-city densification with more dwellings and apartments.

§ 6.2.2 Aims

To get from a project idea of densification and greening to realisation, politicians and policymakers had to be convinced of its values as well as its potential of realistic realisation. The question is also if it will lead to a more sustainable city, as suggested by Florida, 2010; Glaeser, 2011; Bettencourt, 2010; West 2017.
Densification is usually a step-by-step process. Rotterdam has already shown that

densification can contribute to creating a successful city; the Laurenskwartier district is an example of this where more inhabitants fueled amenities and good street life. When comparing the inner city of Amsterdam to Rotterdam, twice as many people live on the same surface area in Amsterdam as in Rotterdam. Would it be possible to house twice as many people in Rotterdam inner city and increase its population from 30.000 to 60.000? To give insight if this is a realistic number within the Rotterdam context, but also to study if this could improve quality of life small scale densification studies were done.
To follow up on this, the research question is: What are potential densification and greening strategies and a stakeholder based urban agenda, which improves the quality of life / liveability of the area as well as its sustainability performance. How can this be measured and enhanced using urban data?
Within this context, the objectives of this paper are:

- Test if densification and greening of the inner city of Rotterdam can lead to a more sustainable city with a higher quality of life.
- Present the outcome of a transition management process as realised in the city of Rotterdam from the problem delineation to agenda setting.
- How to measure sustainability in a sustainability profile? What is the baseline and what are expected results?
- How can these data be used in transition management and a stakeholder environment to explore potential synergies and vision making?
- How to update the measuring of the sustainable city of the proposed sustainability profile to a Synergetic Urban Landscape Planning framework, incorporating new level city data and goals such as ISO37120 and the UN's Sustainable Development Goals (SDGs)?

§ 6.3 Materials & Methods: a stakeholder-based urban densification and greening agenda and building a validation tool.

§ 6.3.1 Organisation and planning

IABR 2012, the International Architecture Biennale Rotterdam which served as a platform for this study, describes that 'by linking urban issues, political decision making and design in an interactive and direct way, it promoted more flexible forms of cooperation and alliances, design instruments and governance' (Brugmans et al., 2012) These are the ingredients of the methodology of this paper.

§ 6.3.2 Inventory, pre-studies & stakeholder analysis

The first part of the study is an inventory, background and history of the area. This is also to know more about the urban challenges in the area related to social, economic or spatial structures. Next is a system analysis studying facts and figures about the urban challenges ahead. A last step is a first link to exploring synergies using design. Design is used to show stakeholders potential solutions to one or more challenges, what it can look like if it fits and if it evokes a positive or negative experience. In a fast changing world, there is a big need for information and data, but also participation. To help strengthening the inventory phase but also to have an overview of which stakeholders to select for a good embeddedness to make the transition happen, a range of stakeholders were selected in meetings. From bottom up to top down, from government to business. In this process three focus group meetings were organised with stakeholders in the city. The first group were the (future) inhabitants. As the topic is densification and greening, the main focus was what kind of city, (future) inhabitants wished to have, who were the clients who would live there. The future inhabitants were identified through housing brokers and their clients in the city. This was a mix of young families living in neighbouring cities but working in Rotterdam, graduating students, former immigrants making a career and pensioners. A second group was a mix of shopkeepers, business people and designers such as (landscape) architects. These people were all connected or members of the 'van der Leeuwkring', an organization concerned about the quality of the public space of the inner city. The third group were market parties and inhabitants that were already setting up initiatives and doing things themselves.

§ 6.3.3 GIS analysis & transition management

Transition management depends for a part on the role of the participants in the process as well as on a good detailed information.
The development of GIS tools such as urban energy maps provided the participating stakeholders in the transition management workshops with valuable information on for instance CO_2 reduction potentials. These tools also allowed for measuring energy consumption and the outputs of the actions that were formulated in the transition management action plan. The stakeholders therefore acquire a good insight in the real impact of their actions and pilots and will be able to compare them with alternatives. The GIS maps and data feed the stakeholder process. A stakeholder process without accurate data and mapping allows for some stakeholder to take the overhand in a discussion or for incorrect assumptions to be incorporated in a discussion. A stakeholder process with accurate data and maps levels the playing field better and can quickly check disputable assumptions. Of course, this depends strongly on the accessibility of the data and maps and requires a good discussion leader and data specialist. There are also other low-tech ways to collect data such as fieldwork with observing situations and interviewing locals. Either way this way of working has additional values when combined with GIS technologies as it gives extra information and knowledge.

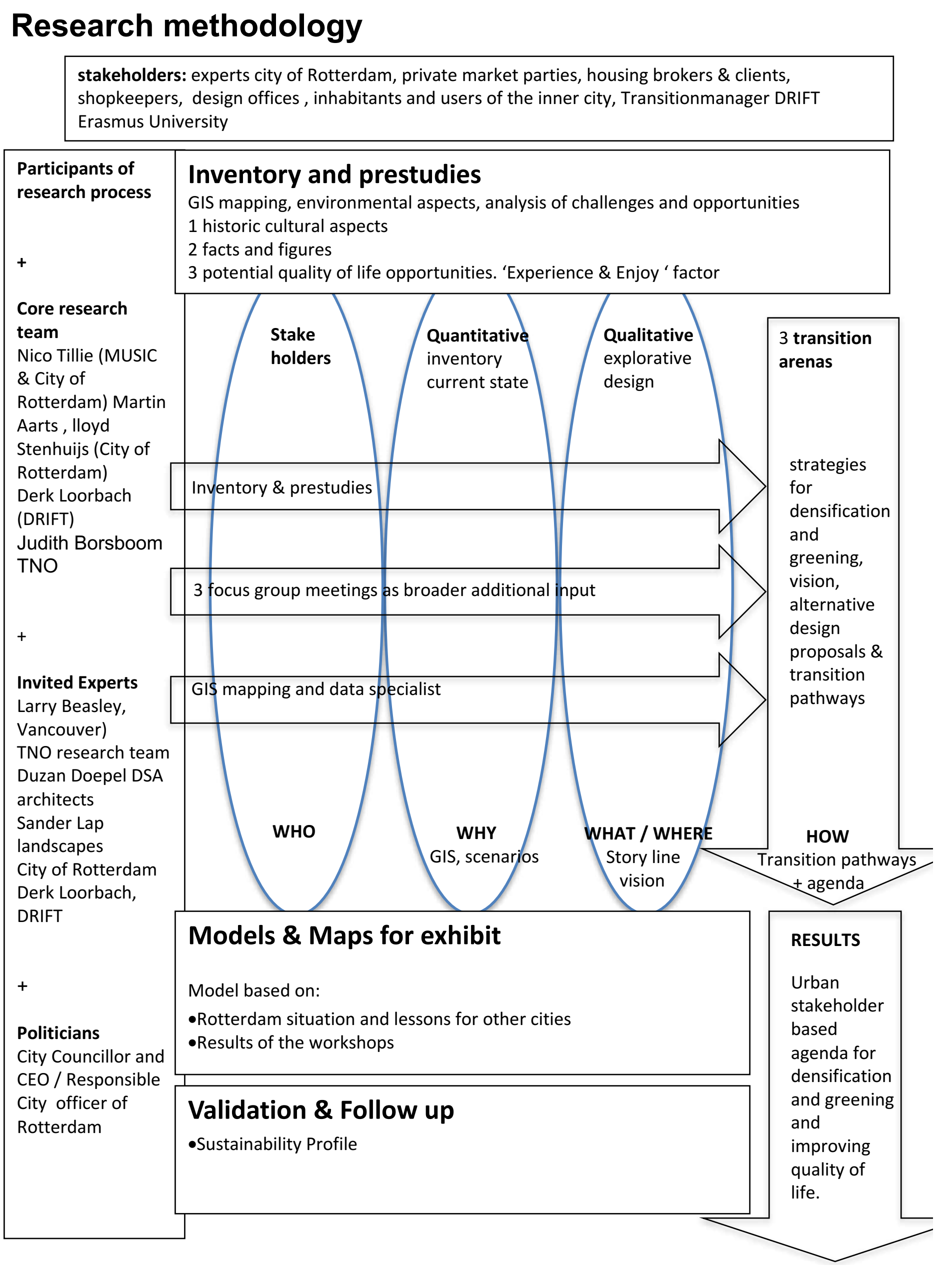

FIGURE 6.3 Research methodology for building a stakeholder-based urban densification agenda linking Quality of life, liveability and sustainability performance. GIS = geographic information system; MUSIC = Mitigation in Urban Areas Solutions for Innovative Cities; CEO = Chief Executive Officer; TNO = toegepast-natuurwetenschappelijk Onderzoek; DRIFT = Dutch Research Institute For Transitions.

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§ 6.3.4 Transition arenas

As a start interviews were held with various stakeholders to find out who as engaged inhabitants and entrepreneurs wished to participate (or should be invited) in giving form to Rotterdam's future inner city. Trend-setters among this group, along with cultural leaders and trend-setters from the Municipality of Rotterdam, participated in transition arenas. Ideas, initiatives, obstacles and problems were debated at these meetings with the aim of reaching consensus on a common vision.
In transition arenas, the urban challenge of densification plus greening in a sustainable way is discussed, elaborated, designed, altered and finally put into a long-term vision with an agenda of actions. The transition arenas were organised to build the densification & greening agenda from vision to implementation.
Three components fed the transition arenas. Firstly, the pre-studies such as historical background, challenges and opportunities. Secondly, the three focus group meetings with housing brokers, clients, shopkeepers, entrepreneurs and designers. Thirdly, an important extra component, as explained earlier, was the use of information coming from GIS maps and city to give direct feedback to (wrong or right) assumptions. In this way, the proposed change can be based on facts (quantitative), wishes, opportunities, stories and design (qualitatively). Stakeholders can see and understand different scenarios or transition paths and choose accordingly. This way the transition strategy and agenda was formed posing for long-term ambitions and short-term innovative actions to go hand in hand.

§ 6.3.5 Validation tool, sustainability profile for measuring

The concept of sustainability is often criticised for its lack of clarity and expressiveness. Sustainability can be explicit though. Data, software tools and sound theoretical context are put to use, in order to present condensed analyses of important selected sustainability aspects that are related to this case of densification and greening.
The concept of sustainability originally stems from ecology, where it refers to ecological and environmental boundaries that should be respected to ensure preservation of stock of fish and forests for future generations (Borsboom – van Beurden et al., 2011a) . In 1987 the Brundtland report, "Our Common Future" (Brundtland, 1987), broadened the concept of sustainability to socio-economic aspects and the balanced development of social, economic and environmental factors; later it was rephrased as people, planet, profit (prosperity).

In this chapter, the impact of densification of the inner city of Rotterdam on sustainability is investigated with the help of a newly developed sustainability profile. As a first step, a framework consisting of 35 indicators was built for eight chosen themes. Figure 6.12 shows an overview of the different themes and indicators. These themes were seen as priority issues by the city at the time being. The themes distinguished cover a broad definition of sustainability, and thus include social and economic aspects as well as ecological and environmental ones (people, planet, prosperity). The subdivision into themes and indicators is based on earlier studies of TNO with sustainability measuring at the regional level. In this case the benchmark of the province of Utrecht for its new spatial vision and a visualisation of chances for more sustainability for the province of Overijssel was used (Borsboom-van Beurden et al., 2011b).

Indicator selection

The selection of indicators was based on priority issues formulated by the city, their relation with urban densification and on the availability of data. Subsequently, a baseline of the Sustainability Profile was set for these themes in the inner city. Following this, the densification strategies and designs were imported into the model Urban strategy (TNO, 2012b) and GIS; the values of the 35 indicators were calculated for 2040 or for the moment the proposed densification and greening is completed. To assess the impact of the proposed densification, the outcomes were interpreted qualitatively by visual comparison, and quantitatively by summarising results and making additional calculations. After that, the values of the individual indicators were combined for all distinguished themes. The outcomes were presented in a spider diagram which was called The Sustainability Profile.

The Urban Strategy model provided the energy, traffic (HB module) as well as the noise and air pollution modules (EMEP, 2011) to assess the impact of the densification proposals on eight sustainability themes. Other models were used in addition: Regina, the regional economic model (Courbis, 1972), SOLWEIG, the heat stress model (Lindberg et al., 2008) as well as the 'Hoogwater Informatie Systeem' or Flooding information system (RWS-DWW, 2011).

§ 6.4 Results

§ 6.4.1 Focus group meetings and transition arena objectives

First focus group meeting - Framing challenges & exploring potential synergies with stakeholders. The launch of a research project was a stakeholder meeting to search for possibilities as well as requirements for densification of Rotterdam's inner city. Common believe among the 20 stakeholders was the crucial role of the quality of life of the (future) inhabitants.
Furthermore, it was emphasised that creating attractive conditions for families is important, even if they only form a small percentage of the total number of inhabitants. It was expected 20% (after densification). Several architects presented their work.
In addition to the existing high-rise strategy, what also emerged was that there are at least six alternative densification strategies to be distinguished for this group of enterprising inner-city inhabitants. A follow-up issue that arose from the stakeholder meeting, as former director of planning of the city of Vancouver, Larry Beasley described it, was to find out whether these bottom-up initiatives would also contribute significantly to the desired numbers as well as attractiveness of the inner city. To avoid the inner city becoming very "stony", greening strategies were developed together with the densification strategies.
The City Councilor for urban development chaired the second focus group meeting with the 'Van der Leeuwkring', an organisation concerned with the quality of public space. During the third meeting, held on the new ideas as well as existing and built plans were shared among each other to show a possible end goal.
After these focus group meetings, the transition arenas took place, during which a transition vision was created.

Table 6.1., shows an overview of the different topics addressed. Figure 6.4, shows the proposition or vision for densification and greening. In this long-term vision densification and greening strategies are defined.

FROM	TOWARDS
1. No-connecte places (loose beads)	1. Connected inner city (a necklace of beads)
2. Open festival area, gate and cleaning up	2. Eveything is allowed provided it fits within a future proof structure (create your own dream world)
3. Various communities going their own way in the city: little interaction or collaboration	3. Community feeling in which the public realm is the meeting place
4. Municipality / companies make the city	4. Rttterdam inhanitants make the city
5. Alienation from outdoor space	5. Feeling at home, outdoor space becomes a living room
6. Playing hide-and-seek	6. Making interests, places and existing energy visible

TABLE 6.1 Overview of the outcomes of the transition arenas (Roorda et al., 2014)

Reconstruction plan after World War II (courtesy City of Rotterdam)

Green densified inner-city plan (courtesy of Doepel Strijkers Architects, Rotterdam)

FIGURE 6.4 This new vision gives a more central role to greening strategies

§ 6.4.2 Densification and Synergies

For this research seven densification strategies, which were identified during the stakeholder sessions, have been explored in terms of their spatial potentials. The ambition of this exploration is not to generate a master plan for densification of the inner city; rather, the intention is to demonstrate that there is more available space in the inner city than one may think, and that, in potential, doubling the number of inner-city inhabitants is spatially realistic without diminishing the existing quality of life. To use realistic data for this research on densification, housing typologies characteristic for certain areas in Rotterdam were used. People tend to live were other people of their own peer group live. An example is that people with children want to live where already other people with children are living (Aarts, 2011). So, the strategy was to start with successful areas which were already present. Below in Table 6.2., the densification strategies are listed in a matrix. For each strategy, the number of potential units are listed per neighbourhood in the inner city district.

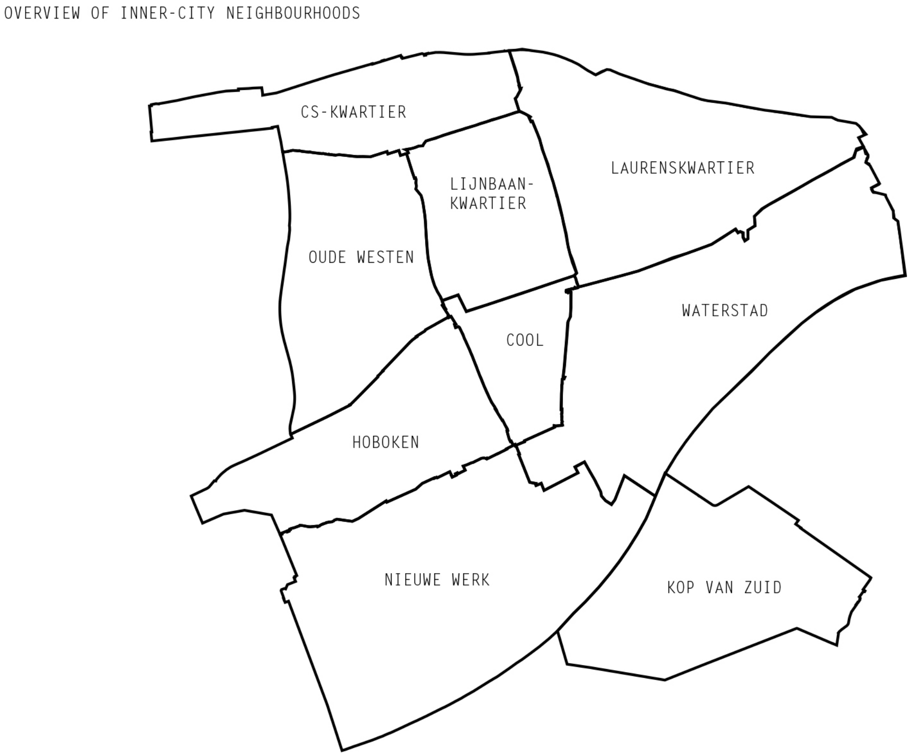
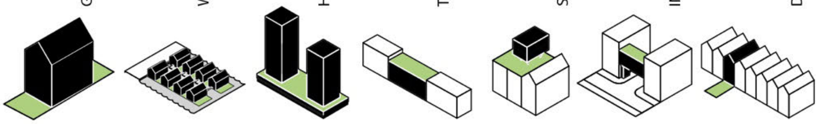


FIGURE 6.5 Overview of the 9 neighbourhoods studied for densification and greening (courtesy of Doepel Strijkers Architects, Rotterdam).



	GROUND-BASED DWELLINGS	WATER DWELLINGS	HIGH-RISE DWELLINGS	TRANSFORMATION	SKYBORN	INFILL	DO-IT-YOURSELF
CS-KWARTIER	0	0	1,870	90	0	0	0
OUDE WESTEN	210	0	200	170	440	100	110
LIJNBAANKWARTIER	60	0	1,580	830	180	120	0
LAURENSKWARTIER	1,110	10	1,870	610	470	120	0
HOBOKEN	600	0	260	130	10	0	0
COOL	50	0	90	290	30	30	0
WATERSTAD	110	120	1,690	1,280	370	150	0
NIEUWE WERK	500	0	740	290	20	20	0
KOP VAN ZUID	260	310	2,750	0	0	0	0
TOTAL IN 2040	2,900	440	11,050	3,690	1,520	540	110

TOTAL POTENTIAL NEW HOUSES 20,250

FIGURE 6.6 Calculations per neighbourhood of potential new housing per densification strategy which totals 20.250 (Courtesy of Doepel Strijkers Architects, Rotterdam).

A short description is given per strategy.

Ground-based dwellings

Access at ground level makes street-facing, ground-based housing particularly attractive, not only because it contributes to the individual dwelling, but also since it increases the liveability of a neighbourhood. Undeveloped plots of land and large public outdoor spaces are useful for this form of densification. A garden and access at street level is what makes this densification strategy particularly attractive for families.

Water dwellings

There are two sites that form natural, potential locations for water-based housing: the old and the former harbours. Not hindered by zoning of land and existing building lines, a multitude of different dwelling types are possible: quay blocks at the interface of city and water, jetty dwellings, pole houses, and floating housing make optimal use of this dynamic environment.

High-rise dwellings

The potential for high-rise dwellings can be realised where regulations and ground conditions allow for it. This should be fully in line with the Rotterdam skyline strategy. These dwellings are situated in the most urbanised areas (high-rise zones), the inhabitants of such dwellings benefit from the proximity of amenities. At ground level, the human scale of the building is important and should be carefully designed. In Rotterdam, the term ‘groundscraper’ was introduced to plan for a good relation between buildings and public space.

Transformations of the inner city’s offices were mapped by Zandbelt & van den Berg. There are a lot of short- and long-term term vacancies all over the city, with a concentration in the post-war office areas. As housing is less sensitive to economic conditions, a mix of dwellings with offices could provide a more stable backbone for an attractive inner city.

FIGURE 6.7 Skyborn densification strategy, Didden Village in Middelland Rotterdam, by MVRDV (photo courtesy of Forgemind ArchiMedia, via https://www.flickr.com/photos/eager/15771369594/sizes/l www.creativecommons.org/licenses/by/2.0/).

Skyborn

This is a strategy where existing buildings with a solid construction are suitable for densification by "topping-up". This is mostly done with houses built after 1950, as they have a concrete or steel structure and flat roofs. The skyborn densification strategy optimally exploits the proximity of urban amenities and green infrastructure. Since new dwellings need to adapt to existing substructures, this strategy encompasses a large diversity of building typologies: from roof villages with a communal character, to individual penthouses. Collective green outdoor space can be created at roof level, with additional private outdoor areas in the form of large balconies or patios. In time, the green roofs, sloping buildings and bridges will create a new layer in the city.

Infill

Infill housing is fit in with great precision. Gaps above narrow delivery streets, undeveloped plots of land and large courtyards can be filled in with dwellings that cross the street like a bridge. Especially around the so-called 'WWII Fire Boundary', where the border between old and new city is most apparent, infill is a valuable strategy. In doing so, the identity of the urban fabric can be strengthened, increasing the diversity and attractiveness of a neighbourhood.

FIGURE 6.8 Left: Mauritsstraat, Cool, infill densification strategy, by Kühne en Co. (Rotterdam, Netherlands); Right: Boomgaardstraat, Cool, by Kühne en Co. (photos by Nico Tillie).

Do-it-yourself

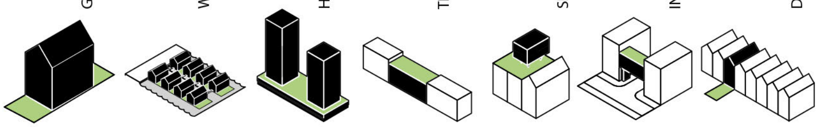
DIY-housing is part of the nineteenth century housing stock with their characteristic facades. These houses appeal to a large group of buyers. Often in a poor state of repair, and way too small to meet current spatial demands, houses of this type can be adapted to suit the lifestyles of young professionals and families. This best practice is now also used in other cities and old apartment blocks. Sometimes it is not about densification in terms of square metres, but rather about the adaptation of building blocks to house more inhabitants. In other areas of the city, housing associations or developers ensure that the foundations are stable and the roof is watertight, while the new home owners are responsible for an interior structure that suits their individual lifestyle. These dwellings are extremely suitable for young families.

FIGURE 6.9 Mapped overview of potential new dwellings per neighbourhood. (Courtesy of Doepel Strijkers Architects, Rotterdam)

§ 6.4.3 Greening and Synergies

The city's wish to attract more inhabitants and visitors to its city centre will only work if the city offers a pleasant living environment that develops along with the densification. The public realm plays an important role in this. Research has shown that an attractive public realm, one in which green amenities are the essence, is an important prerequisite for city life, in terms of day-to-day living and for the work and leisure environment (Gehl, 2004). The more attractive this public realm, the more people would like to spend time there. In this research hypothesis 5,000 new trees should be added along with other green covering a total area of 150 football pitches (90 ha).

The Municipality of Rotterdam (Gemeente Rotterdam 2005, 2009), notes that more green space in the inner city is desired, as well as greater diversity in the green space and a better quality of green design and management. This implies that the construction of new dwellings should be accompanied by the provision of extra high-quality urban green, to compensate for previously unmet or future demand. In any case, to welcome the inhabitants that come with new dwellings, as well as for people living there already, more and better quality urban green is needed. An attractive green infrastructure in the inner city is conditional to the popularity of living in the inner city. The current green infrastructure needs to be expanded and complemented with new qualities. Below in Figure 6.10, the greening strategies are listed in a matrix. For each strategy, the number of potential m^2 of green is listed per neighbourhood in the inner city district.



	GROUND-BASED DWELLINGS	WATER DWELLINGS	HIGH-RISE DWELLINGS	TRANSFORMATION	SKYBORN	INFILL	DO-IT-YOURSELF
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TOTAL IN 2040	2,900	440	11,050	3,690	1,520	540	110

TOTAL POTENTIAL NEW HOUSES 20,250

FIGURE 6.10 Calculations per neighbourhood of potential new green per greening strategy which totals 141,7 ha. (courtesy of Doepel Strijkers Architects, Rotterdam).

A short description is given per strategy.

Boulevard

The boulevard strategy aims to complete the tree structure along main roads. The diversification in tree stock creates more variety and reduces vulnerability for species-specific diseases and aging. Trees and grass on roadsides, alongside and in-between tram tracks make roads and streets more attractive and improve the microclimate of the city. Green streets and roads invite people to walk and cycle and provide routes leading to green areas a high-quality flowscape.

Quay

The quay strategy aims to transform the riverbanks and stony quays into an attractively connected, green recreational landscape. This is all about a new perception of the river Maas, the old river mouths and old harbours. Getting rid of car parking on the quays wherever possible and designing new green spaces will create a continuous walking and cycling route along the river with connections in the direction of the inner harbours and the areas beyond them. The city is once again connected with the water.

Square

The square strategy aims to give each square in a way its own character with various uses: a palette of different squares. Squares function best when surrounded by buildings with mixed programmes at street level and amenities in the form of terraces or attractively decorated public places (Projects for Public Spaces Inc., 2000). Trees and attractive green in the form of scented flowering bushes and plants attracting insects can play an important role in providing a square with a pleasant ambiance, as well as contributing to its identity and character. Sculptures and playing facilities also play an important role in this. Flexible use of space can also provide opportunities for inhabitants to have a barbecue, a children’s party or have other events.

Parks

Concerning parks, the inner city has no more room for a large metropolitan park at ground level, but many small parks can also green the inner city. The park strategy aims to have a park within walking distance (250 m) of every home. The parks will differ from each other in form and use. Existing qualities in parks should be maintained and reinforced as much as possible. The west side of the city has a continuous network of good parks, which can contribute to the perception of green in the entire inner city, provided they are well connected.

good parks, which can contribute to the perception of green in the entire inner city, provided they are well connected.

In a densifying city parks and greenways on rooftops are not only an option but probably a necessity.

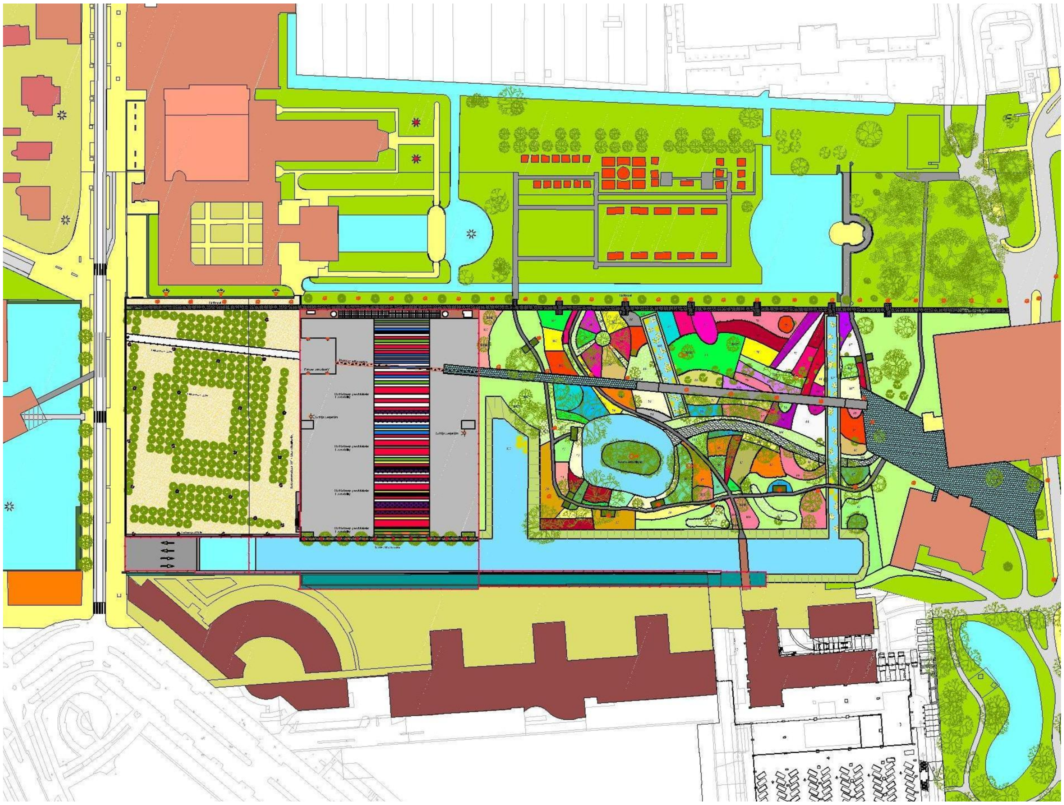

FIGURE 6.11 Greening strategy of strengthening existing qualities, such as the Museumpark Rotterdam. Redesign of the Museumpark by Chris van Duijn OMA, Petra Blaisse Inside Outside and Nico Tillie (Delft University of Technology/City of Rotterdam) (Map courtesy of Rens Fransen, City of Rotterdam).

Playgrounds

The Municipality of Rotterdam intends to create lively oases for children: squares, parks and gardens that encourage children to play with sufficient places to sit. Child-friendliness entails more than just creating a few playgrounds: it encompasses the entire design of the public realm. Broad sidewalks, slow-traffic routes and speed-bump zones play an important role. Broad sidewalks provide informal space for games.

1 2 3 4

FIGURE 6.12 Greening strategy of playgrounds. Left: Speeldernis or 'Play Wilderness'. Right: Green roof and green facades in the urban fabric in Singapore as an example (photos Nico Tillie).

Green roofs and facades

Green roofs and facades provide extra ecological quality, capture fine particles, and can provide green scenery and green recreational (sitting and playing) environments. Moreover, they have a positive effect on the densified inner-city climate and function as water buffers, thus contributing to urban water management. Green roofs and facades also provide excellent locations for realising urban agriculture. Combinations of building functions (e.g. restaurants and schools) and agricultural activities on roofs and facades also have social and economic value.

Furthermore, this can all be combined with installing solar panels. In the MUSIC project the online Rotterdam energy atlas was produced for inhabitants to see the potentials for solar energy on their roof.

Glamourous Green

Glamourous Green or outdoor space of excellent quality is needed for the busiest and most characteristic places in town. The design of this public realm is decisive for the atmosphere, tempting people to dwell longer and, finally, to feel more connected with the city.

FIGURE 6.13 Mapped overview of potential green per neighbourhood.(Courtesy of Doepel Strijkers Architects, Rotterdam).

§ 6.4.4 Validation results

The densification and greening proposal resulted in quantifiable outcomes such as number of houses and trees. This was direct input in the scenario models which than resulted in for example energy use. When this was not possible, a consensus of expert opinions and views were used, combined with sources of geographical data. The results were analysed with geographical information systems (GIS). For each of the eight themes in Figure 6.12., the outcomes of one or more indicators are explained below.

Energy

Energy use; Doubling the number of dwellings will strongly help to decrease the average energy consumption per dwelling of the inner city area.

Average use of energy per dwelling will decrease because new housing will have to meet stricter standards of energy efficiency. New buildings will have to be energy neutral after 2020. However, substantial efforts will be needed to upgrade the energy efficiency of the existing housing stock. Ideally, upgrading could be carried out while densification strategies are being realised. Densification has the added benefit of contributing to a more compact urban form: more clustering within the urban morphology leads to more energy efficiency as well. Furthermore, existing district energy networks will become more efficient and profitable because they will supply energy to a greater number of buildings; also heat exchange between buildings will become possible (Tillie et al., 2009). Lastly, a compact urban form also has a favourable effect on energy consumption by urban transport such as public transport, walking and cycling, are all forms of low carbon transport.

Renewables; The growth of renewable energy production within the city can be expected. Solar photovoltaic units can be installed on many flat roofs, either alone or combined with green roofs. In urban transport, the combination of less car use and more frequent use of public transport, walking and cycling, in combination with more energy-efficient vehicles, will largely compensate for the additional use of energy.

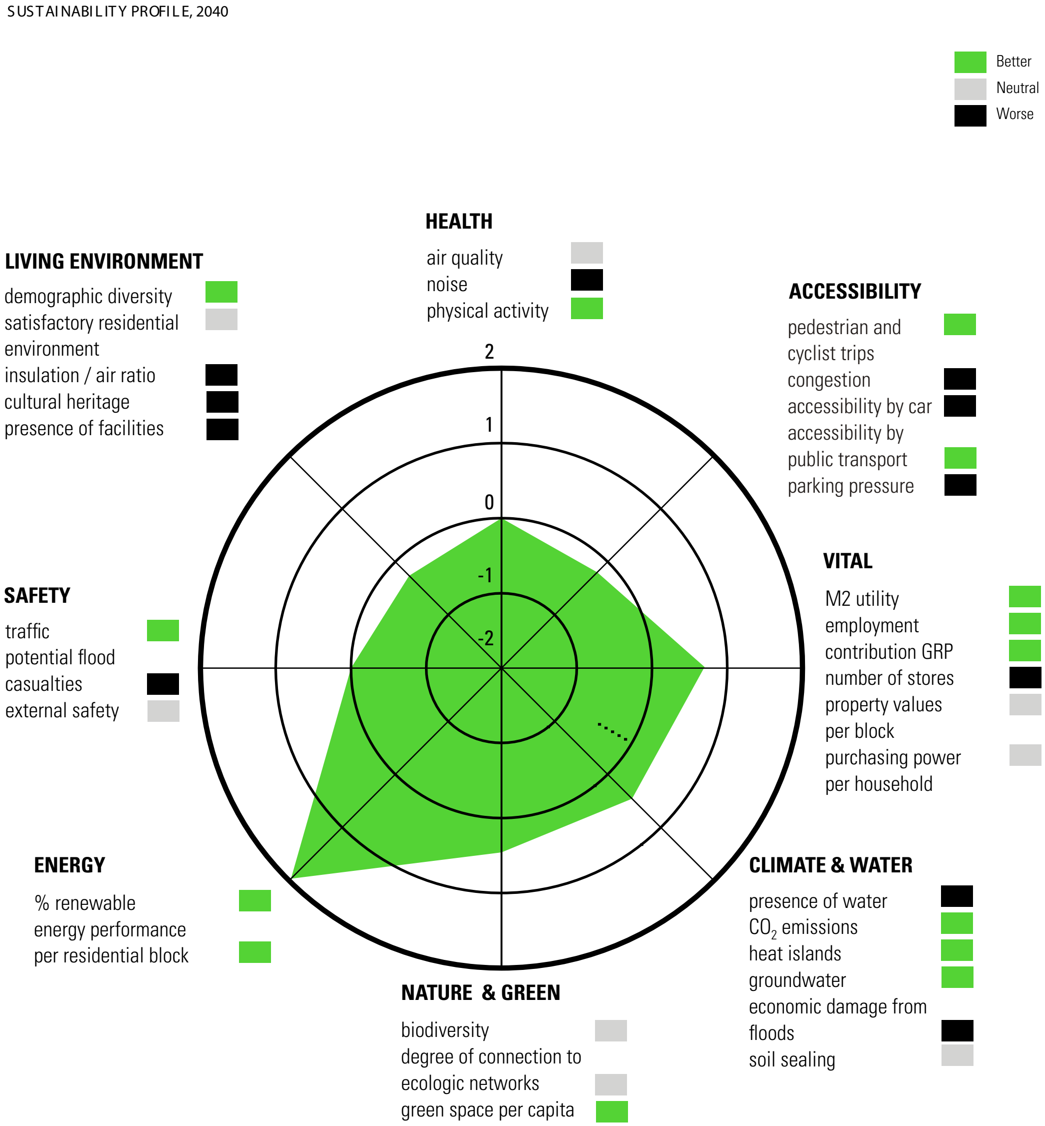

FIGURE 6.14 Sustainability profile outcome of the densification and greening strategy of the Rotterdam inner city. (courtesy of Doepel Strijkers Architects, Rotterdam).

Climate and Water

CO_2 emissions - low carbon; Since all the new houses will comply new energy regulations, 44 tonnes of CO_2 emission will be avoided on a yearly basis, compared to a business as usual scenario, i.e. 18% of the current residential CO_2 emission of houses in Rotterdam. Of course, as long as new buildings are not energy neutral, adding new buildings will increase carbon emissions of the built environment. New buildings will have to comply with stricter norms on energy performance as from 2020. This means that all new buildings will be nearly carbon neutral. Apart from decreasing energy consumption for buildings and transport the energy mix for the inner city should change to make it carbon neutral. Heating and cooling should either shift from natural gas to zero carbon electric or district heating and cooling systems and the electricity should come from renewables off grid or form a zero-carbon grid. Scenario studies in GRIP (Carney et al., 2009) for Rotterdam have shown that this is possible. CO_2 emissions avoided in new buildings has been defined in comparison with business as usual. However, for future studies it would be interesting to know more about avoided CO_2 emissions when comparing living in a densified neighbourhood to an alternative, for instance living in a suburban neighbourhood. Similar for the GAP indicator (the green area preserved) (Dobbelsteen et al., 2004), by not building outside, but inside the city.

Heat stress

The increase in urban heat island effects by adding building mass to the inner city is compensated by adding urban green and shadow cast of high building blocks.

The densification strategies as described in paragraph 5 are accompanied by ambitious urban greening strategies. Higher buildings lead to more prominent heat island effects. However, higher buildings also create more shade, which compensates for increased urban heat island effects. Also, development of more urban green mitigates these heat island effects even further. As a result, heat stress does not increase significantly compared to the existing situation. Several parts of the city that warm up during summer were mapped; the greener the area, the smaller the chance that during a warm period the critical radiation heat will exceed 55ºC. Note that radiative heat is not the same as air temperature; radiative heat is usually much higher than air temperature.

Soil sealing, flooding and economic risk; Soil sealing and flooding risks remain at the same level. Economic risks increase as a result of potential flooding, not because flooding occurs more frequently, but because the total economic value of real estate is higher as the inner city has grown.

Health

Physical activity factor; In this example, higher density stimulates walking and cycling. With more inhabitants living in densely built-up areas walking and cycling can be promoted, particularly so because car use becomes less attractive as a result of a limited supply of parking spaces and an urban design attuned to cycling and walking. Ambitious urban green development induces physically active behaviour. More playgrounds will be created through strategies for urban greening and existing playgrounds can be used more intensively. A high-quality flowscape for pedestrians and cyclists depends on the quality of the urban design of the densification strategies. Examples of relevant elements in a successful urban design may include lanes with separate walkways and cycle paths, the establishment of attractive green areas and the reduction of barriers by providing extra connections such as bridges for slow traffic or simply zones where pedestrians and cyclists have right of way. On the other hand, new blocks of buildings could limit the possibilities for physical activity around the city. Improvement of physical activities occurs when new green areas and infrastructure is developed, while decline takes place when blocks of buildings are added. It is clear that the new city structure includes some blocks for which it is less inviting to venture out on the streets, because there is little urban green or barriers to walking and cycling are present. Additional analyses of the combined effect of physical activity, air pollution and traffic safety show that extending the possibilities for physical activity lead to extra years of healthy living.

Noise pollution will increase slightly due to more automobile traffic on a few throughfare roads. Effects of busier traffic are countered by buildings that act as acoustic screen. However, more than half of the new inhabitants will experience noise levels above the strict future norms. After the realisation of the densification strategies, about 18,000 of the new inhabitants will experience noise levels greater than 48 dB at the outer walls of their dwellings. This is primarily due to an increase in the number of cars. The policy limit of 48 dB anticipates new, stricter policy norms in the future; 55 dB is the current norm. Very few houses are expected to experience noise levels above the current norm of 55 dB. Noise levels above 50 dB are mainly confined to roads; noise levels at the facades of homes are mostly below 50 dB.

As for congestion, few changes occur between the old and new situation. There are few places where an increase of more than 5 dB will take place. In contrast, many places show a decrease of noise hindrance due to the assumed higher importance of public transport, walking and cycling as means of transport. Although densification will not as such substantially aggravate noise levels in the inner city as compared to current standards, action (e.g. reduction of car traffic) must be taken to comply with future norms.

Air quality; It is expected that air quality will improve, by 2016 heavy polluting vehicles were not allowed to enter the inner-city anymore, with air quality improvement as a result. As a consequence of densification, more people will be exposed to the existing levels of air pollution. At the same time, adults and children will have more possibilities for physical activity, which in combination with relatively less car use can lead to two more years of healthy living according to the models.

Vital City

Employment; Densification leads to a significant increase in employment in service activities.
A denser inner city leads to a higher demand for services, such as shops, restaurants, hairdressers, and the financial and administrative services that in turn support these companies. Employment and added value per square meter will increase as a result of urban densification and the resulting increase in inner city inhabitants.
Market value of new houses; Although the average current market value of houses per city block is known, it is difficult to accurately predict the future value of houses since there are too many variables that influence their future price. We can nevertheless give a first indication of price developments based on observed correlations between the number of new homes and the development of housing prices, taking that all other factors stay the same. These correlations show that if up to ten houses are added to a residential area, house prices will rise only slightly. This is because a small investment indicates a small scale of improvement of an urban area that has been already developed. If more than just a few houses are added, the data show that prices will drop. This can be explained by the simple mechanism of supply and demand: the more apartments or family homes in a certain building block, the less new owners are likely to pay more for them. Indication of the relative change in house prices in Rotterdam per city block were studied, as well as the current average values per block before and after densification. However, a strong reservation should be made about the outcome, since it is only based on the number of homes; other factors determining house prices such as location, house type and number of rooms have not been researched. Differences can be seen between the north-western and north-eastern parts of the inner city. Unfortunately, data is missing for some city blocks.

Nature & Green

Biodiversity; The current initiatives to improve biodiversity will compensate for a more intensive use of the inner city area. The amount of urban green is expected to increase significantly also there is more diversity of green such as green roofs, sloping roofs linking street level to a roof network and green walls. Nevertheless, it will be used by more people, so the area of urban green per inhabitant slightly decreases.
Ecological networks & green space per capita; the availability of urban green improves, but it will be used more intensively. An expansion of urban green will be realised, although the increase in numbers of inhabitants is relatively larger than the volume of urban green added. In this analysis urban green available for daily activities (within a range of 250 m of the dwelling), such as recreational walking and cycling, was distinguished from urban green available for weekend activities. (within a range of 500 m of the dwelling). It appears that the total amount of urban green per inhabitant decreases somewhat in spite of ambitious strategies for urban greening. However, the

good news is that for many inhabitants their proximity to urban green is significantly closer, especially for those who live in existing buildings. Less urban green per inhabitant will lead to more intensive use of the urban green in place. This can result in "cosy crowdedness" and "more eyes on the street" (Jane Jacobs). The presence of people attracts other people. The quality and characteristics of urban green is important as these influence, how green areas are used, because there are more factors such as access and linkage, safety, sociability and activities (Gehl, 2004; Projects for Public Spaces Inc. 2000; Whyte, 1980). Although the quantity of urban green decreases per inhabitant after densification, from 37 to 34 m^2 per inhabitant, green space of high quality can partly compensate for this and thus contribute to creating a satisfying living environment.

Living Environment

Facilities; In the search for new housing locations, the number of leisure facilities and services available often play a minor role. Nevertheless, in order to maintain an adequate service level, places need to be identified where leisure facilities and services should be added or expanded. All stakeholders should be aware of the needs of entrepreneurs and organisations at an early stage. Diversity and flexibility of space for leisure facilities and services should allow for easy adaptation to actual needs in future. The location of bars, restaurants, hotels, theatres, galleries, museums and other cultural points of interest per city block were mapped. Also, the anticipated increase in the number of new facilities needed in relation to the location of new dwellings and new inhabitants after densification were studied. Especially the areas around the railway station and the Kop van Zuid district need a boost in leisure facilities.
Demographic diversity; More demographic diversity due to the settlement of families contributes to greater satisfaction with the living environment. Measures to design childfriendly neighborhoods such as routes and continuing pavements have a positive effect on safety and well-being, not just for children but also for elderly people.

Accessibility

Accessibility in the inner city appears to be largely dominated by the voluminous traffic flows of commuters and visitors rather than the doubling of the number of its inhabitants, so the effect of densification is relatively small. Besides, for the inner city, the limited supply of parking places (0.48 parking place per dwelling 2012, and shrinking) and increasing numbers of other means of transport, such as public transport, walking and cycling, will lead to reduced use of cars. Although the Urban Strategy model predicted for congestion to get worse on a few throughfare roads as a result of higher traffic intensities outside the area studied.

However, when interviewing the traffic department in Rotterdam it turns out that congestion in the inner city overall has not increased in the past 4 years. In fact, some roads show a decline in car use and car traffic.

Safety

In terms of safety, the results show that traffic safety improves due to relatively less car use. In the past years there is a downward trend for car use in the city. Also design solutions for a child friendly city improve traffic safety.

Safety from flooding remains the same: the risks do not increase, although the number of potential casualties is higher.

§ 6.4.5 Results in the city itself

Densification

Real life projects are not the results of the last few years only. During the third stakeholder meeting, the trend-setters were already demonstrating how they were already practising various initiatives. Sometimes the Municipality of Rotterdam was the initiator, as in the case of some DIY houses. Surveys among inhabitants and potential dwellers/buyers clearly indicate that this initiative is very much appreciated by enterprising inhabitants because they have an opportunity to satisfy their individual wishes and needs. Entrepreneurship is key to such developments, as demonstrated by Joost Kühne, spokesman for a group of initiators who develop small new housing projects as urban infill, financed in advance by market parties, that demonstrate how small interventions can have great impact on a neighbourhood. Another built example comes from ERA Contour, with 'block city', or the housing corporation Woonstad by selling houses, destined to be DIY houses in the district of Het Oude Westen. The DIY ideas were awarded with a European prize and are now applied in many other cities. Also, the recent renovation of the Bijlmermeer in Amsterdam was very successful using a similar approach.
Transformation of vacant office buildings and municipal real estate is also an issue high on everyone's agenda. This is why the Municipality started inviting creative entrepreneurs to come forward with plans to exploit the opportunities provided by vacant (municipal) real estate.
Also in 2017, new areas came to life regarding facilities such as bars and restaurants. Places that were not developed well a few years ago are now hot, such as the area near

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the central station, the former office of Nationale Nederlanden (sandwich bars and coffee), Kop van Zuid, and 'Onder de Bogen'. This area developed very fast as a result of the 'Luchtsingel', a crowdfunding initiative from the Rotterdam office of ZUS linking different parts of the city by building a wooden bridge over the railway. This was also one of the IABR2012 projects.

2014 proofed to be a turning point for the popularity of the inner-city with new developments such as the new Market hall, Central Station and the multifunctional Rotterdam Building near the Erasmus bridge.

Greening

The greening strategies in Table 3., show that a significant expansion of urban green space is possible under densification. Green roofs and Quays form the biggest part of this. A number of plans have already been built, such as the green quays at Leuvehoofd. This was designed by Piet Oudolf. New developments go further and in some areas tidal parks are built at the river. As such, the whole riverfront can be seen as a (potential) metropolitan park.

With the greening strategies it is important that, in addition to the municipality's involvement, private parties and developers can also contribute. For example, private initiatives such as the urban agriculture garden on the Müllerpier or former garden in Delfshaven near the roof park. Existing green roofs, facade gardens and other urban agriculture initiatives are also contributing to the city's green. The number of initiatives has grown. Extrapolation of the effect of densification and greening strategies indicates that there is sufficient space to extend these approaches on a larger scale and increase the involvement of inhabitants, and as such reinforce the vitality of the city.

About Transition management and stakeholder follow ups. Over the years, stakeholders got more involved in different processes. Over the past 4 years the so-called city conference or 'stadscongres' was organised. This is basically a yearly conference of one week, where the city officials present their new plans and ideas for input and where city plans as well as local initiatives link up with each other and other organisations. There are hands-on work sessions to prepare short-term actions in a long-term vision. As such it is a kind of big dating event where people and organisations who like to improve the city get together.

A newer initiative is the 'wijkraden' or neighbourhood boards. Each neighbourhood has a group of active inhabitants or organisations that are involved in making a better city. As such, the transition arena group of the IABR2012 can be seen as an early neighbourhood board.

Another but older initiative that ran for four years is the city competition. Politicians agreed that for four years, inhabitants of the city could vote each year for the best initiative they wanted to be built in the city. The winner would be granted a few million

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euros for the project to be built. Actually, the 'Luchtsingel' described earlier as the wooden bridge was one of these projects. One of the positive side effects was that many people got involved in many initiatives. Even if their plan did not win, it created a lot of positive energy and ideas that were often realised later on.

§ 6.5 Discussion

§ 6.5.1 Synergies

In paragraphs 6.4.2 & 6.4.3 many synergies were listed with the densification and greening strategies. The strategies are implemented in such a way that synergies occur. The synergies comply with other urban agendas in many cities, such as climate adaptiveness, child friendliness, good quality biking and so on. By planning for synergies, the densification and greening agenda in cities relates directly to local broader social, environmental and quality of life issues. In a follow up study, this could be compared and linked to for instance ISO37120 standard on city services and quality of life and the UN's Sustainable Development Goals.

§ 6.5.2 GIS and city data information

An important component to adapt the stakeholder sessions and transition arenas to local context and needs was the use of GIS maps and city data in the transition arenas to give direct feedback to (wrong or right) assumptions. Using a third party (TNO) to test alternatives and future plans was crucial as they are an independent party in the process. As a city testing and valuing one's own plans would be less credible.
The outcomes showed that linking GIS mapping and city data to the stakeholder process and transition management proved extremely valuable.
The outcomes of the process also showed positive results for the densification and greening hypothesis in order to improve the sustainability of the city. It also showed that it is a very delicate process were stakeholder involvement is crucial to get things right. 'People make the inner city' was a phrase coined in this context.

Using the Sustainability Profile was very helpful although at a practical level the themes and indicators did not match existing indicators at neighbourhood and city level. Follow up research should take this into account.

§ 6.6 Conclusions

Densification and greening of the inner city of Rotterdam can lead to a more sustainable city with a higher quality of life. In this study, ambitious concepts and strategies for providing low-carbon urban transport are a side effect (walking, biking and public transport). Electric cars and sustainable distribution of goods are strategies that have not been explored in this study. The hypothesis stated earlier is therefore only partly verified: low-carbon transport strategies are missing and still need to be articulated better. For specific conclusions on the different themes in Figure 6.12 paragraph 6.4.4 describes the outcomes of this research.
The outcomes of the transition management process from problem delineation to agenda setting were successfully presented. In this case the focus groups as well as the use of GIS mapping and a data specialist were new.
Although the Sustainability Profile served as a good baseline to measure improvements it was difficult to (re)use for the employees of the city administration as they used slightly different indicators. In the follow up process the indicators were adapted to the ones used by the city administration (the Sustainability Profile was renamed into Smart City Planner).
These data sets were used in transition management and can be used in any a stakeholder environment to explore potential synergies and vision making?
The overall conclusion to be made is that the densification and greening strategies can contribute to a higher level of urban sustainability.
The research results also made clear that densification and increase of urban green need to go hand in hand with good parking solutions and an ambitious mobility strategy. The inner city has evolved into a pilot project for finding out which measures will succeed in turning the entire city of Rotterdam into a sustainable, vital one. This approach can also be copied to other cities.

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Borsboom-van Beurden, J.; Doepel D.; Tillie N.; Sustainable Densification and Greenification in the Inner City of Rotterdam; - conference proceedings cupum2013.geo.uu.nl

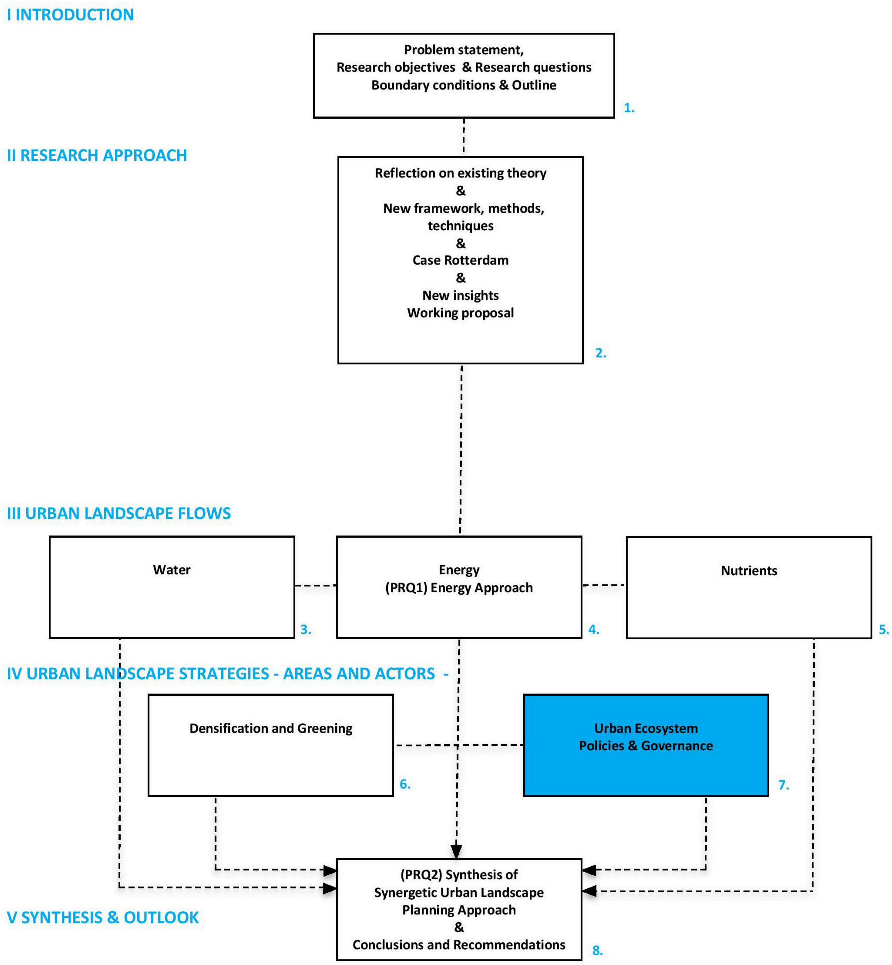

FIGURE 6.15 Bridgin six-seven

Bridging six-seven

In Chapter six a strategy was set for densification and greening while at the same time planning for synergies, improving quality of life and the sustainability performance. This process seemed a good base to develop the smart city planner which is briefly explained in chapter seven. It helps with the use of city data and maps to plan for synergies and inform stakeholders during that process. The smart city planner will be elaborated on more in chapter eight.

Where chapter six focuses on the area of the inner city and looks for spatial strategies, chapter seven focuses on the entire city and studies policy development over time, using the results mentioned in this thesis. The main issues are how the **actor** ‘government’ played a role in this and how ecosystem governance found a place in the policies and projects of the city of Rotterdam.

First an overview is presented of the different green and sustainability policies of the city. Than a few approaches and traditional ways of spatial planning of the city are discussed. One of them being the tradition of turning liabilities or challenges into opportunities.

Additionally, a few tools in policy making and planning are discussed. Data collecting and mapping form the basis, leading to the smart city planner. The goal of the smart city planner is to link accurate data to policy making and explore potential synergies. Other tools presented are in this case focussed on storm water events. Chapter three already has covered some of these issues from a different perspective.

Finally, the 'dakpark' or roof park Rotterdam is presented as an example of a project that showed the involvement ofactors, inhabitants as stakeholders. Also, the city administration is seen as stakeholder. From an **actor** perspective, this is a different approach.

7 Urban ecosystem governance in Rotterdam

an overview

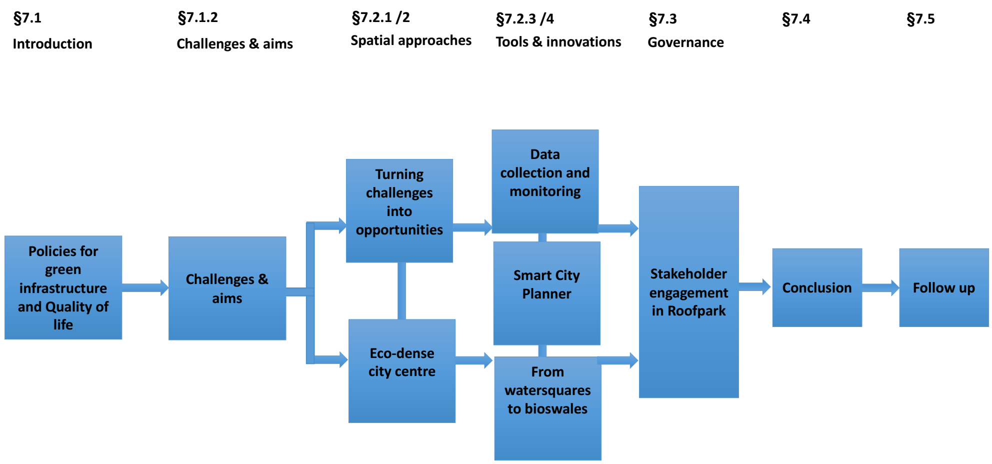

FIGURE 7.1 Outline Chapter 7

Note in advance

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§ 7.1 Introduction

The role of actors and urban governance in an urban system is a crucial part. This will be elaborated on using the green infrastructure strategy outlined for the city of Rotterdam. This strategy deals with approaches, tools, technical innovations, and testing, and draws conclusions plus lessons learned.
Protecting, maintaining and creating green areas combined with the recreational needs of the residents can be challenging. The research into the needs of different lifestyles, ages and backgrounds can offer clues to make more variety in design and management of green at the neighbourhood level within a basic green infrastructural framework. Often there are trade-offs between economic and ecological developments. Temporary planning tries to deal with these dynamics. The concept of 'Temporary Nature', which has been successfully used in the Rotterdam port area is an interesting idea that can be developed further, combining economic and ecological goals. The rare Marsh Helleborine orchid shares temporarily unused industrial space with 21 other endangered species. It has also been found in industrial areas in use.

In applying approaches to become a more sustainable city, implementing green infrastructure is crucial. However, the term green infrastructure was not used in public engagement. In a series of stakeholder sessions in 2012 there was more interaction with stakeholders when discussing improving the quality of life from people's perspectives. This ranged from having a job to safe playgrounds for their children or the availability of good-quality housing. When discussing these issues and the role of different stakeholders it became clear that the common goal we had was a sustainable city. However, often it was difficult to pinpoint direct links between building green infrastructure and health effects, cost effectiveness and capacities.
Instead of having a few green infrastructure projects there should be an overall interrelated network linked to hard infrastructure. More research is needed how green infrastructure compares to hard infrastructure, for instance bioswales compared to sewage pipes for drainage. How do costs, capacities, maintenance and positive effects compare and where to have which solution? Politicians and citizens like to know the expected effects on quality of life improvement. Provide city planners with easily communicable data and what are the outcomes, and how does it improve the quality of life for citizens?

In the past decade, many policies for strengthening green infrastructure have been developed in Rotterdam. The leading theme has always been improving the overall quality of life in a city, providing a better living environment (see also ISO37120). There is always a long-term and short-term outcome. Often instant effects should be visible, since these are related to politicians' goals, such as opening a park or a water

storage. The terms ecosystem services and green infrastructure are not often used in policy making. The policy maker has to provide strategies and plans in a language that politicians can communicate to the public easily. What are the goals, what are the outcomes and how does it improve the quality of life for citizens?
In that sense, it is no surprise that Rotterdam chooses – where possible – for an integrative approach. Common criteria across multiple policy documents and studies such as the Urban Green Infrastructure Strategy, 'Groenplan' (Gemeente Rotterdam, 2005), and the densification strategy, People Make the Inner City (Tillie et al., 2012) can be found.
All developments must comply with the following criteria:

- Lead to a more child-friendly, green, clean and healthy living environment (Gemeente Rotterdam, 2012);
- Create economic value today and on the long term (Gemeente Rotterdam, 2012) and affordability for its citizens;
- Contribute to a 50% carbon reduction and a 100% climate proof city (Gemeente Rotterdam, 2012).

Parks are a main element in the urban ecosystems governance in Rotterdam. It has 117 public parks (1,765 ha), some of which are well known to citizens and highly visited.

One of the most popular and most visited urban parks is Zuiderpark, which was opened in 1952 to enhance green and sport facilities in the South of Rotterdam. Zuiderpark was renovated in 2002 in order to sustain the quality of green space as well as to improve the water quality in the area. It has become more accessible and more open to the public. Amongst other measures, wetlands (helophyte filters) have been built to clean water in an environmentally friendly way and biodiversity is monitored annually.

§ 7.1.1 Policies for improving green infrastructure and quality of life in Rotterdam

To protect and develop green infrastructure, several green and public space plans were developed over the years. The implementation of the 2005 regional green blue plan (*Stadsregio Rotterdam en Provincie Zuid Holland, 2005*) resulted in more than 13 km of new bike lanes and 500 ha of new green and recreation area. The 'Vlinderstrik', a green and ecological zone of 140 hectares, is an example of this. It links two regional landscapes for recreation and ecology.
The urban green infrastructure strategy as described in the 'Groenplan' (Rotterdam,

2005) connects the urban area alongside the Meuse river with the surrounding landscapes. The Meuse river is considered as the largest urban ecosystem in the region. The 'Groenplan' broke with previous green infrastructure plans, which used an abstract concept such as the '4 green Corners'. The plan is based on the natural conditions and (potential) flowscapes of rivers, biota and people. In Rotterdam-North the (north-south) Schie and Rotte rivers and the Ringvaart canal are the major ribbons, which give structural support for the green infrastructure. They form a radial structure as kind of green wedges from the city centre to the outskirts of Rotterdam. At a lower scale, there is different green infrastructure, such as the 'Singels' which connect these three main ribbons.
Rotterdam South has a different structure. The structural support to the main green infrastructure is not radial (north-south) but based on half rings (east-west) which follow the old dike structures along the Meuse and Zuiderpark [Figure 7.2].

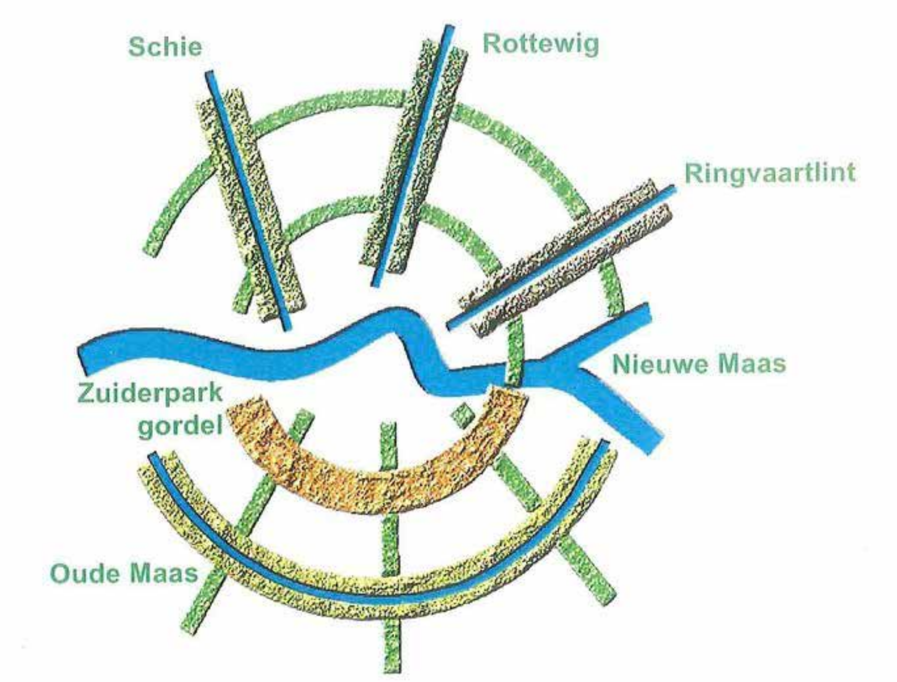

FIGURE 7.2 Scheme of the basic urban green infrastructure in Rotterdam (developed by Nico Tillie, 2005)

The areas along the rivers are underutilised as a recreational landscape. In the city, the river landscape offers an attractive image right in the city centre. The rivers are natural connections to the regional green areas. It is logical that the rivers have a prominent role in the green-blue network. The structural support at city level – radials and half rings – are attractive green areas and form the chain that link different parks.

For cyclists, walkers and roller-skates these are ideal routes. For nature, they form main lines along which plants and animals enter the city.
The 'Groenplan', is still in force and supplemented with an urban vision on the tree structures that will create a network of green infrastructures in the city of Rotterdam (Gemeente Rotterdam, 2009). Concerning the types of green introduced in the city, it is worthwhile to mention that the city used to grow mainly Plane *(Platanus)* and Lime *(Tillia)* trees due to their majestic appearance. After the Second World War, many Poplars *(Populus)* were planted to achieve quick results. Fifty years later many of them need replanting, so a well-balanced mix for aging trees is necessary. The Tree Structure Vision estimates where trees tend to grow strong, based on soil and habitat knowledge. The 'Groenplan' is implemented in a step-wise manner and its implementation is organised by a public space manual for greening – the 'Rotterdamse Stijl' – that includes guidelines for more quality, consistency and recognisability in the public space. As discussed in chapter 4, in recent years, urban farming has been promoted. In the city, there are some 134 small-scale urban agriculture initiatives that add to the quality of the green space.

§ 7.1.2 Challenges and aims

From a planning perspective in the 'Groenplan' plan the major challenges were strengthening radials and half rings as well as making connections between them and maintain natural conditions. A famous example of such a north-south link is the newly built 'Blauwe Verbinding'. This is a thirteen kilometres long waterway that links Zuiderpark to a regional water retention buffer. It discharges water, increases biodiversity and provides for recreational activities.

Another main goal is preservation of existing nature areas and parks and improvement of the green areas and ecological network in the city.
A challenge from the perspective of usage was to complete a biking and walking network, accessibility of green and water, as well as having 'the right green in the right place', as it was refered to. This addressed the problem the city had of having a lot of square metres of green per capita yet not many people experiencing this. The green

areas where not articulated often for a specific or integrated purposes or use. There was a need to create a lot more variety in the green areas, in image and usage and also linked to the needs of the residents. It is important to have a variety of green areas with intrinsic qualities.

Other goals linked to green infrastructure come from other policy documents such as 'investing in sustainable growth' (Gemeente Rotterdam, 2012). They link directly to green infrastructure. Reducing motorised traffic in the city centre, for example, is a policy goal which benefits from new and upgrading of green bike and walkways.
Other goals linked are improving adaptive capacity for rainwater storage, providing green areas larger than 2 ha within 300 m of people's homes and improving social interaction.
From a policy but also political perspective it was clear that many goals came together in building green infrastructure. The main question was how to scale up good practices in the city and where to start? As such, data collection, interviews and mapping were important steps.

§ 7.2 Planning approaches, tools and innovations adapted to challenges of climate change and urbanisation

§ 7.2.1 Turning challenges into opportunities - approach

Due to its global port and industrial functions, the open connection to the sea and its location in the lowest-lying delta region in Europe, Rotterdam faces specific challenges. The city has developed a traditional approach in turning challenges into opportunities for issues such as better public space, housing, recreation and connectivity. An example is the vision for Water City 2035 (Greef et al., 2005) and its action plan Waterplan 2 'Working on water for an attractive city' (Gemeente Rotterdam, 2007), both discussed in chapter 3. Already in 1854, this integrative approach was applied to solve sewage and cholera problems. The Rose Waterplan was more than a solution to flush out filthy canals with river water. It also planned for 'Singels', beautiful new waterways in English landscape-style parks with new housing areas around them. Now 150 years later, these areas are still considered as the better parts of the city.

§ 7.2.2 Eco-dense city centre - approach

Densification of the (inner) city forms one of the main policies of the city. As discussed in chapter 6; Compared to the centre of Amsterdam, in Rotterdam, only half the number of people lives on the same size of land. Due to the post-war reconstruction in the 1950s and later, more offices and virtually no housing was planned. Since 1985 this has changed. The centre of Rotterdam has had a growing number of inhabitants ever since. In the coming five years more than 3,000 additional homes will be created, using the compact eco-dense city as leading concept and complying with the local Green Building agreement. The next step to accelerate this was a study developed for the International Architecture Biennale Rotterdam 2012 (Tillie et al., 2012): how to add 30,000 inhabitants and plant 15,000 trees in the city centre within 15 years while creating a clean, green, healthy and sustainable area where families with children like to live?
Vancouver's eco-density approach (Beasley, 2009) was translated to the local situation, which means dealing with different economic, social, spatial and cultural contexts. This was done by introducing seven densification strategies. Only Rotterdam examples were used to proof its local feasibility. The same was done with seven greening strategies. The study showed doubling of the inner-city population is possible while improving quality of live. This was largely the result of adding more parks, trees, green roofs, green walls, green children's' playgrounds, allowing for urban agriculture, floating green, and replacing hard surfaces, mainly parking lots with green. This study and exhibit – free of political constraints – was in fact an enormous accelerator for further eco-densifying the inner city as it convinced politicians opening the exhibit.

§ 7.2.3 Data collection and monitoring tools

The Office for City Nature (BSR, Bureau Stadsnatuur) is a very active office for advising on the formulation of the city's biodiversity policies. The Office for City Nature are involved in the performance of the current state of biodiversity in the city of Rotterdam that will be the basis for nature conservation measures for the improvement of habitats of endangered and protected species, regular monitoring of these species and habitat types, and revitalisation of degraded areas within the city. This performance includes mapping of current ecological state of the city. Such holistic performances are often lacking since planning and policy evaluation work is often realised at a project base rather than at a city-wide level.

Next to an inventory for nature and biodiversity there are many monitoring systems in the city. There are several indices such as child friendliness, health, safety, social and so on. In an integrative approach, it is most valuable to link these data to green infrastructure projects and eco-system governance.

§ 7.2.4 Smart City Planner Tool

The Smart City Planner links datasets and provides new insights. In the City of Rotterdam, geographical information systems (GIS) are used to compute, analyse and present spatial information about climate change and urbanisation. Data are stored at the lowest scale possible such as building or block level, individual trees etc. All have a geographical reference. This allows to use and present the data at different aggregation levels (scales) and scale up. At the same time, it becomes possible to not only show what is going on in terms of demographic changes, but also where these changes are happening (at district level). Combining biodiversity data, habitat data and existing parks create a wealth of information that can by linked to many ecosystem services themes such as health. The number of data sources and mapping possibilities are huge. Presenting too much information can be overwhelming. It is for instance impossible to discuss 100 maps with stakeholders in one meeting. To solve this an interface was built which serves as a kind of area profile [Figure 7.3] that uses available data ranging from the social index, precipitation, and energy to traffic and air quality data. It consists of a baseline study with 17 themes directly linked to ISO37120 standard for indicators for city services and Quality of Life. There are about 100 local people, planet, and prosperity indicators in a selected area. The interface shows the key themes through a spider diagram with traffic light colours. The colours are used to see how the themes and indicators score compared to a chosen threshold (orange). In a simple way, green colour is used for indicators that are above the chosen threshold, red for indicators that are below the chosen threshold. The areas that, can be selected, are scalable from, in some cases block level, to 1 or more neighbourhoods, to the entire city, which consists of 90 neighbourhoods. An example can be as follows. Among the red scores in an area were storm water management and shortage of recreation and public green space. Possible solutions to both challenges are water-gardens and parks or water squares. Which relate to improving adaptive capacity as well as public space.

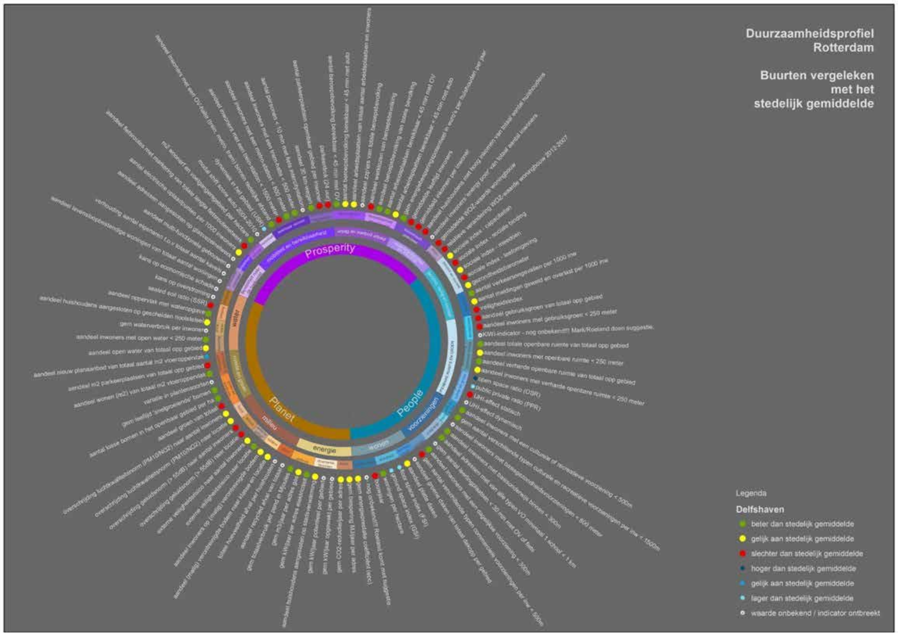

FIGURE 7.3 The smart city planner shows the sustainability profile for each area in the city of Rotterdam

§ 7.2.5 Innovations from water squares to bioswales

Making Rotterdam an attractive place to live, work, study and recreate – improving quality of life – whilst resolving water and other environmental issues, is a challenge. Traditional solutions are often inadequate or need to be complemented with green infrastructure. Innovations or existing solutions such as (1) water squares, (2) water gardens, (3) waterparks, (4) bioswales, (5) green walls, (6) green roofs, (7) underground water storage in cisterns or crates, and more alternative forms of water storage are essential in our strategy.

In 2012 the first water square was built. It combines playground and water-based fun with peak water storage during heavy rainfall. Additionally, a 10,000 m³ underground sewage overflow facility was built to prevent sewage water contaminating the waterbodies in the city. In addition to a 5,000 m² vegetation wall, 50.000 m² of green roofs have been fitted throughout the city. The city learned a lot from other green roof programs such as in Toronto. A direct lesson is the green roof subsidies in Rotterdam (€30/m²). During the 'Green Year' in 2008, the City of Rotterdam constructed

eight vegetation roofs, the largest of which was on the Sophia Children's Hospital. The goal was to communicate by showing not only that the green roof is beautiful and aesthetically acceptable, but also the benefits of green roofs for water storage, insulation, air quality improvement and biodiversity.
Other built solutions are the regional Olympic rowing track park. It is either a park or a pond, which can flood when necessary. Nice water storage ponds were built beneath a motorway intersection.
The next level in applying these projects in the city is to apply them everywhere. Instead of having a few projects, green infrastructure should become the natural thing to do, to complement hard infrastructure with green infrastructure where possible.

§ 7.3 Example of linking stakeholder engagement to green infrastructure in the 'Dakpark' project

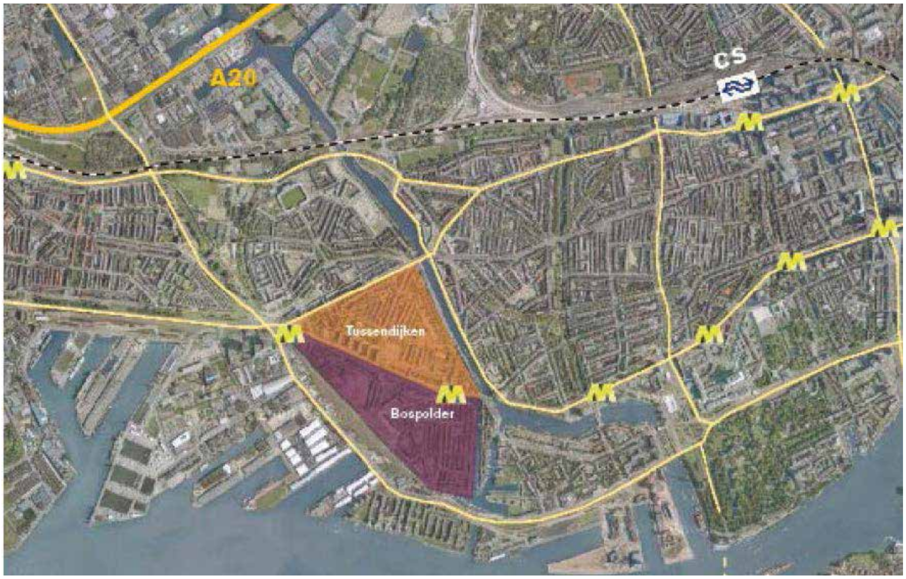

FIGURE 7.4 The former railway yard, now 'Dakpark', is located in one of the most densely populated districts of Rotterdam. The wide brown strip along the whole southwest edge of Bospolder.

This example is not so much on environmental performance but on achieving things through stakeholder engagement and bottom-up initiatives, a crucial and often underestimated part in urban ecosystem governance. An old railway yard southwest of the Bospolder -Tussendijken neighbourhoods blocked the access to the river. Now it is a beautiful park on top of a shopping mall and a river levee. How did this happen? Thirteen years ago, there were rumours that the rail yard would be released. The owner wanted to use it for economic activities, while local residents wished to turn it into a park. Eventually the decision was made to serve both interests with double land use (employment and green for recreation). Residents contributed ideas and also organised activities during the planning phase. They came forward with clear principles for the plan of the park.

These principles were: good connections between the park and surrounding neighbourhoods, easy access for disabled visitors and people with prams. Furthermore, it was important that one could picnic, barbecue, wash their hands, play (with water), and provide both sun and shade, as well as shelter against the wind to linger. In addition, residents felt it essential that the park experience itself should already be felt at street level. That is why at the start and at the end of the Bospolder-Tussendijken area, the park shows a lively and green slope [Figure 7.4].

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FIGURE 7.5 1: An impression of the roof park above the shopping mall against the dike. 2: Daily use of the roof park which opened in 2014.

Designers translated these principles into a beautiful and powerful vision and plan, capturing the imagination of many and in which all parties and many different people could identify themselves.
In the summer of 2014, the roof park was opened. The role of residents was crucial for the overall quality of the park. They were involved with professionals and repeatedly made sure that the right priorities were at the centre of the focus. After the park opened, the involvement of residents entered a new stage. Active residents have united and founded 'the Dakpark Foundation'. Mentally they feel owner of the park and work for a good, lively and pleasant place in Rotterdam West. Multiple workgroups volunteered, including supervisors, park guides, a green group and an activities & promotion group. Together with this foundation, the municipality and green contractors, new ways were discovered of working together on the management of a public park and at the same time expanding Rotterdam's green infrastructure **[Figure 7.5]**.

§ 7.4 Discussion & Conclusions

First outcomes measured

In the inner city, the percentage of inhabitants that have green and/or water within 300 metres has increased with 8% since 2001. Currently, 53% of the inhabitants live within 300 metres of public green and 95,8% of the inhabitants lives within 300 metres of public green and/or water areas; for the city centre this number is 89%. The areas that lie outside the 300-metre zones are mainly situated in the old pre-war neighbourhoods (such as Charlois, Feijenoord and Delfshaven). The City of Rotterdam has committed itself to increasing the green spaces in at least 10 of the most built-up areas between 2001 and 2014. This work is performed in close cooperation with the housing corporations and the inhabitants. An important co-benefit is the social cohesion that results from cooperation between neighbours. For example, a group of citizens and professionals founded the initiative Edible Rotterdam and are investigating opportunities for urban farming, making the food chain visible and the city more attractive inside the dense environment. An example of increasing green spaces is the creation of more green playgrounds. In the district of Feijenoord, the first green schoolyard was created with the help of the pupils. In 2012, twelve schoolyards were turned into green get-your-hands-dirty playgrounds.

In the past years there was a model shift from 14% to 20% bike-use. The 2014 World Council on City data comparison (WCCD, 2014) shows Rotterdam having the most extended biking network per capita, compared to cities like Helsinki, Amsterdam, Barcelona, London and Toronto.

§ 7.5 Follow up

When planning the first water square in Rotterdam, many people living close by were opposed. There was no good involvement of the neighbourhood and people were not informed in time. The result was that many people opposed to the plans, because they were afraid that children would fall in the water or mosquitos would spread. Because of this failure, the next trial at Benthumplein was more successful. In fact, the inhabitants in Zomerhofkwartier (ZOHO) were very enthusiastic and helped in realising the first climate-proof district in the city with green infrastructure.

Local participation and education are essential for protecting, understanding and maintaining green areas' nature and biodiversity. Also, research into the needs of different lifestyles, ages and backgrounds can offer clues to have more variety in design and management of green at the neighbourhood level within a basic green infrastructural framework.

Temporary planning tries to deal with economic dynamics. The concept of 'Temporary Nature', which has been successfully used in the Rotterdam port area, is an interesting idea, which can be developed further. As an example, the rare Marsh Helleborine orchid shares temporarily unused industrial space with 21 other endangered species; it has also been found in industrial areas in use.
Showing best practices or parts of a solution from your own city when possible, builds confidence in project opportunities and outcomes.

How to make few green infrastructure projects into an overall urban strategy is a challenge. In Rotterdam one of the cornerstones to do this is organising neighbourhood workshops and give space to local initiatives like the roof park, but also in ZOHO, where local ideas turned the area into a climate-proof one. Practical agendas are formulated together. The policy maker acts as an information broker and provides a platform.
In order to give more information on costs and (indirect) benefits more research is needed how green infrastructure compares to hard infrastructure, for instance bioswales compared to sewage pipes for drainage. How do costs, capacities,

maintenance and positive effects such as health benefits compare? Politicians and citizens like to know the expected effects on quality of life. As such new research should provide city planners and policy makers with easily communicable facts and figures: how does it improve the quality of life for citizens?

§ 7.6 Link to main research objectives

Main conclusion for SULP

Top down and bottom up initiatives should go hand in hand. A local platform should be given to these kinds of initiatives to guide energy of inhabitants to strengthen a long-term vision.
The use of a good measuring tool is only beneficial when it is used in a feedback loop. The used sustainability profile in chapter 6 was a first attempt to do this but was not effective enough as it lacked the direct link between indicators and mapping. Also, the proposed indicators were not used in the city. Indicators should link more directly to a cities' needs and available data. This is exactly what the smart city planner solves.

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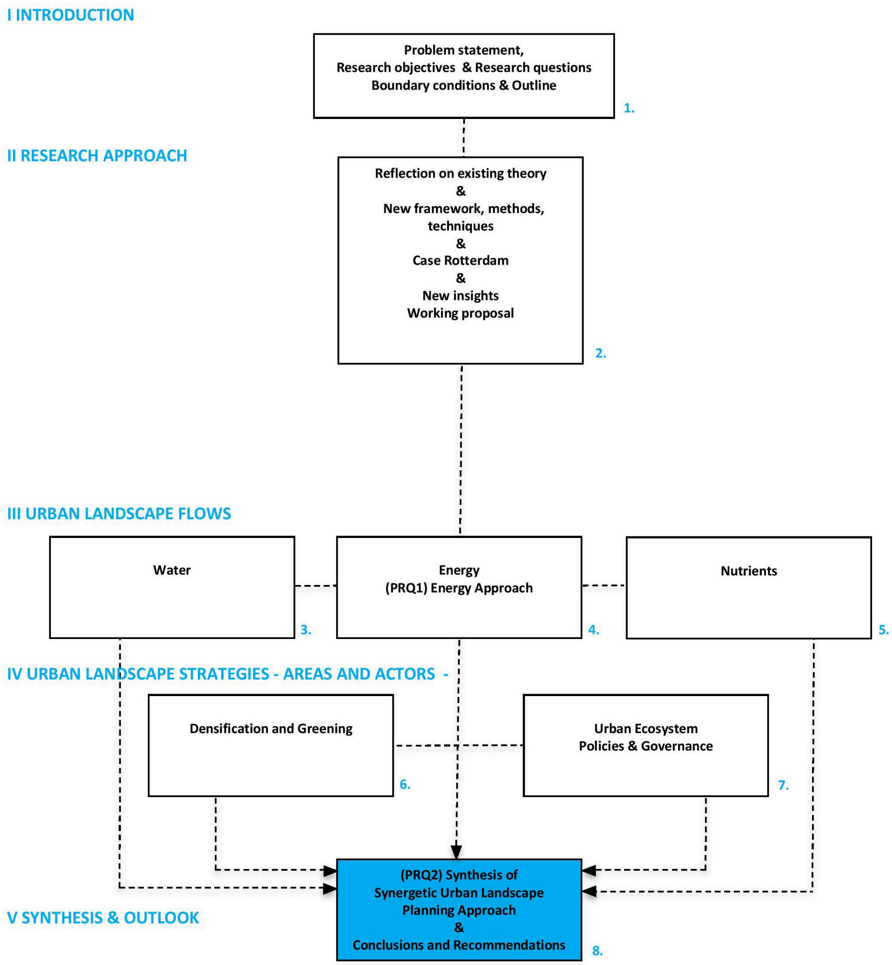

FIGURE 7.6 Bridging seven-eight

Bridging seven-eight

The different aspects of urban landscape systems are discussed in the previous chapters. Their **functions** (indicators for quality of life), **flows** (processes) and **areas** (patterns, plans, designs). Also, several chapters discuss the roles and use of **actors** (stakeholders). In chapter seven for instance, a special actor, (namely the government) is highlighted so as to study their policies for urban ecosystem governance.

The chapters in this PhD thesis are presented in chronological order. The content of every chapter is about (or related to) a real-life case in the city of Rotterdam and is tested. Outcomes of each chapter were taken as lessons and experience into the next chapter. Chapter four has learned from the outcomes in chapter three, five learned

from two, three and four and so on. Also, after finishing each chapter, the main outcomes for SULP, accumulated in chapter eight, where they were updated and fed back into the chapter at hand so as to develop an iterative process.
The result is that throughout this PhD thesis different elements or modules of the synergetic urban landscape planning framework (SULP) have been formed (in some cases, early on) and are improved step by step while moving through the chapters.

In chapter eight the answers to the primary research questions and the secondary research questions per chapter are provided. Together with the core elements these are joined together in a **synthesis** using **functions**, **flows**, **areas** and **actors**, leading to the final **SULP framework** with indicators as a way to explore synergies. The framework is tested in several neighbourhoods in Rotterdam and used to define neighbourhood agendas in 2015. In fact, in chapter six all elements were more or less present and represents as such an early application of the synergetic urban landscape planning (SULP) approach.

The potential synergies are also highlighted and combined with discussion points and recommendations.
In the **discussion** and as a set of **recommendations** the possible lessons and aspects to be followed up by the disciplines of urban ecology, landscape architecture & spatial planning as well as governance are described and discussed.

PART 5 Synthesis & Outlook

8 Conclusions, discussion & recommendation

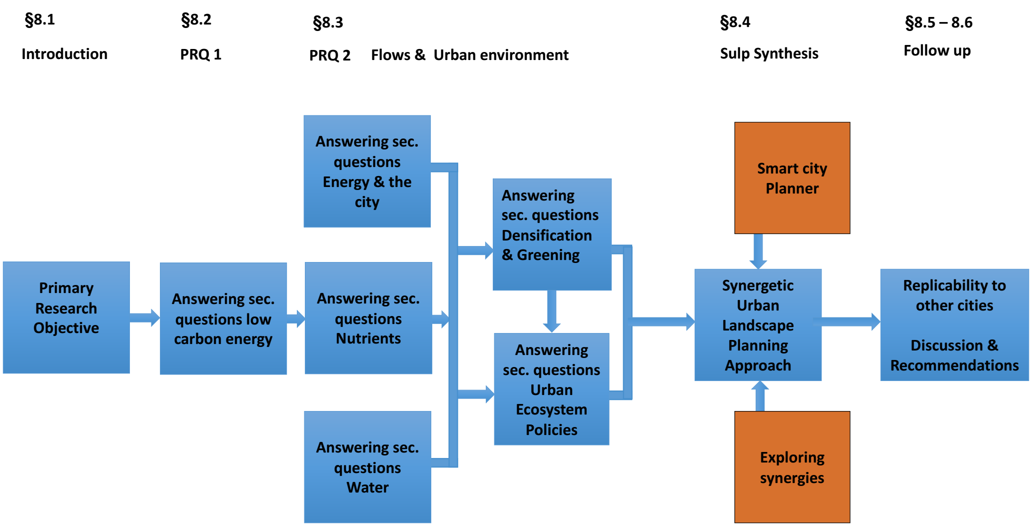

FIGURE 8.1 Outline Chapter 8

§ 8.1 Introduction

This final chapter, presents a synthesis of findings and conclusions.
The main objective and related research questions consist of *two intertwined themes* namely the ***transition to a liveable low carbon city*** and ***exploring potential urban synergies to improve quality of life***. What approach for urban landscape planning can be developed for this?
The answers to these research questions are related to each case presented in chapters three to seven. In each chapter the findings can also be treated as stand-alone outcomes such as the relation between energy and urban landscape planning which

deals with primary research question one. Additionally, the outcomes form elements in the answering of primary research question two and the synthesis of a synergetic urban landscape planning or SULP approach.

§ 8.2 Primary research question one: transition to a liveable low carbon city

Primary research question one was posed as: what is a possible urban landscape planning approach to help the transition to a *liveable low carbon city?*
This primary research question is subdivided into secondary research questions (I-V).

§ 8.2.1 Research Question I

How should we link the urban flow of thermal energy to urban planning while making use of heat waste flows to reduce carbon emissions? This question was answered by developing the REAP methodology as the main subject of chapter four. It is specifically answered in paragraph 4.2.2. and shown in **[Figure 8.2]**. In REAP, the new stepped strategy is used at the building level and scaled up to that of a building cluster, neighbourhood, district and city level. The exchange of waste heat at different scales is linked to urban objects and as such, linked to urban planning.

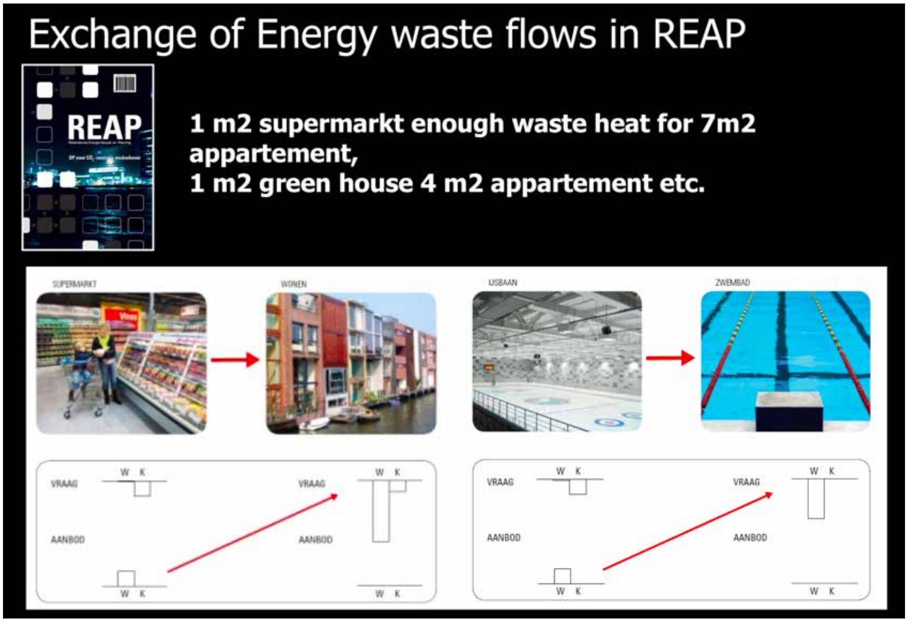

FIGURE 8.2 Example of the potential exchange between waste heat between different building typologies. (Tillie et al, 2009).

§ 8.2.2 Research Question II

What are the built environment's energy (heating) requirements in the city as well as its related CO_2 emissions? Mapping methods are discussed and shown in paragraph 4.3 and in [Figure 8.3] . Energy use and CO_2 mapping of urban areas (shown per block of buildings) is introduced when developing the REAP method. In some cases, estimations are needed as there are no data available. In this particular case, it was possible to obtain the energy use data at the block level with a block consisting of a few buildings.

In this way it was possible to map energy use and CO_2 maps as well as to point out the quick wins.

FIGURE 8.3 Energy reductions potential maps are combined with CO_2 and energy use maps to identify quick wins.

§ 8.2.3 Research Question III

What is the potential for renewable energy in the city?

In paragraph 4.3 one of the mapping methods used is the Energy Potential Mapping method. The EPM for the Rotterdam project is combined with GIS so that combinations with other urban functions and services could be made. Maps of income levels, combined with energy billing maps and potentials for reduction of energy demand and potentials for renewables gave insight into several processes in the city that might speed up decision making and convincing stakeholders. See **[Figure 8.4]**.

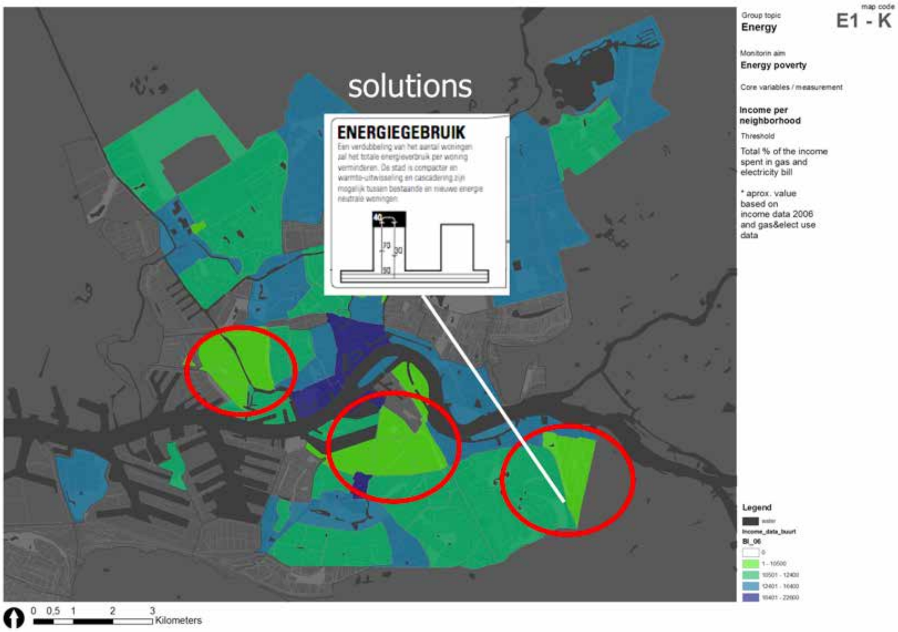

FIGURE 8.4 This maps shows the relation between income levels and what people spend on energy bills. After insulating and other measures to reduce energy demand, EPM showed potentials for waste flows and renewables.

§ 8.2.4 Research Question IV

What are the spatial/technical concepts for tuning demand and supply of heat and cold in cities? In the case study REAP2, described in paragraph 4.2.4, several technical as well as spatial options are explored for attuning demand and supply of waste flows. Five different strategies were distinguished and, as waste heat flows are rarely at the right temperature storage facilities and heat pumps play an important role.
The REAP2 explorations are used and further developed in the Celsius City project as well as in several other studies.

§ 8.2.5 Research Question V

What stakeholder based energy scenarios might be possible in the city and how can we define them? In paragraph 4.4 energy planning with the scenario tool GRIP is explained and applied to the city of Rotterdam and data for primary energy use were collected and used in the GRIP tool. Several scenario sessions were held with different groups of stakeholders. Combined with EPM and GIS, this tool was used in setting up the first energy vision for the city of Rotterdam informing the city council on district heating developments. In 2014 GRIP was applied to the province of South Holland and later on to the whole of the Netherlands. In 2018 this combined approach was applied to the city of Charlotte NC, using per capita emissions in GRIP.

§ 8.3 Primary research question two: exploring potential urban synergies to improve quality of live

Primary research question two was posed as: what is a possible approach for synergetic urban landscape planning (SULP)?
This primary research question is subdivided in secondary research questions (VI-XI).

§ 8.3.1 Research Question VI

What elements should be part of a conceptual model for a sustainable city with the goal of developing an approach to urban landscape planning,. for the transition towards a liveable, low carbon city as well as the exploration potential urban synergies to improve quality of life? The conceptual model or framework is the chosen paradigm or lens to approach this research question.
Thematic structuring is used for all kind of issues related to sustainable development to link principles and indicators to vison and policy making as well as actions. Paragraph 2.3 explains the use and linkages of the six sector subsystems by Bossel (1998).
This system bridges the theory of sustainable development to hands on practical sustainable urban development principles and indicators to be applied in practice and as such become useful in synergetic urban landscape planning.

A In addition to water, energy and nutrients, what other functions and city services are required in a liveable low carbon city to improve quality of life? What are sustainable city principles and indicators?

In paragraph 2.3.1, this question was dealt with by doing research on existing sets of principles on sustainable urban development. Also, city rankings and other assessment tools for urban areas were studied. By combining the outcomes of this study to indicators for city services and quality of life of the ISO37120 standard on sustainable development, a defined set of indicators and themes could be selected or added.

B How to measure these functions and city services at an (inter)national, city and neighbourhood level?

The ISO37120 standard is a way to measure performances of cities on quality of life aspects in an international context. It also links to the UN's SDGs or sustainable development goals [Figure 8.5]. At the local level however, these indicators need to be locally embedded and they should be georeferenced. To overcome this, the smart city planner using local data in Rotterdam was built. This is discussed in paragraph 8.4.

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FIGURE 8.5 Left: The ISO37120 themes presented by the WCCD and right: Recent publication by WCCD linking these themes directly to the UN's Sustainable development goals.

Main conclusion for SULP

For creating a SULP approach crucial elements include local data on themes and indicators that refer to holistic sustainable development goals. Each urban intervention should improve the sustainability performance and with that improve the quality of life of the city.

Intermezzo - three research lenses, urban flows -

Three research lenses on flows of water, energy and nutrients were used to evolve from the conceptual framework to a liveable low carbon city approach and a synergetic urban landscape planning approach. The process followed for these three flows can be used as a template for other urban flows not addressed here. Each analysed flow has its own dynamics and challenges as related to the urban landscape. For each flow, a series of secondary questions was formulated which in some cases led to new concepts linking urban landscape planning to the specific urban flow. Urban flows link directly to urban metabolism. In practice, the study of urban metabolism involves an overall quantification of the inputs, outputs and storage of **energy, water, nutrients, materials** and **waste** flows for an urban region (Kennedy et al., 2011). This however can be broadened with related flows such as logistics, biota etc. From a spatial perspective the question is how these flows can be influenced in such a way to improve a city's quality of life as well as its sustainability performance.

§ 8.3.2 Research Question VII

Secondary research question VII for water is as follows: How can we deal with urban storm water flows to prevent flooding, improve water quality as well as develop synergies with other functions and city services to improve liveability?

A What steps can be followed to identify potential *synergies*, from challenge to opportunity? In paragraphs 3.5.2 the Master Case Approach is explained. The main step for identifying synergies involves knowing what there is to synergize. The pre-studies are a crucial part that cover background, history & cultural aspects; facts and figures, data and lastly how to relate to quality of life the experience and enjoy- factor and how this can be fulfilled from a design perspective. Sharing outcomes of the pre-studies among stakeholders beforehand, effectively levelled the playing field,so that stakeholders were ready to construct a vision and plan for synergies, paragraph 3.7.2 gives an overview of the formulated synergies.

B What can be done to improve water quality related to sewage overflows?
In chapter 3, strategies to lower the extremes of rainfall are described. Basically, the city designed as a sponge or peat bed (as it used to be as a natural system). This is done by means of green roofs, water squares, infiltration areas, urban floodplains and adding open water. These first steps are taken to lower the pressure on the sewage system. In other areas with combined sewage systems, temporary underground sewage overflow facilities were planned and built. Separate sewage systems for rainfall and sewage water is also a solution to improve surface water quality as there will be less sewage overflows.

c What measures are taken to prevent flooding due to precipitation? Chapter 3 describes a few strategies and measures as discussed above. Paragraph 3.6.4 discusses how these different solutions cover the right amounts of water to be temporarily stored in the city, for instance on roofs, in water squares or in ponds and park [Figure 8.6]. Another way of providing extra temporary water storage is by the RainGain precipitation monitor which predicts precipitation in certain areas very accurately up to half an hour before the event. Pumps already start pumping half an hour before the water fills up the system and in this way extra storage capacity is created.

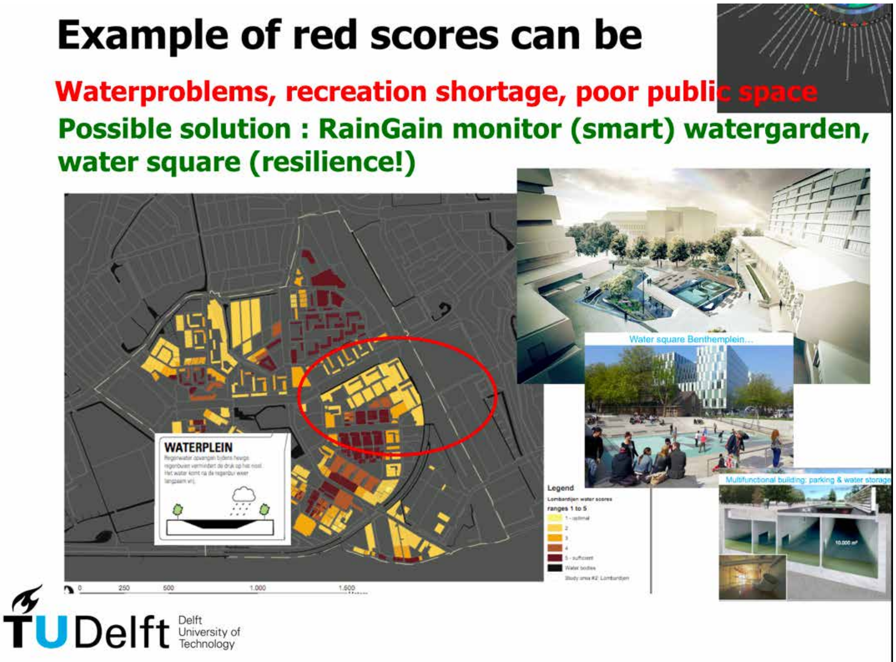

FIGURE 8.6 This figure shows the outcome of the smart city planner data identifying challenges which are solved providing synergies.

Main conclusion for SULP

Pre-studies are important to inform stakeholders and create a more level playing field when planning for synergies. Apart from placing challenges in a cultural and historical context, they also help to make clear what there is to integrate.

§ 8.3.3 Research Question VIII

Primary research question one already discusses the main aspects of energy. Under primary research question two, the secondary research question for energy is as follows: how can we deal with (heat) energy flows and develop synergies with other functions and city services to improve liveability?

As a predecessor of the REAP approach, the zero carbon Rijn- Maashaven study was completed in 2008. The idea was to show how a low carbon city could also improve quality of life. For that, new design solutions and synergies with waste heat where developed such as open air heated swimming pools. Another example is the Rotterdam energy falls. Although some ideas where not realistic to be realised they triggered the imagination of stakeholders and paved the way for follow-up discussions and projects **[Figure 8.7]**.

The REAP study paragraphs 4.2.2 and 4.2.3 describe the different steps and applications within projects. However, to get these ideas accepted by stakeholders and politicians in Rotterdam, it was important to visualise these steps and ideas. The exploration design work in 2007 and 2008 of the city of Rotterdam, DSA architects, JA architects, VHP unit (now Urbanisten) and TU Delft was crucial in this.

FIGURE 8.7 Although the Rotterdam Energy Falls were not a realistic project as shown in this picture, it helped the imagination and made clear that energy was to become a much stronger force in urban landscape planning and design (from projectgroep CO_2 neutrale Rijn-Maashaven, image courtesy of Florian Boer).

Main conclusion for SULP

New futures have to be imagined, designed and drawn for many stakeholders to understand what is possible and desirable or not.

It is important to understand the expected future make-up of a city so that one plans for todays as well as for possible future challenges. Vision making, scenario planning and back casting is covered in paragraphs 3.6.1 for water and in 4.4.1 for energy.

§ 8.3.4 Research Question IX

The secondary research questions for nutrients is as follows: how can we deal with urban phosphorus flows and how can we develop synergies with urban agriculture and liveability? This research was actually twofold and focused on the improvement of liveability aspects in Rotterdam by means of urban agriculture. It also explored Phosphorus (P) flows in Rotterdam.

A What is the value of urban agriculture, in terms of liveability, and are there other synergies?
Paragraph 5.4 describes the value and synergies created by urban agriculture in Rotterdam ranging from health benefits to economic benefits and improved social cohesion in neighbourhoods.

B Can urban farming have a role in the local phosphorus metabolism?
Paragraph 5.3, 5.6 and 5.7 describe how some forms of (urban) farming can act as kind of nutrient collecting point in the neighbourhood and promote Phosphorus. However, paragraph 5.5.6 describes that the amount of Phosphorus that is not retrieved is so big that its potential far exceeds its use solely in urban agriculture. This means that to close P loops, urban agriculture points can have a collection, storage and distribution function for some sorts of P and from there, distribute it out of the city. In future, urban agriculture could develop into a more P demanding sector if the large-scale greenhouses of commercial growers are more integrated into the city.

Main conclusion for SULP

The study on urban agriculture initiatives in Rotterdam and its uptake in policymaking shows the value of small scale projects on the one hand as well as planned experiments on the other hand.
Paragraph 2.2.3 on governance and the institutional perspective describes this as well.
Urban agriculture in greenhouses can have tremendous synergetic effects in cities all over the world.
Low carbon energy, water, food, nutrients and an improved quality of life could be generated

Intermezzo urban landscape strategies: areas and actors

The outcomes of the three research angles are tested in different areas in Rotterdam involving different actors. For the inner city of Rotterdam, a densification and greening study was done with the goal to improve quality of life and sustainability performance. For the whole city of Rotterdam different projects and policies were studied directly related to the three research angles, framed as urban ecosystem governance.

§ 8.3.5 Research Question X

The secondary research questions for densification and greening are as follows: what are potential densification / greening strategies as well as a stakeholder based urban agenda, to improve the quality of life / liveability of the area as well as its sustainability performance? How can this be measured and enhanced using urban data?

In Paragraph 6.4.2 a stakeholder-based urban agenda is formed. Seven densification strategies are described as a result of stakeholder meetings, local initiatives and potential studies in Rotterdam. The proposals have multiple benefits and synergies which can improve the quality of life in the city. The same approach was followed for the greening strategies described in paragraph 6.4.3.

A sustainability profile with indicators was built for measuring the sustainability performance and is described in paragraph 6.5.1. To enhance the process of measuring and feedback into policies and design, GIS maps were used, using different sets of indicators.

Main conclusion for SULP
The stakeholder based agenda is a crucial step in SULP as stakeholders put forward local challenges and opportunities unknown to others. Also, their direct involvement is a good growing medium for future initiatives and project realisation.

§ 8.3.6 Research Question XI

The secondary research questions for urban ecosystem governance are as follows: how was urban ecosystem governance incorporated into local policies and projects and what role, actors such as the local government and inhabitants played in planning, designing and maintaining these goals.

Paragraphs 7.1 to 7.3 give an overview of how different policies over the years have been adopted by the local government. Starting with a long-term vision on the city's urban ecology networks based on the natural layers, the new ideas, initiatives and projects could simply be added to the vision. Over the years, the urban ecology vision was strengthened by the water vision 2035 (chapter three) as well as with urban agriculture initiatives (chapter five) and densification and greening (chapter six).

In the search for how to scale up a few urban greening projects into an overall urban greening strategy for the city, different perspectives were found. In paragraphs 7.1 to 7.3, how a top down vision formed a framework while at the same time fostering bottom up initiatives is described. It was crucial to get the local and regional scale together. In Rotterdam one of the cornerstones of this was the organisation of neighbourhood workshops and provision of space to these local initiatives such as the roof park, but also in ZOHO, where local ideas rendered turned the area more climate proof one. Practical agendas are formulated together and as such the policy maker acts as an information broker and provides a platform.

Main conclusion for SULP

Top down and bottom up initiatives should go hand in hand. A local platform should be given to these kinds of initiatives so as to guide the attention of residents in order to strengthen a long-term vision.

As most ranking systems have pre-set objectives and indicators when assessing cities, there is little room to add indicators that deal with the specific needs or qualities of the city involved. Also, the engagement of policymakers, politicians and the public is low or absent with the result that ranking results are not specifically used to improve policies and sustainable development.

The use of a good measuring tool is only beneficial when it is used in a feedback loop. The sustainability profile used in chapter 6 was a first attempt to do this but was not effective enough as it lacked the direct link between indicators and mapping. Also, the proposed indicators were not used in the city. Indicators should link more directly to a city's needs and available data

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§ 8.4 SULP: Synergetic Urban Landscape Planning approach using Smart City Planner

§ 8.4.1 Smart City Planner

Planning for sustainable synergies in a local context also requires that these synergies are beneficial to sustainable development in a global context. In order to link these two scales, it is necessary that the local agenda links directly to the global one. The UN's Sustainable Development Goals can actually be measured and planned for at city level, using the ISO37120 standard.
In the follow-up of the sustainability profile (chapter 6) a direct link between global goals, local goals and local planning and design has been searched for. In earlier studies (Tillie, 2012b; 2012c) existing neighbourhood tools ranging from BREEAM, LEED, DPL and GPR have been studied. Although these tools all have valuable qualities they were not used in Rotterdam, because:

1. None of these models could handle geographical (GIS) data, which is the direct link to planning and design;
2. There were too many unavailable data points at the local level;
3. Weightins are applied in all models without being able to influence this, it turns outcomes into a black box;
4. In most cases, outcomes show average rates of change, which is difficult to trace and difficult to link to policy improvements.

The local data points can differ per city as they reflect the main local qualities and challenges. However, for reasons of comparison and learning, the ISO37120 data points should be similar and often are collected on a 'per capita' basis. In Rotterdam, this and local data is stored at the smallest scale possible (so scaling up is an option) and includes geographic references. GIS is used to compute, analyse, and visualise these data, allowing the city to present the data at different levels of aggregation. It also becomes possible to not only show what is happening in the city as an average number per area, but to pinpoint specific cases. It might be easier to read one map than a dozen excel sheets however, as soon as the number of themes and indicators grow and with that the number of maps, it becomes impractical to present one hundred maps and discuss them meaningfully with stakeholders. To solve this problem, an interface was built which serves as an area profile. The interface is called Smart City Planner and uses available local city data ranging from the social index, precipitation,

and energy, to traffic and air quality. It also links to a baseline of about 100 indicators in 17 themes (related to ISO 37120 and SDGs) for a selected area. A crucial aspect of the Smart City Planner is that behind almost every local data point there is a scalable (GIS) map. **[Figure 8.8]**, shows a spider diagram where ISO & SDG themes are linked to local indicators. This way urban data, challenges, planning for synergies and design can be more easily combined. The spider diagram is set up to be used in stakeholder sessions. Orange, the city's average is a set threshold value. Stakeholders can quickly zoom in to the red dots and the related maps and recognise if this is an important issue to address. Different areas or different stakeholder might choose different red dots to focus on. In other words, it as a context and stakeholder driven approach, they decide the 'weight' of the indicator. The selected areas can be scaled from block to neighborhood, or include several neighbourhoods, quartiers or the entire city – which consists of ninety neighbourhoods in total. This scalar approach is crucial as it links (ISO) urban standards to projects and activities.
The primary goal is to help determine the challenge and opportunities for each theme per area with regard to sustainable urban development. Stakeholders have an overview and can plan for synergies. As there are as many requirements as stakeholders, the transition process helps to guide this. The smart city planner simply provides a focussed agenda for synergetic (urban landscape) planning to be discussed.
Using local data is very valuable as it directly links to the people living there. This way of working can be done for any city or area in the world.

In Rotterdam, multidisciplinary meetings were held to formulate neighbourhood agendas for sustainable development. Theoretically, it is possible that two neighbourhoods might have the same challenges presented, but as different stakeholders are active in different areas, some might choose to solve issues on storm water whereas others focus on energy efficiency. The project results can be compared later with the baseline to see if improvements have been made. The whole process is based on informed decision making.

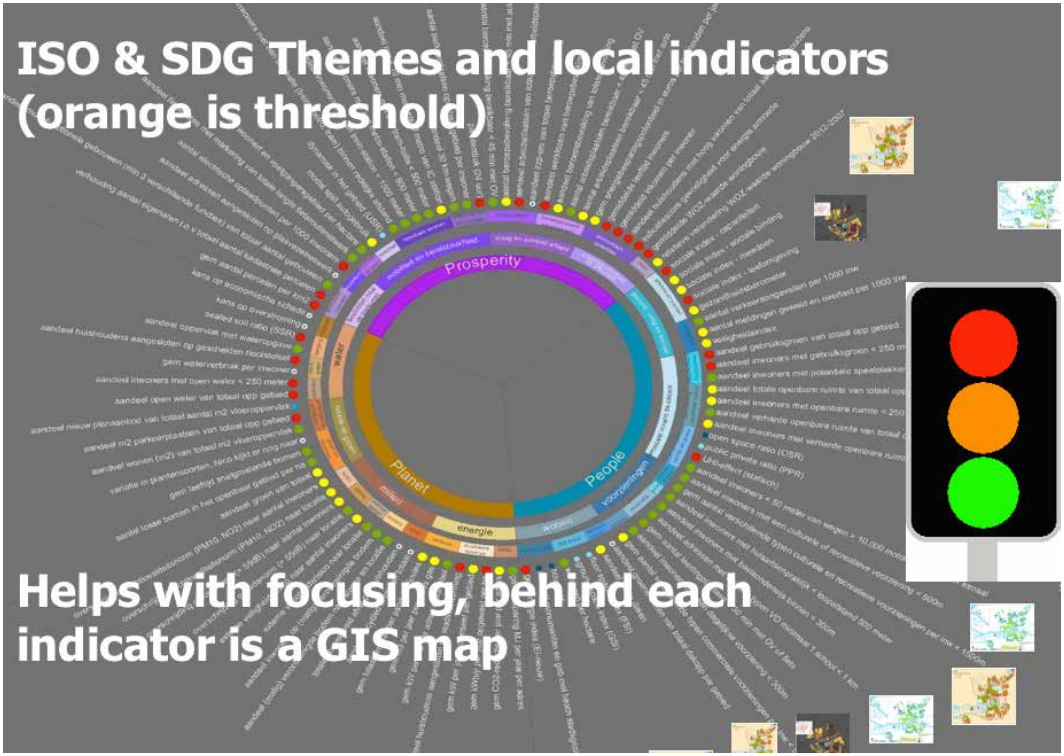

FIGURE 8.8 Spider diagram where ISO & SDG themes are linked to local indicators, behind almoste every indacator a scalable GIS map is available.

International and local data integrated

In chapter six, a number of quality-of-life themed indicators were tested with regard to densification and greening. It turned out that almost all indicators improved as compared to an average of all Rotterdam neighborhoods. Rotterdam became more child friendly, more walkable, more bike friendly, and more energy efficient. Local businesses flourished and life expectancy increased by two years on average. The outcome of the research resoundingly showed an improvement in general quality of life. The question still remained: how did these significant improvements compare with other cities? As the threshold now was the city average. Being a member of the World Council on City Data made it possible to put the Rotterdam results into an international perspective, while still being viewed through a local lens. Rotterdam can now identify best practices for specific themes and for local use and often other cities come to Rotterdam to learn how to deal with certain challenges themselves. As such, ISO 37120 can provide a framework for more effective city governance and facilitates learning across cities globally and locally.

§ 8.4.2 SULP approach

SULP elements are described. in paragraph 2.6, where these elements are positioned in a process that links to 'main conclusions for SULP' in answering the secondary research questions VI-XI. [Figure 8.9], illustrates the process of how this has been used in the cross-thematic agenda setting and planning for synergies in all neighbourhoods of Rotterdam.
This method is also applicable in other cities.

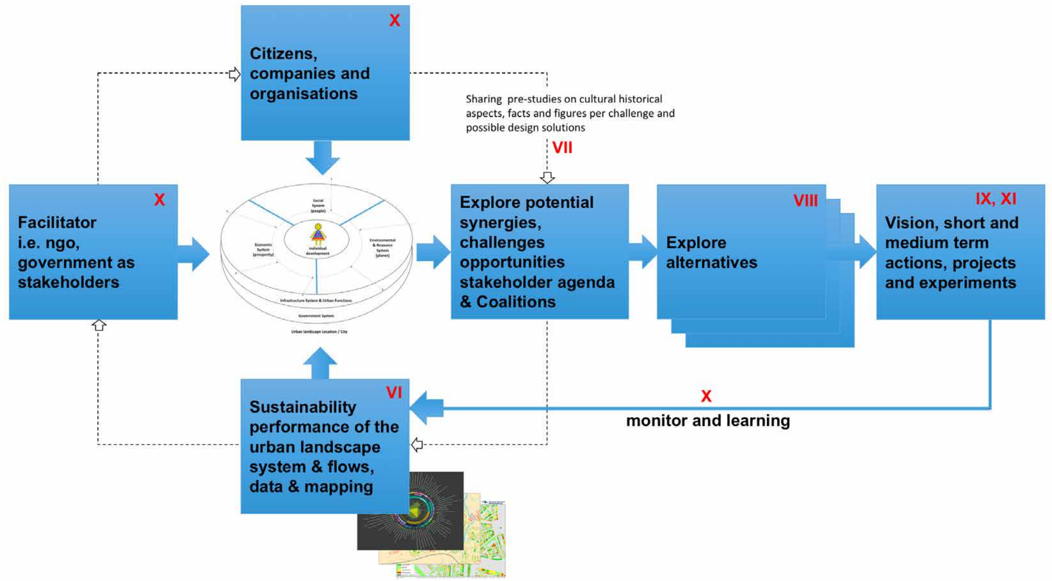

FIGURE 8.9 SULP, Synergetic Urban Landscape Planning is part of the transition process using the Smart City Planner. The figure shows the urban landscape as the object of study in the centre (see also Fig. 2.14) exemplified by the conceptual model for sustainable development. Building blocks from Fig. 2.13 are positioned in a process which resulted from lessons from answering secondary research questions VI to XI.

This process was used more than thirty times in Rotterdam as a preparatory step ahead of various action plans ranging from water strategies to promoting health and child-friendly neighbourhoods.

§ 8.5 Replicability in other cities

Although most of the research described was done and applied in Rotterdam the outcomes can easily be applied in other cities. Throughout this research there was contact with many other global cities via conferences, guest lectures, key note speeches, international projects and students.
As each city, is unique, the outcomes need local translation. As described in paragraph 3.7.3, outcomes for dealing with storm water have been applied in other cities from New York to Copenhagen. Also, other outcomes have been shared and used in other cities. The REAP methodology was the basis for the Amsterdam Guidelines for Energetic urban planning (Leidraad Energetische Stedenbouw, LES) and was used in several European projects.
As for the SULP approach and the Smart City Planner, this was applied in workshops in Taipei and was presented and used by expert groups building the ISO37120 standard. The same process is starting in cooperation with other Dutch cities and the Statistics Netherlands.

§ 8.6 Discussion

§ 8.6.1 Uses and outcomes of the research

This research on synergetic urban landscape planning has a broad focus, yet it specialises in some cases at the detailed levels of for, for example, water, energy and nutrients. Dealing with storm water, and at the same time adding quality of life to a city was a simple concept but at the same time a very strong and effective way to pick up this particular urban challenge.
It has been demonstrated that the REAP approach (in relation to other energy tools) makes it possible to plan for low carbon cities from an energy and urban landscape planning perspective. The REAP approach has been applied to several projects in building clusters where waste heat from one function in the complex is used for another function. The building 'De Rotterdam' has used this method successfully. It is also applied in several cities where ice skating rinks and swimming pools are built near each other and exchange waste heat. Furthermore, this approach is used in the follow-

up projects such as REAP2, the MUSIC project and it was at the basis of the CELSIUS cities project on innovative district heating concepts for cities. Lastly, developing REAP influenced the discussions with the district heating company. This dialogue influenced the REAP outcome but it also changed the view on heating networks in Rotterdam, for instance opening up ideas to connect existing buildings to the network.

Another important outcome is the use of the smart city planner incorporated in SULP. Apart from exploring synergies it allows for local issues and data to be linked to local as well as global challenges as addressed in the SDGs.
Designing or influencing existing areas by design and planning to reach high quality urban landscapes with a good sustainability performance requires knowledge of the urban landscape system i.e. its areas, flows and actors. These themes have been studied in the research angles such as for water and energy (chapters 3-5). It is also applied in the greening and densification studies Chapter 6). As such the knowledge in this PhD is very relevant to design disciplines such as landscape architecture and urban planning. A new aspect in this is SULP which in a structured way helps to identify synergies which can then be applied in planning and design.
Governance models such as transition management can also be strengthened using this approach. This is demonstrated by the use of the smart city planner. One of the strengths of the transition arena is the different backgrounds and knowledge stakeholders have, that allows them to put forward their ideas much more strongly. However, this can also be a disadvantage as there is a risk that misinformed, or very convincing stakeholders might have more weight in the process than others. Doing pre-studies and sharing the results levels the playing field for a certain part. Also, the smart city planner can help as a neighbourhood can be assessed more objectively. City data and (GIS) mapping can be used in discussions resulting in a more interactive and objective process.

§ 8.6.2 Limitations

Although the separate research angles have clear boundaries, the SULP approach is does not offer this. The approach offers a way to explore synergies and apply them from an urban landscape perspective. The broadness of this topic is a strength but in a way also a weakness as each synergetic effect might have a temporal or area limitation. There is also the concern that a synergetic effect from one angle often has a contracting effect from another. So essentially, what is required is an in-debth study of many synergetic effects, considering time, reach etc. This was not part of this PhD.
While measuring the outcomes of new interventions, it is possible to logically reason

what might have triggered these. But as urban systems are complex it is difficult to predict and pinpoint a change in quality of life according to a certain measure taken. In this research, models, as well as real-life projects were investigated to overcome this. This is not possible in each situation.
Another limitation is that financial and economic analyses are missing. Romero-Lankao (2017) mention that tackling interdependencies among food, energy, and water security is promising. However, they identify challenges to effectively operationalise this. Although science-policy integration and cross-scale issues are described in this PhD research, path-dependencies in infrastructure and socio-institutional practices are not.

§ 8.6.3 Reflection on the research process

This research was for the main part conducted in the city of Rotterdam as a real project over a period of a few years. This research benefitted from me being at the core of many interesting developments in the city relating to sustainability and dealing with climate change issues as well as energy transition. It was very useful to work in an environment with many good motivated professionals that had one goal in mind: to improve the quality of life in the city. At the same time, there was a tension within this research that often focused on the long term (yet using short term projects). So, for many the use of this wider approach and its added value was not directly visible. Also, politicians are usually in place for a few years only, demanding quick results and often not applying the most optimal solutions. Or the case of managers managing their project and seeking to be successful for one or two projects without seeing the broader picture. Or dealing with financial issues influencing choices not to study certain issues.
Overall the embeddedness in the city of Rotterdam was very useful. Without testing and involvement of the community and practitioners in cities, planning frameworks have the risk of being merely academic exercises. Several outcomes such as REAP, the Smart City Planner and SULP are used and tested successfully in the city.

§ 8.6.4 Final recommendations

Finally, this research gives a lot of opportunities for follow up and more practical applications.

To strengthen the link between design disciplines and urban ecology a new research angle from the perspective of urban biodiversity would render the outcomes more valuable. This could already begin with a landscape architectural vision for how to link the ground layer to green walls and roofs. Also, the use of integrated greenhouses offers a lot of potential to plan for multiple synergies.

Further research is required to make the Smart City Planner easier to use. It is a simple, yet effective method for many cities around the world. A study for a group of cities linking SDGs and ISO37120 to local data and planning as well as design solutions could have a huge environmental impact.

On the topic of synergies, SULP can be placed within a wider perspective. Cluster analysis research by Carmela Lo Bue & Klasen (2012), in which mathematical relationships between goals, systems and functions of the Millennium Development Goals (MDG) were studied, show interesting outcomes. In their research on identifying synergies and complementarities between Millennium Development Goals, they mention that economic growth is, for instance, accompanied by steady or declining inequality. Also, they state that the presence of good institutional frameworks is not just critical for income poverty reduction. As a matter of fact, they improve synergies between MDG achievements. This can also be of use in new studies on SDGs at the local level. A policy framework should be developed that maximises synergies between SDGs

The new ISO37120 standard and the WCCD can play an increasingly more important role in sustainable development in cities if contact between assessors, platform and policymakers evolves. Data organisations alone are not always capable of identifying critical needs within cities (Freed, 2011). Indicators evolve, so does feedback and recommendations provided to cities, so does the knowledge of sustainable development. Dialogues have already begun but there should be more scaling up and linking to smart city development

Food and consumer goods are not (yet) included in city data. Only in eco-footprint studies one can find these aspects. As food and consumer goods account for one third of the energy and resources consumption (Calcott et al., 2007), future city data or ISO standards should aim to incorporate this.

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Curriculum vitae Nico Tillie

Nico Tillie was born on the 3rd of October 1972 in Maastricht, the Netherlands. He grew up next to the visitor garden of Ber Slangen in Amby (part of Maastricht) and was slowly being trained as a gardener and plantsman. His interests in plants and nature lead him to Wageningen University where he started off in Biology and completed his Bachelor degree in Horticulture and his Master's degree in Plant Breeding and Genetics. During this period, he worked for a year and a half in the Royal Botanic Gardens Kew in London, in the gardens as well as in the Jodrell Laboratory resulting in a thesis on the plant taxonomy and phylogentics. Having studied DNA it was time to put things in perspective and look at a larger scale. In 1999, he received another Master's degree from Wageningen University this time in Landscape Architecture.

After his graduation, he worked for Paul van Beek Landschappen in Amsterdam and designed planting schemes, private gardens, corporate gardens, parks and urban & regional landscapes. For fourteen years he worked as a Landscape Architect for the spatial planning department of the City of Rotterdam. He worked on various projects ranging from urban ecology, groenplan Rotterdam, nature developments with Natuurmonumenten, the Floriade exhibit plans with MVRDV, energy and water systems, smart city Rotterdam, urban metabolism and citywide densification, climate adaptation and mitigation strategies. He was also responsible for the redesign of the Museumpark with OMA and Inside Outside and did all the planting schemes for the Romantic Garden.

In 2014 and 2012 he was responsible for the city of Rotterdam's main proposals and publications for two Rotterdam Architecture Biennales themed Urban by Nature focusing on Urban Metabolism and Making City on densification and greening. He is (co)initiator and (co)author of three successful European projects MUSIC, CityKeys (Rotterdam) & Celsius Cities (TU Delft).

In 2009, he entered academia and started as a researcher in sustainable urban energy planning for the Climate Design & Sustainability chair of the Department of Architectural Engineering + Technology, Faculty of Architecture & the Built Environment, Delft University of Technology (TU Delft). In 2013, he started working for the chair of Landscape Architecture in the department of Urbanism where he was invited to focus on urban ecology, planting and urban metabolism. His work on climate adaptation, energy, urban metabolism and city data lead to his PhD on 'Synergetic urban landscape planning '(SULP). Among other activities such as lecturing and tutoring graduation students in the Flowscapes Studio, he now leads the Dutch Waterscapes design studio and the graduation studio Harvest BK.

Among several scientific publications and book chapters, he is principal author of several books such as the Rotterdam Energy Approach and Planning; REAP (2008), People make the inner city (2012) and Urban Metabolism-sustainable development in Rotterdam (2014). Nico Tillie is also a garden designer and writes on gardens and plants for garden magazines.

Since 2008 he has been representative of the Rotterdam region in the German Marshall Fund in Washington DC as part of the comparative domestic policy program.

Since 2014 he has been vice president of the World Council on City Data and director of the European office. He is a Senior Fellow of the Global Cities Institute of the University of Toronto in Canada.

In the past few years, he has lectured and given key note speeches all over the world. He is an advisor to local and national governments as well as international networks, World Bank, African Development Bank and UN bodies.

At the end of 2018, he will become research fellow urban ecology for Vogelbescherming Nederland (Birdlife Netherlands) to start a center of excellence for urban ecology in the department of Urbanism at TU Delft.